

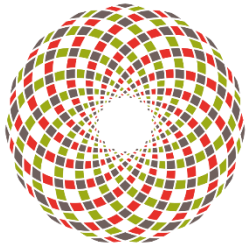
LINK ONLINE, 7 July 2020

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

**Alex James
Nic Steyn**

**Michael Plank
Rachelle Binny**

**Shaun Hendy
Audrey Lustig**



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Data ■ Knowledge ■ Insight



Manaaki Whenua
Landcare Research

Te Pūnaha Matatini - *'the meeting place of many faces'*



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



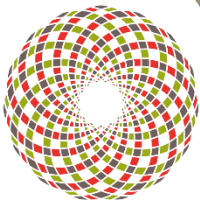
Alex James



Mike Plank



Nicholas Steyn

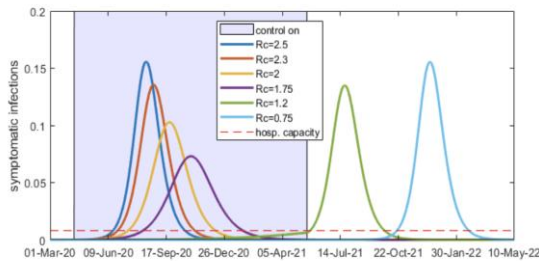


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Modelling timeline

March

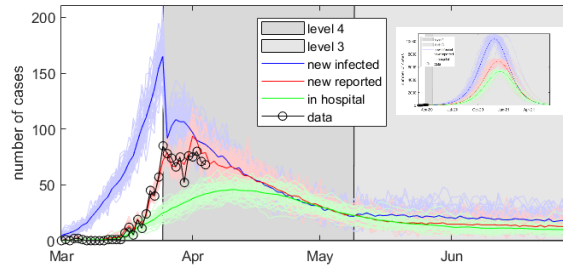
Deterministic
SEIR model



- Long-term scenarios for an established outbreak

Early April

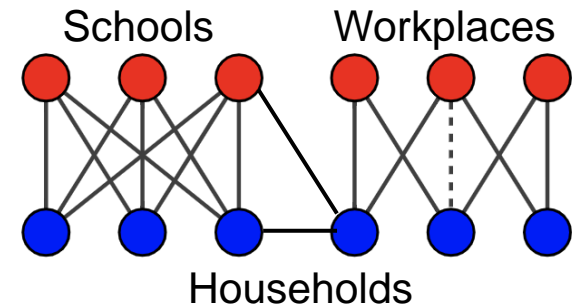
Stochastic SEIR
model with case
isolation



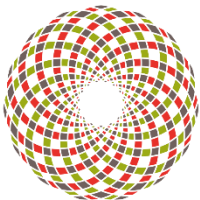
- + Short-term containment or elimination scenarios

Early May

Network/agent
based model



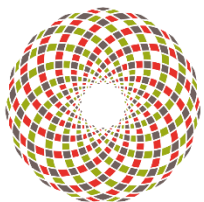
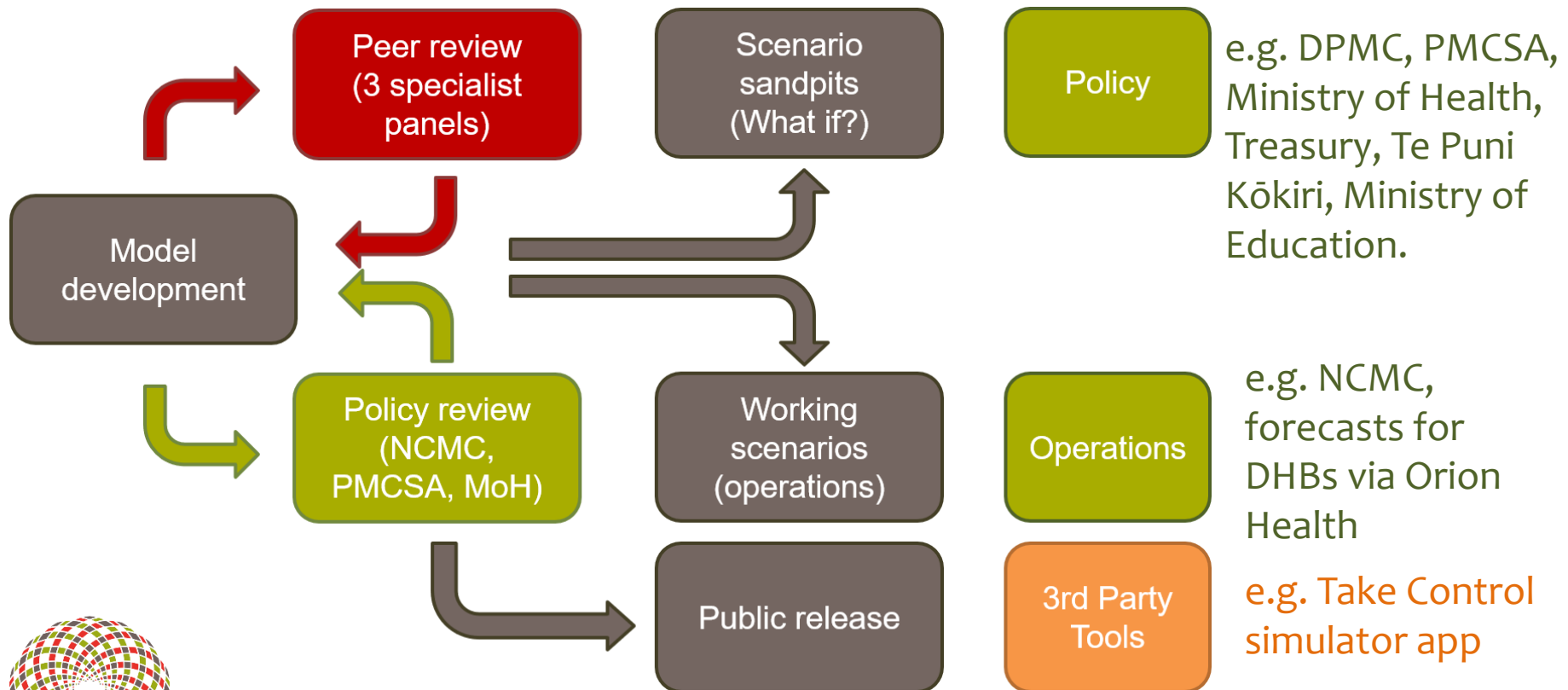
- + Ability to segment
Alert Level restrictions



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Workflow

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



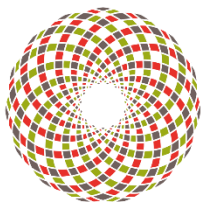
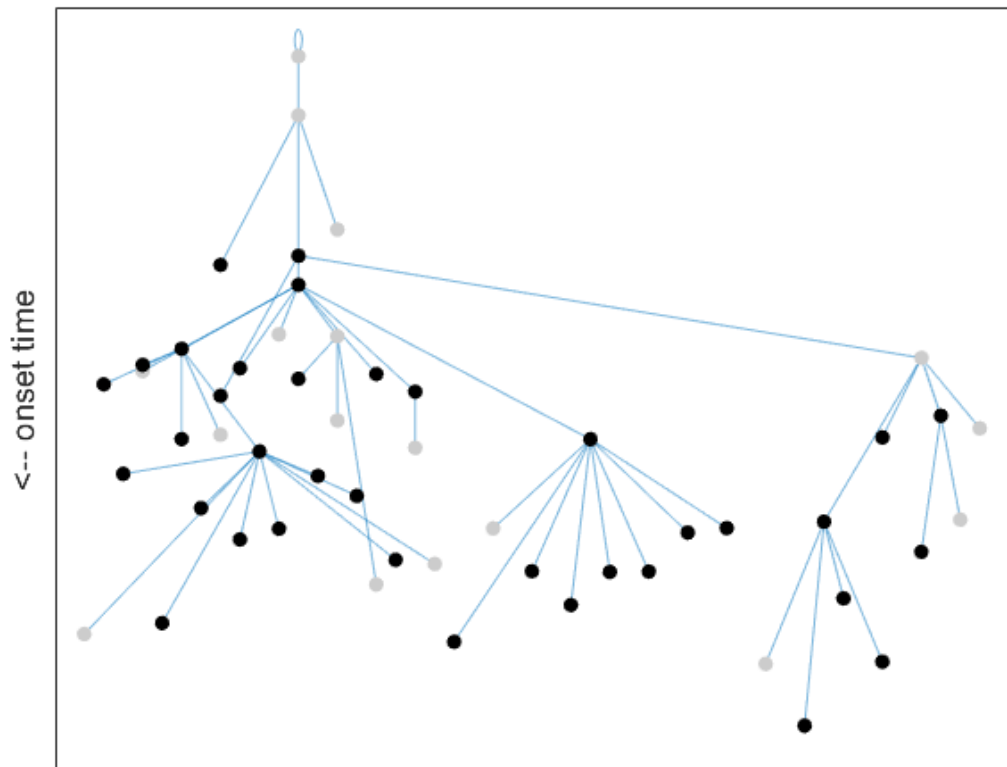
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E.g. Mainstream media

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

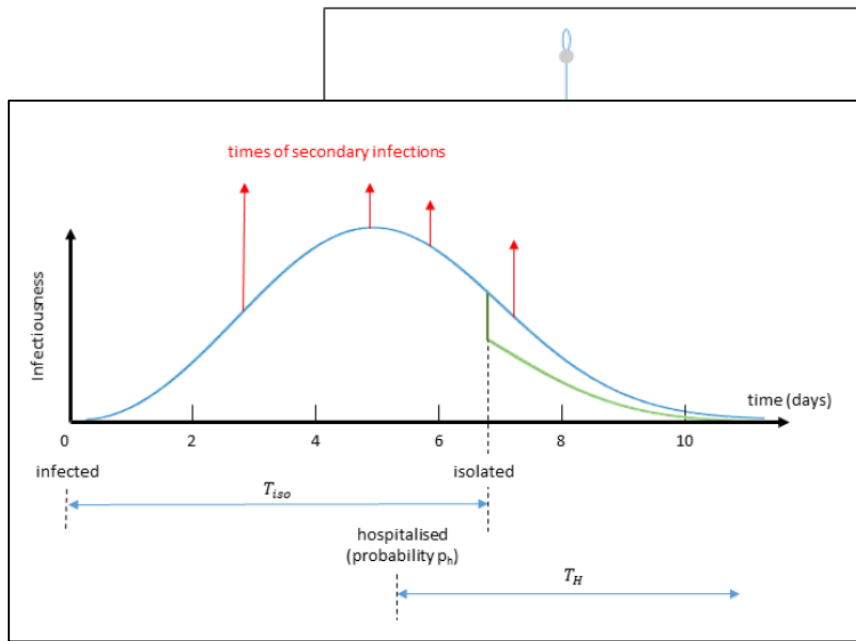


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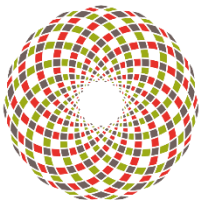
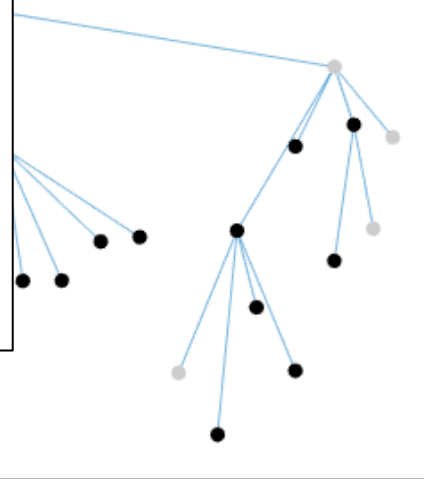
Plank MJ, Binny RN, Hendy SC, Lustig A, James A, Steyn N (9 April 2020). A stochastic model for COVID-19 spread and the effects of Alert Level 4 in Aotearoa New Zealand. MedRxiv preprint, doi: <https://doi.org/10.1101/2020.04.08.20058743>

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

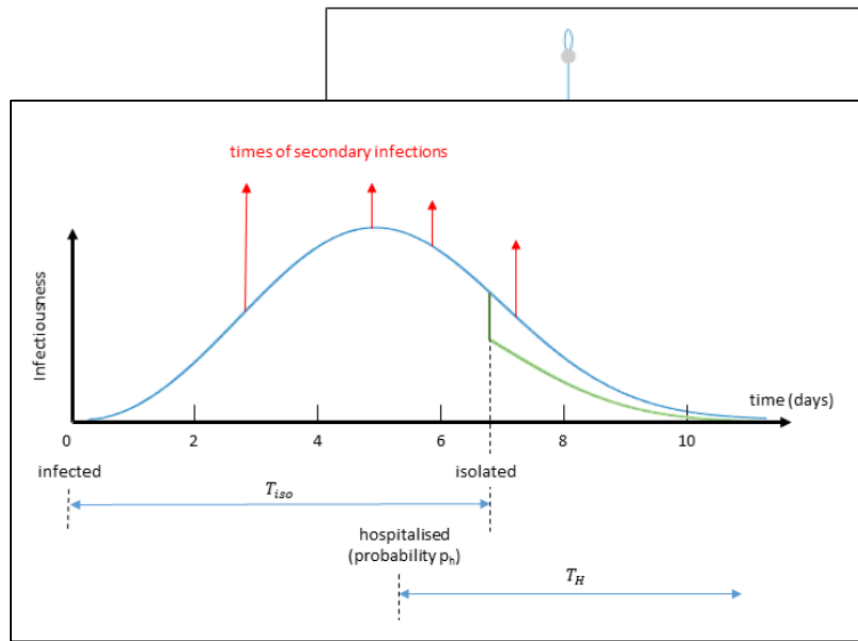


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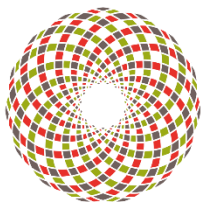
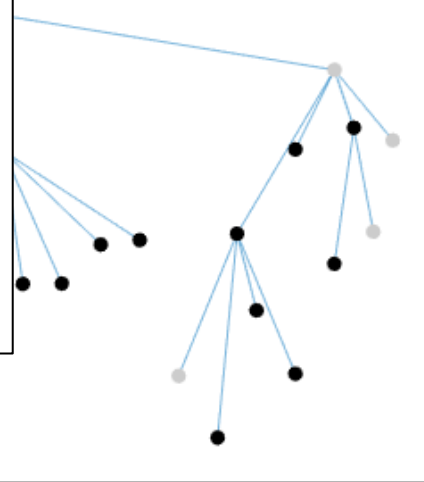
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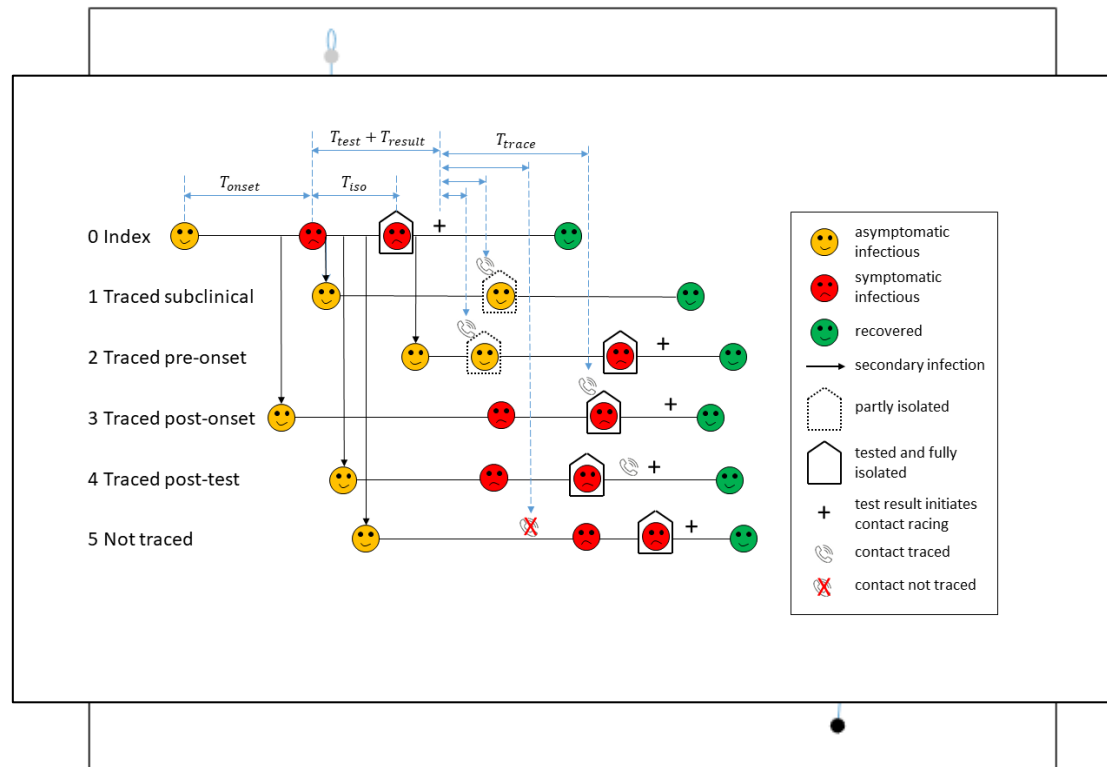


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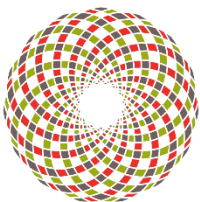
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**Contact
tracing**

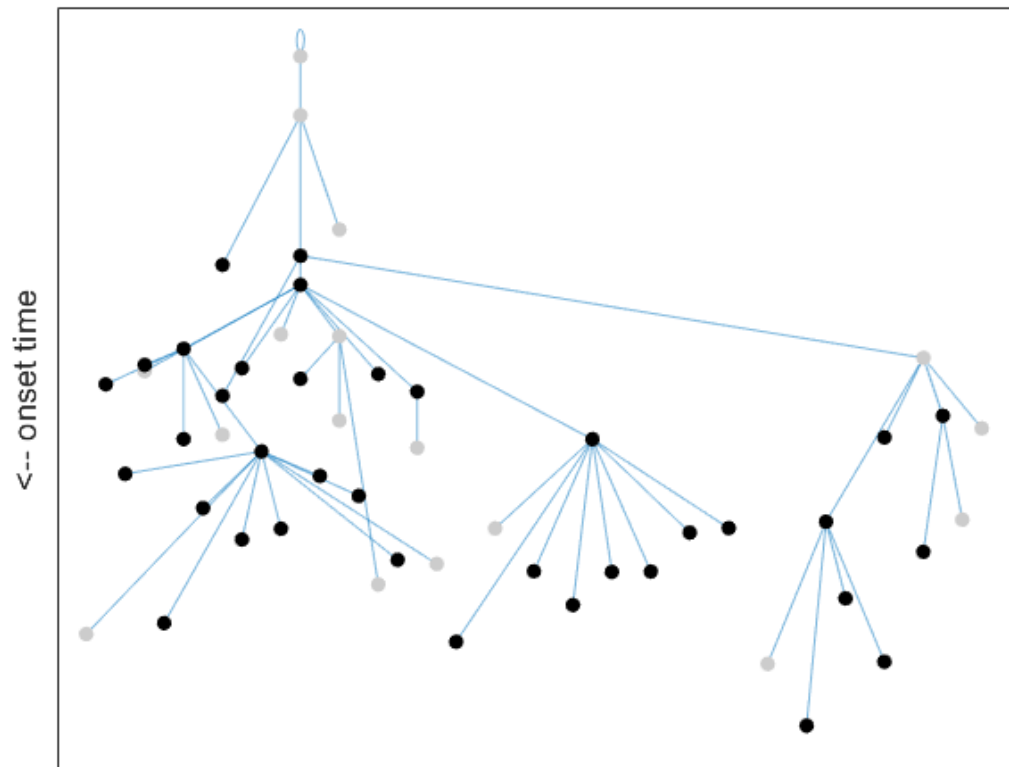


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James A, Plank MJ, Binny RN, Lustig A, Steyn N, Hendy S, Nesdale A, Verrall A (2020). Successful contact tracing systems for COVID-19 rely on effective quarantine and isolation. medRxiv preprint, doi: <https://doi.org/10.1101/2020.06.10.20125013>

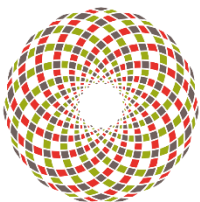
Stochastic model

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



**Contact
tracing**

**Age structure
& inequitable
access to
healthcare**

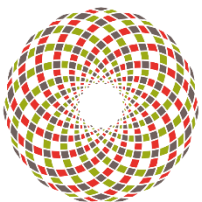
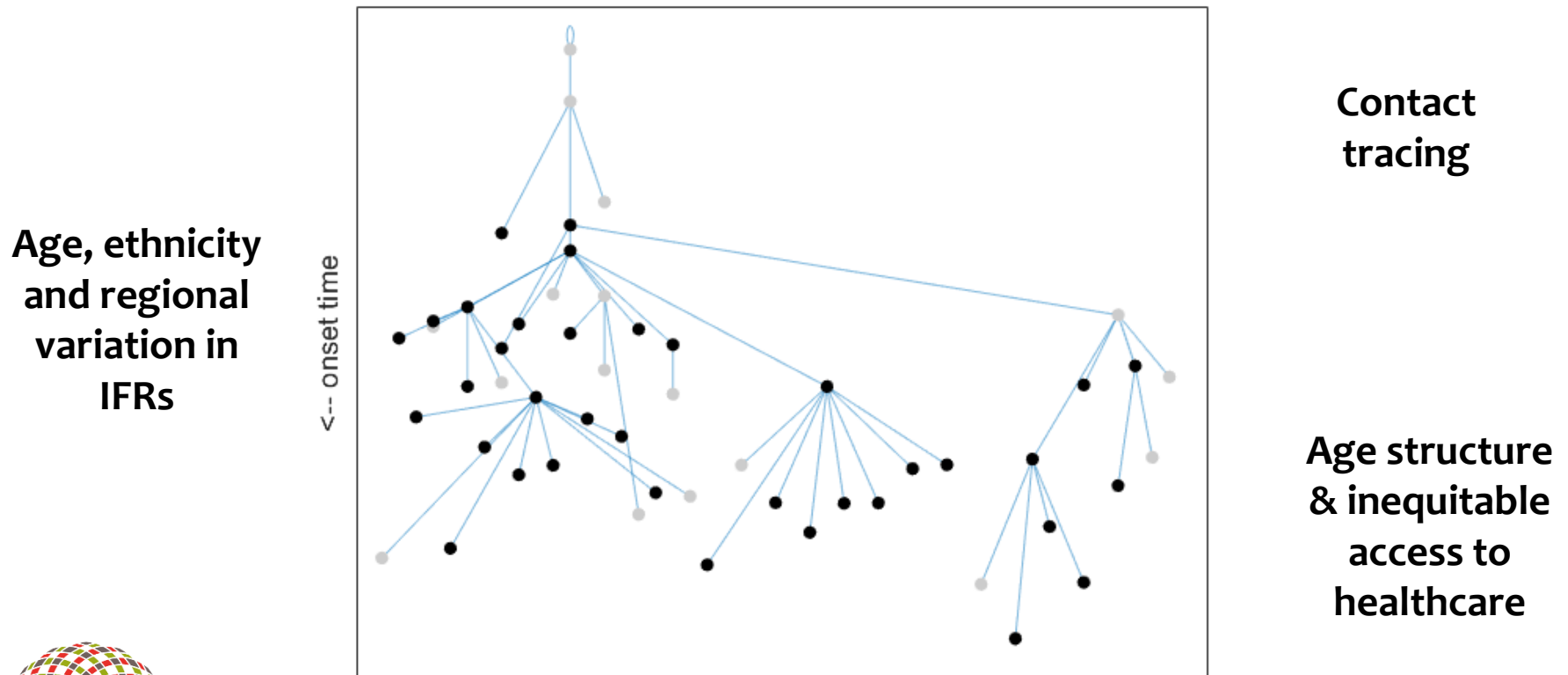


Te Pūnaha Matatini
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James A, Plank MJ, Binny RN, Hannah K, Hendy SC, Lustig A, Steyn N (2020). A structured model for COVID-19 spread: modelling age and healthcare inequities. medRxiv preprint, doi: <https://doi.org/10.1101/2020.05.17.20104976>

Stochastic model

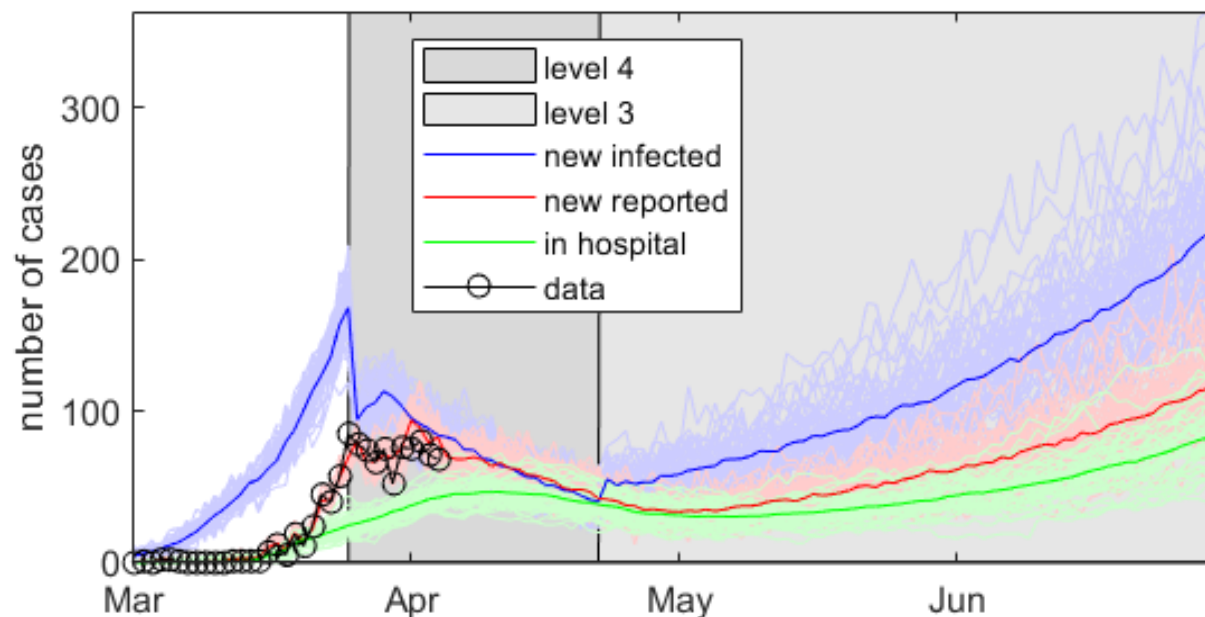
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Steyn N, Binny, RN, Hannah K, Hendy SC, James A, Kukutai T, Lustig A, McLeod M, Plank MJ, Ridings K, Sporle (2020). Estimated inequities in COVID-19 infection fatality rates by ethnicity for Aotearoa New Zealand. medrxiv preprint, doi: <https://doi.org/10.1101/2020.04.20.20073437>

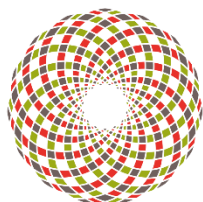
Stochastic model scenarios



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



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

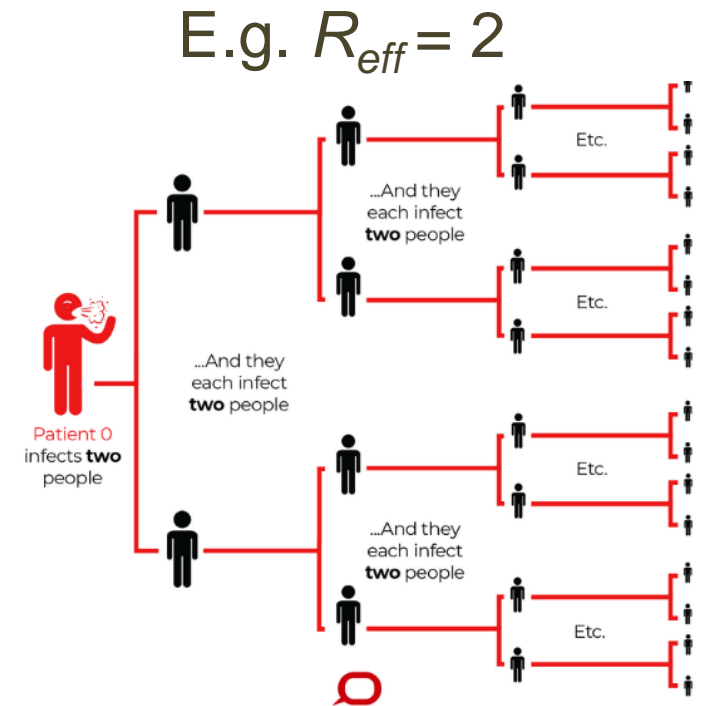
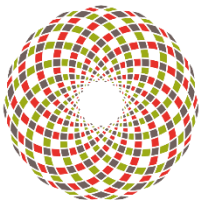


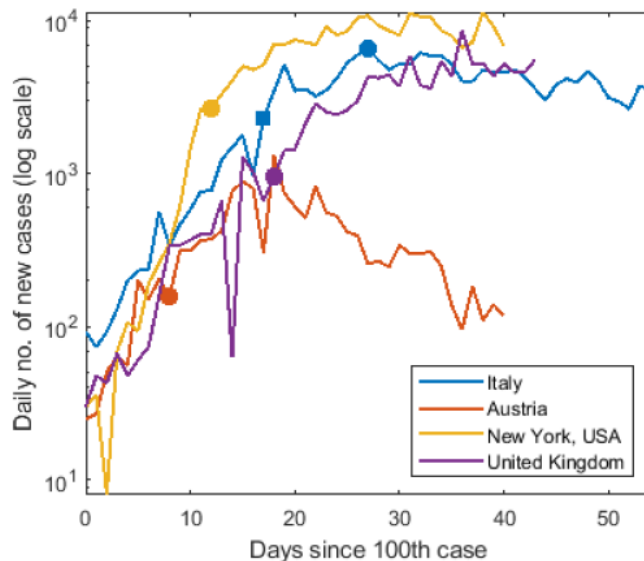
Image: The Conversation



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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)



Effect of Alert Level 4 measures on COVID-19 transmission

Science Policy

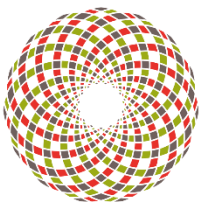
COVID-19: New Research

Effect of Alert Level 4 on R_{eff} :
review of international
COVID-19 cases



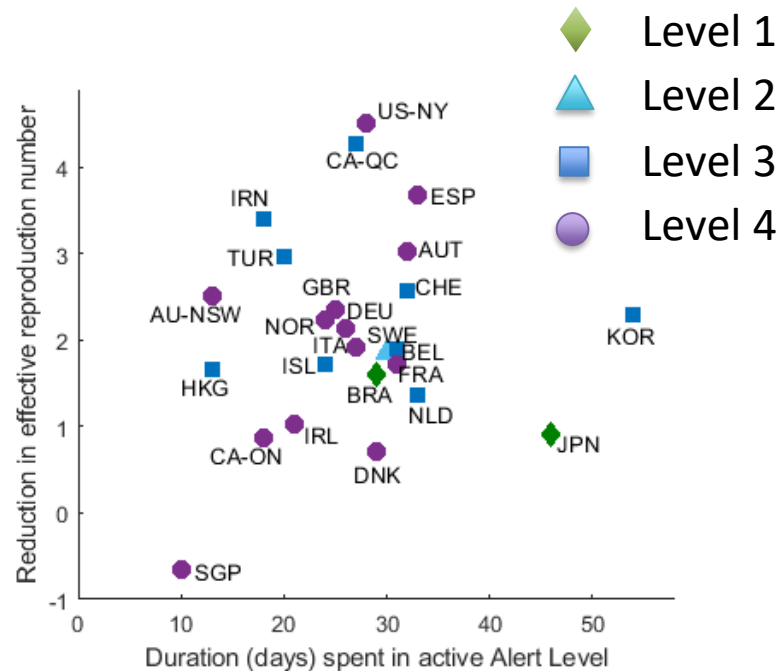
NEW RESEARCH — LINK TO FULL PDF HERE

22 April 2020



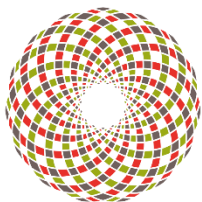
Binny RN, Hendy SC, James A, Lustig A, Plank MJ, Steyn N (6 May 2020). Effect of Alert Level 4 on R_{eff} : review of international COVID-19 cases. MedRxiv preprint, doi::<https://medrxiv.org/cgi/content/short/2020.04.30.20086934v1>

International review of R_{eff} after interventions



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)



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>

Italy

Alert Level 4



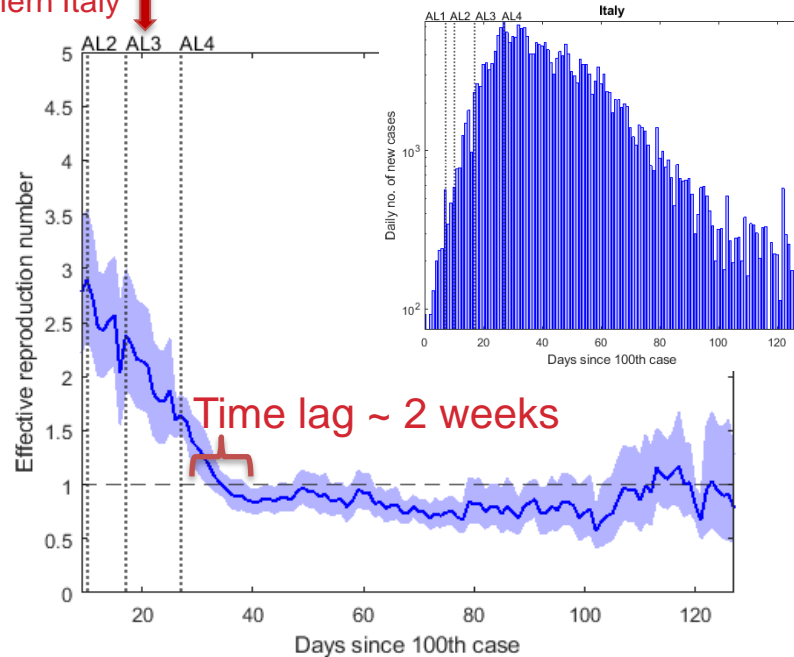
Image: REUTERS/Flavio Lo Scalzo

Singapore

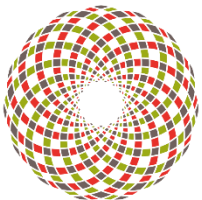
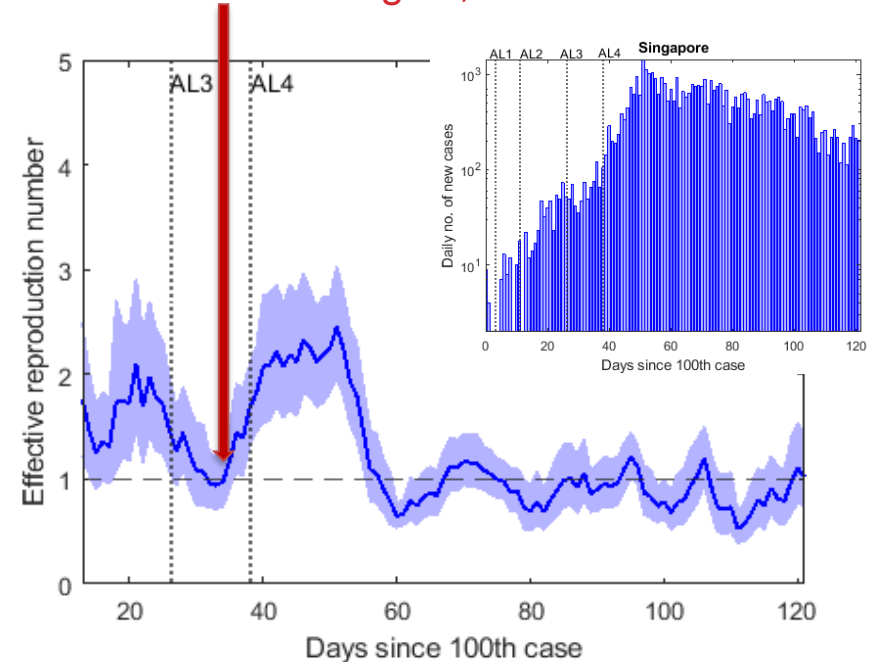
Alert Level 4



Healthcare system
overloaded in
Northern Italy



Second wave begins, 30 Mar



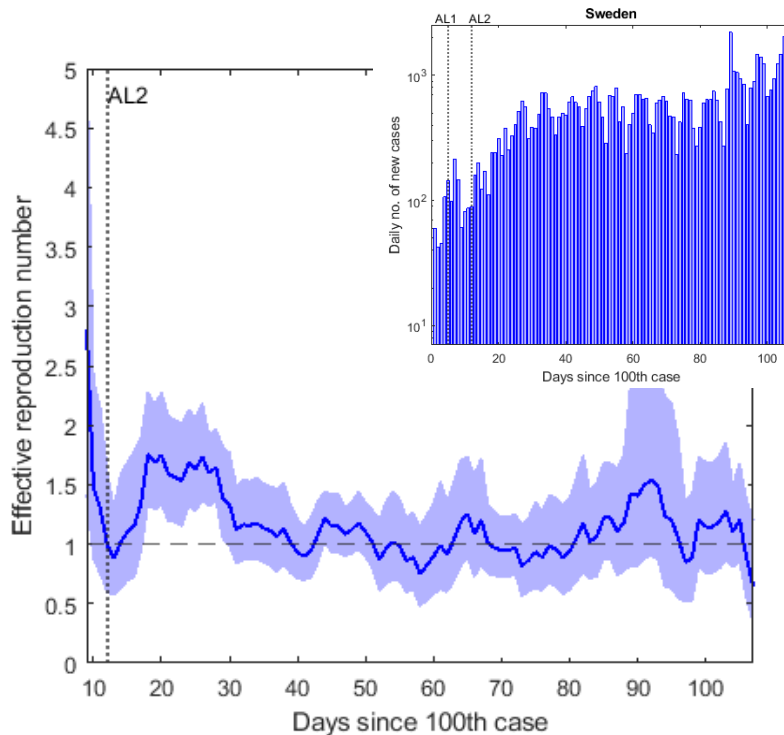
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Sweden

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

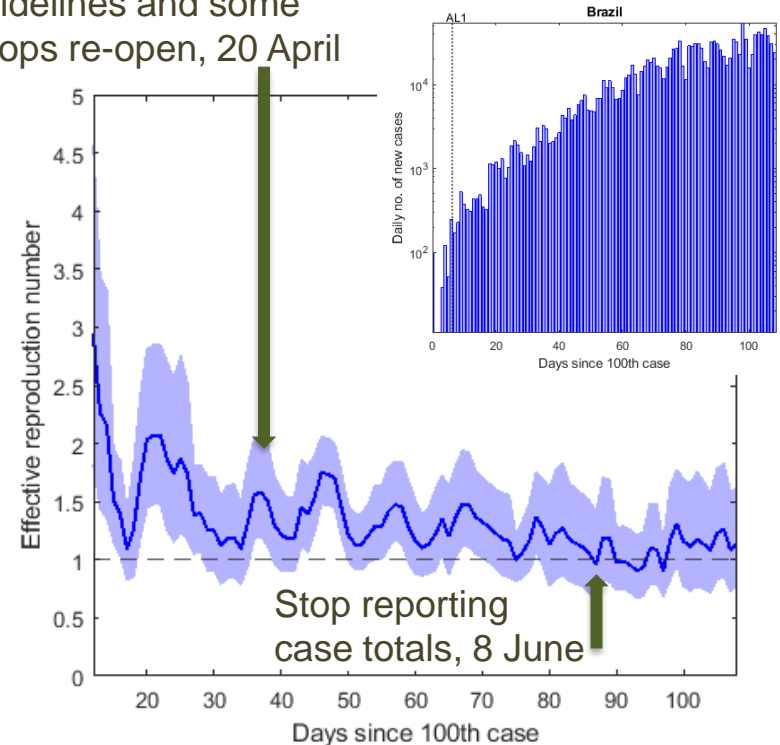


Brazil

Alert Level 1

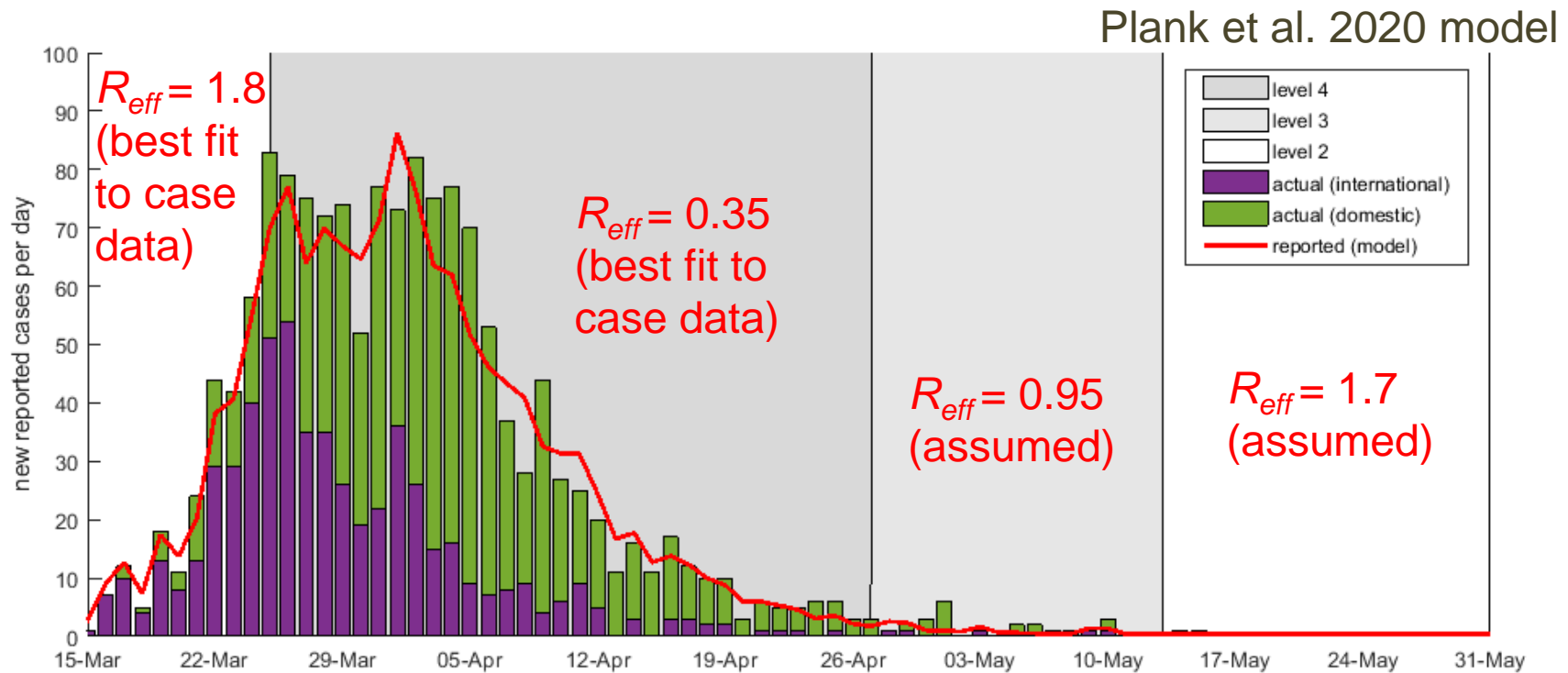
Total cases (1 July)	Total deaths
1,408,485	59,656

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

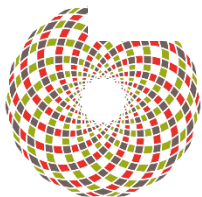


New Zealand's effective reproduction number

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



(Case data source: Ministry of Health)



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Total cases (1 July)

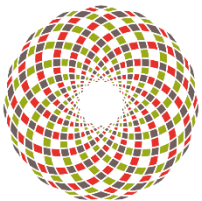
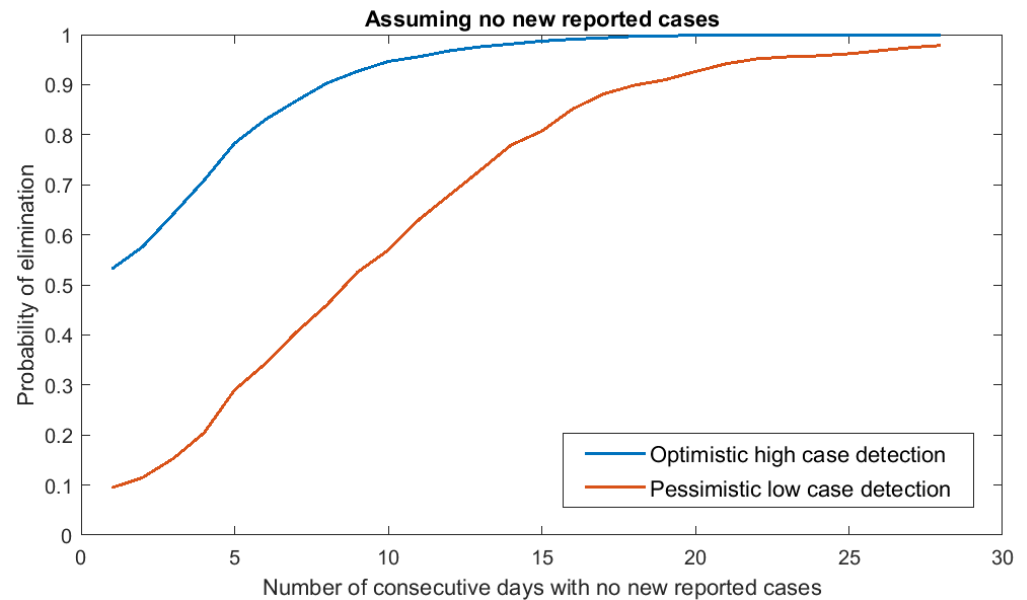
1528

Total deaths

22

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

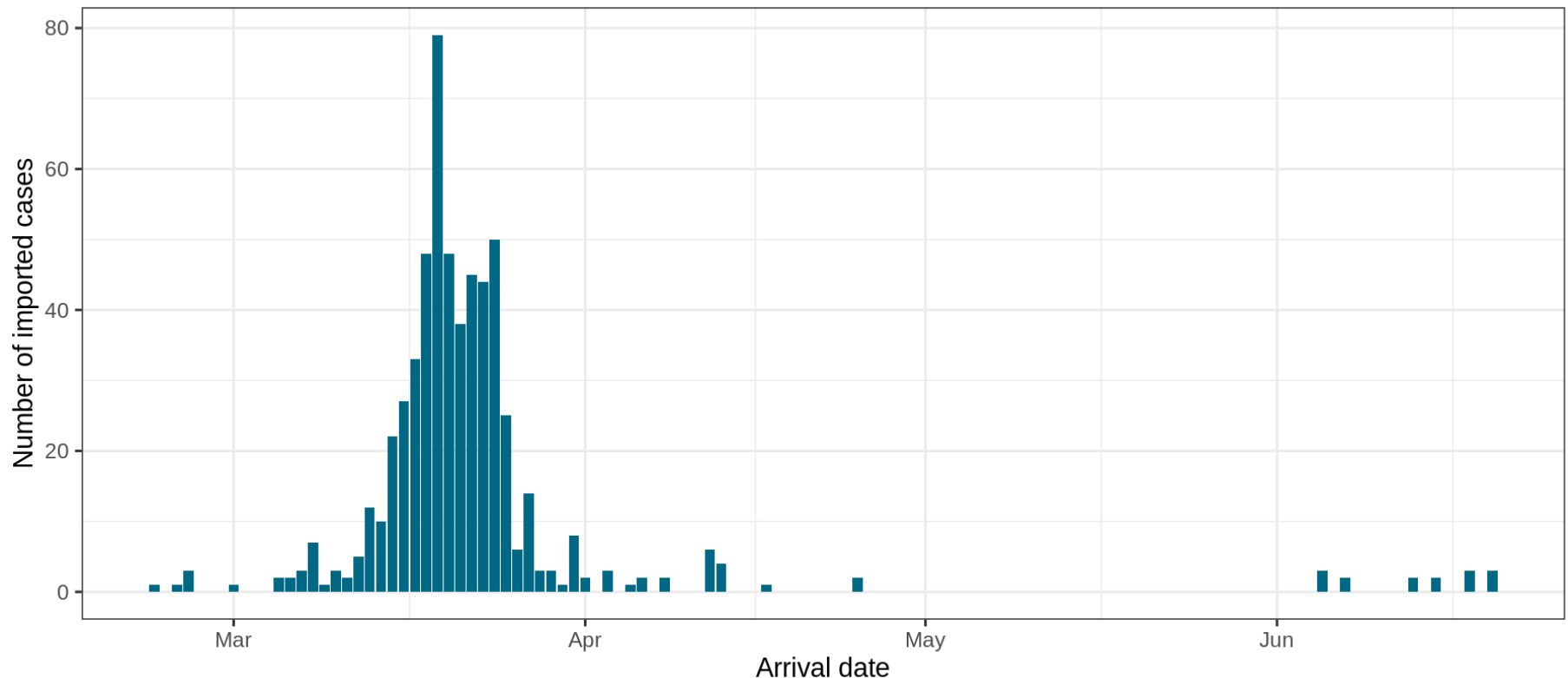


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<https://theconversation.com/new-zealand-hits-a-95-chance-of-eliminating-coronavirus-but-we-predict-new-cases-will-emerge-139973>

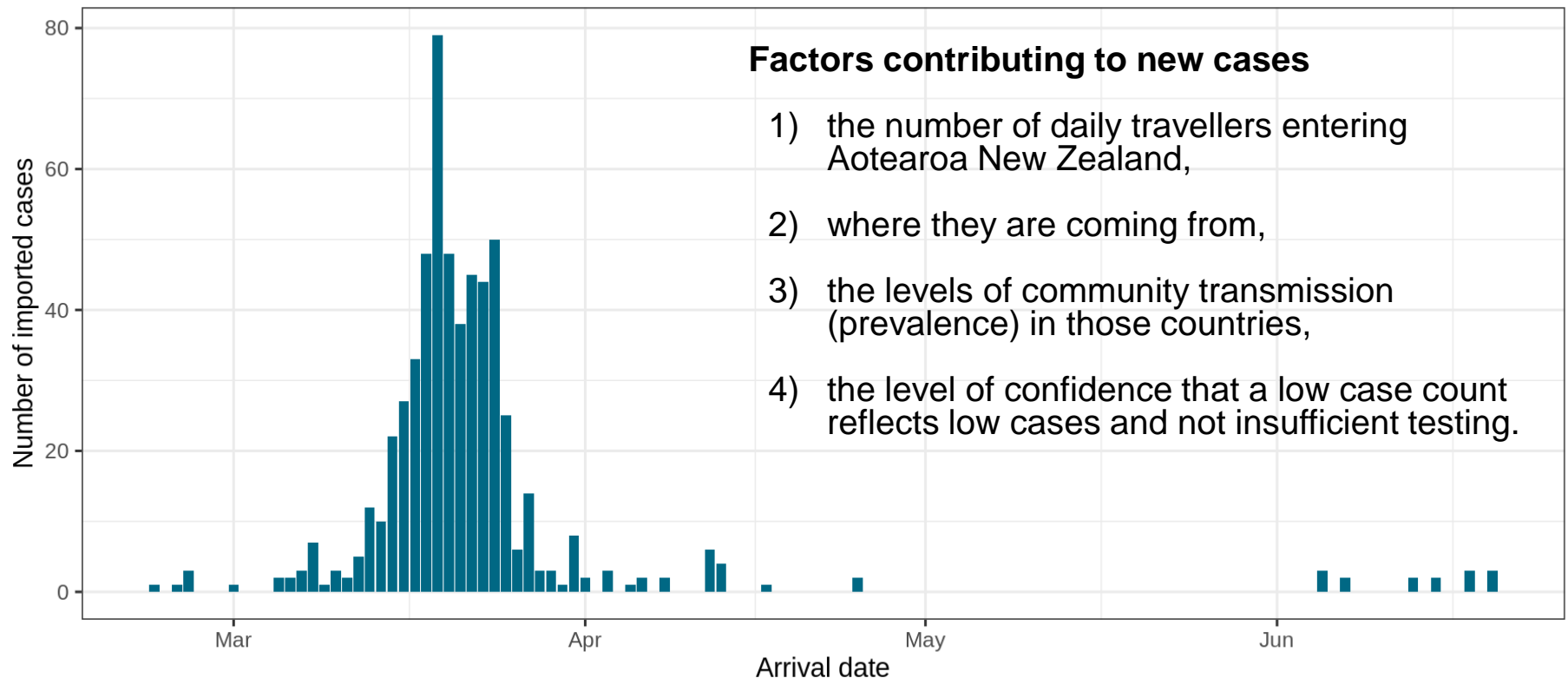
Modelling border risk and controls

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)!



Modelling border risk and controls

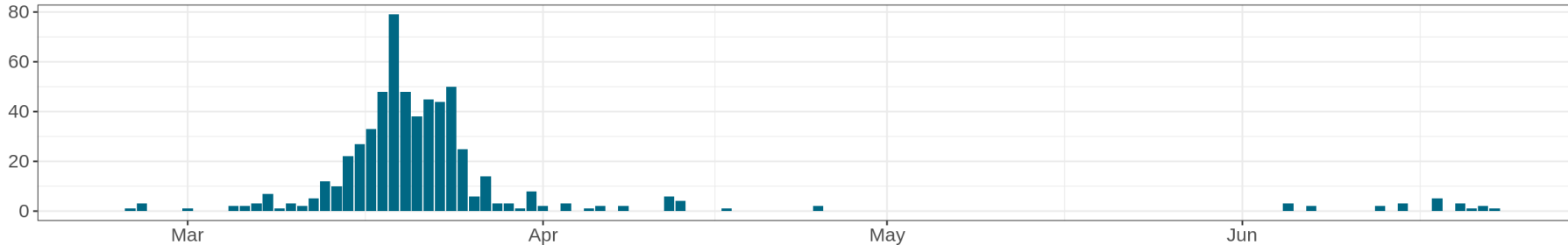
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Volume of arriving travelers

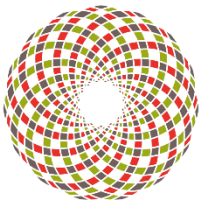
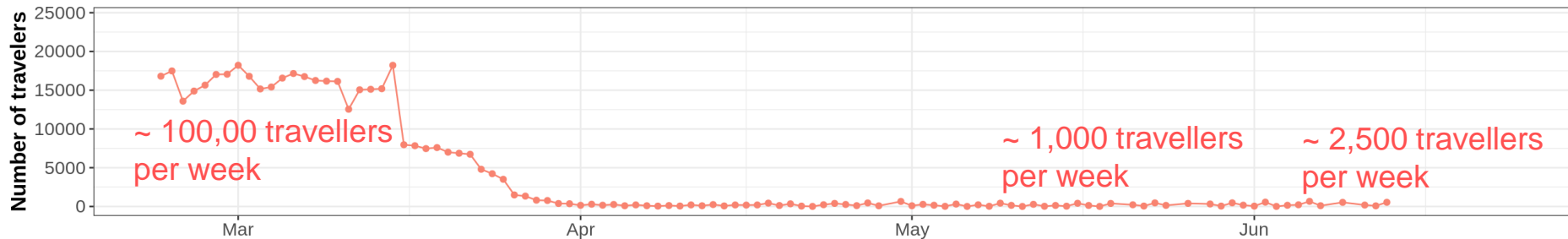
Number of imported cases

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



Number of travelers

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



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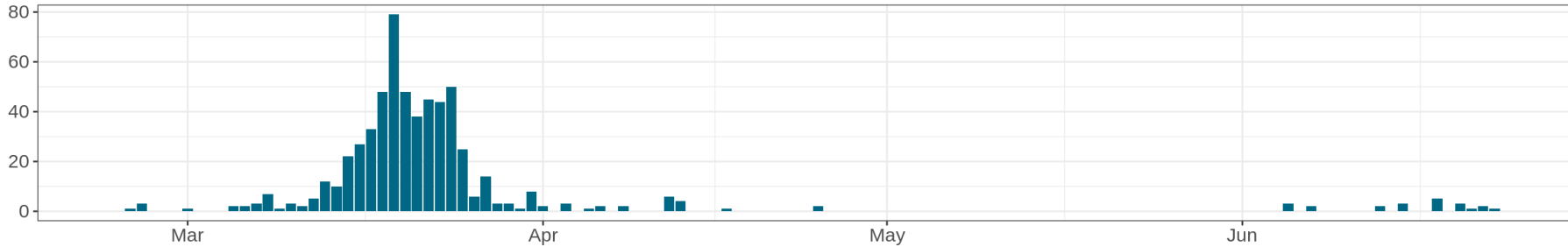


Source: The Spinoff

Prevalence at source

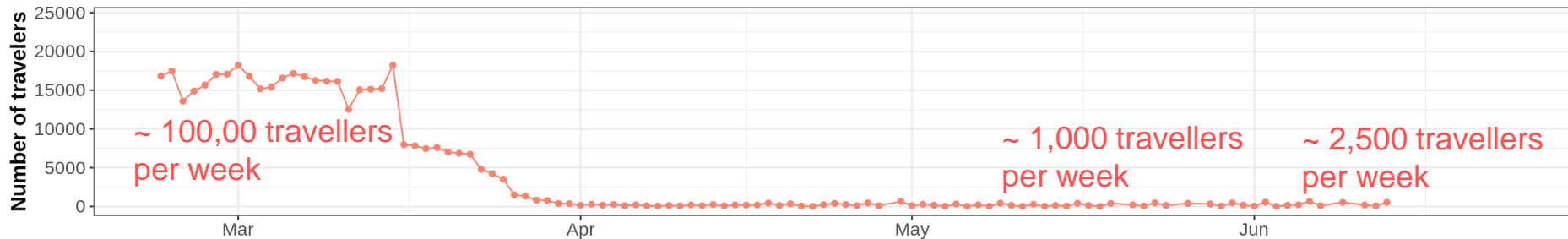
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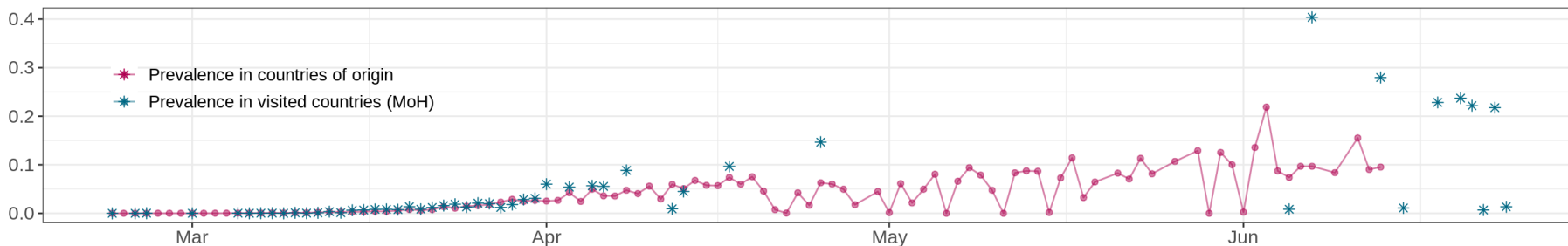
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Prevalence at origin (%)

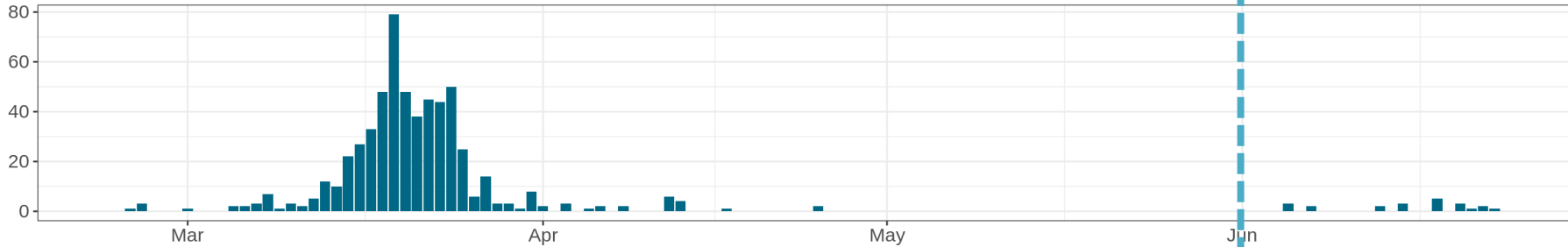
The prevalence has rapidly increased in countries people are traveling from



Prevalence at source

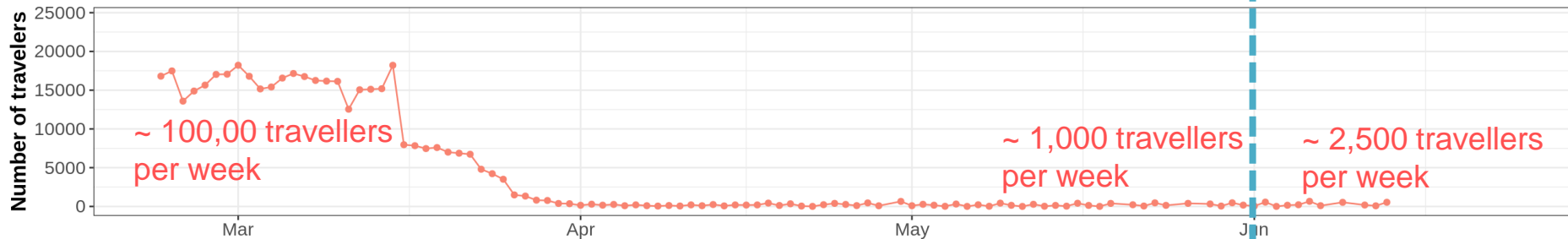
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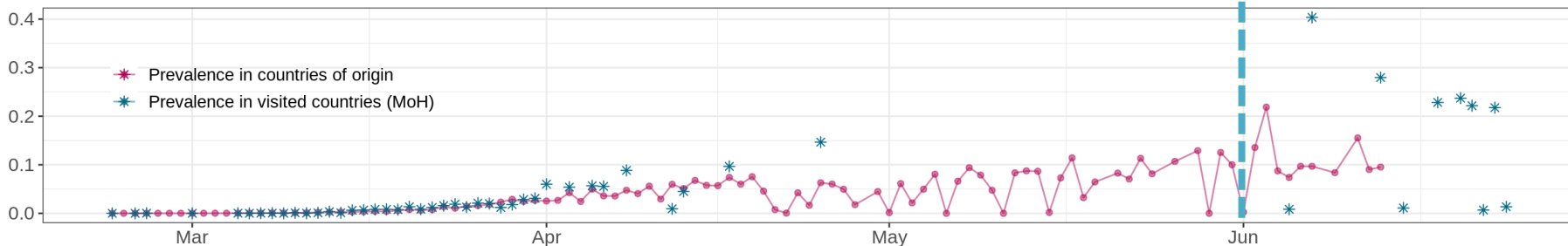
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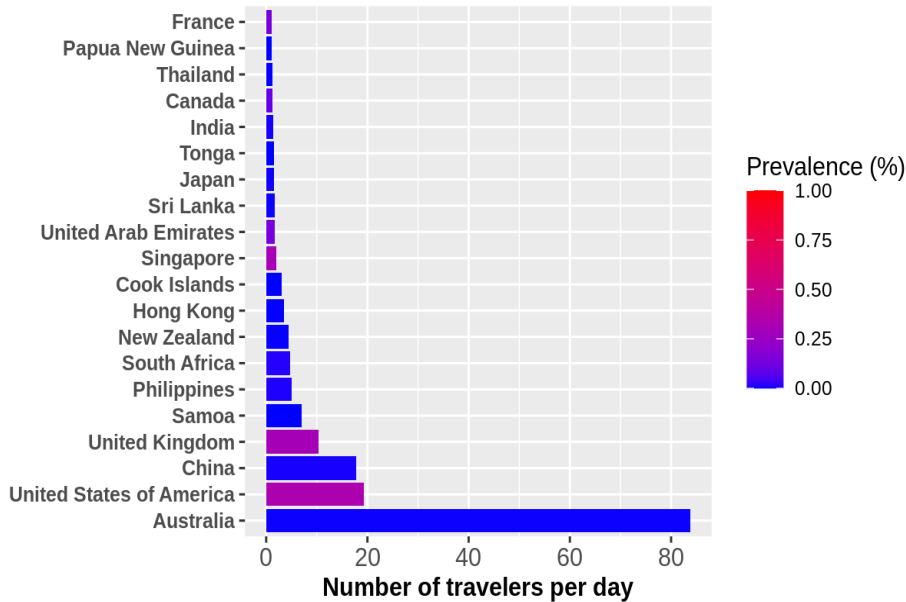


Increased testing

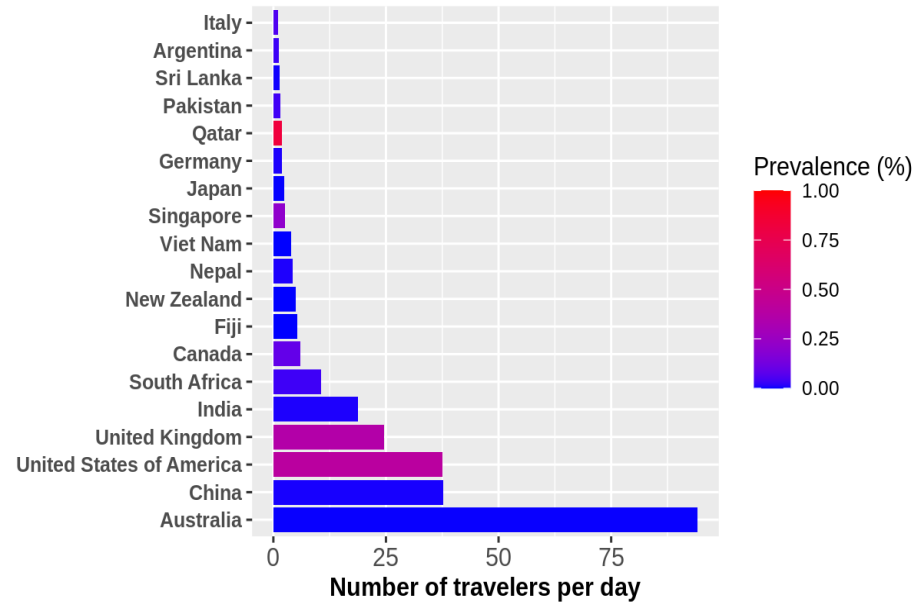
Make up of countries people are traveling from

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.

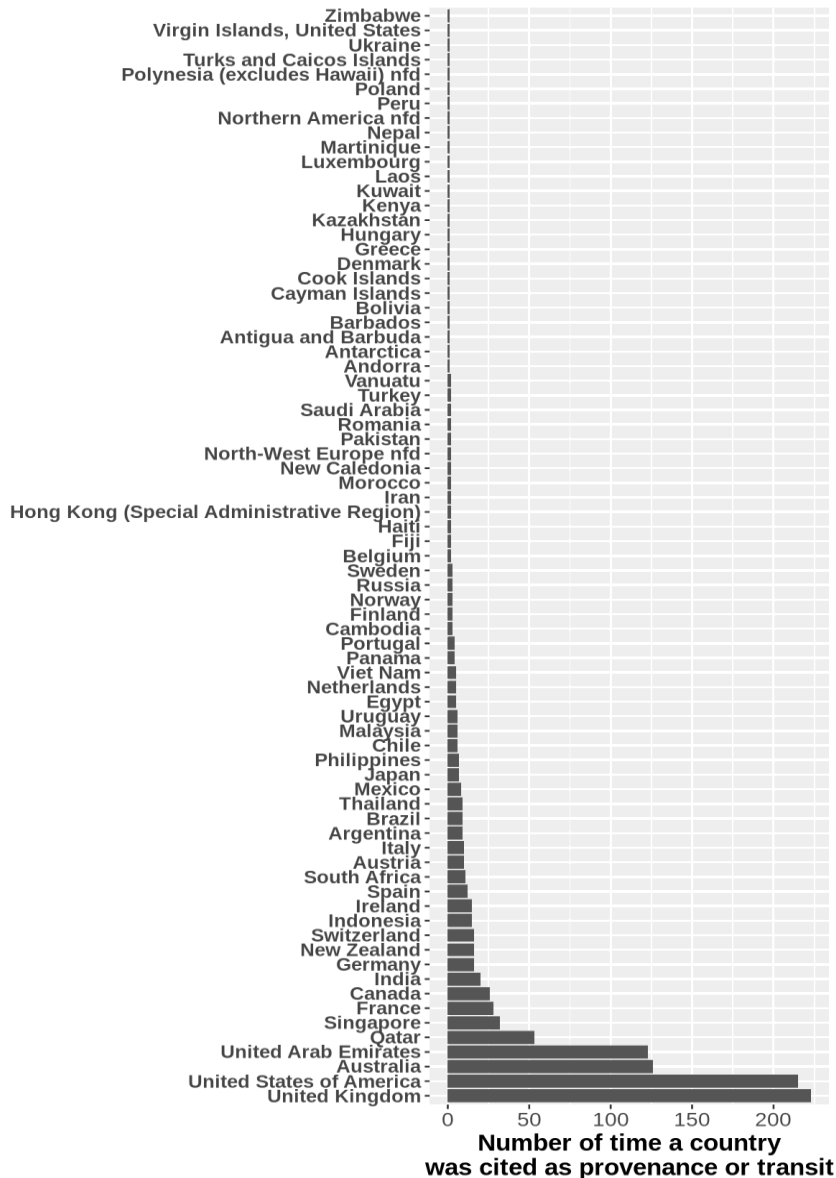
May



June



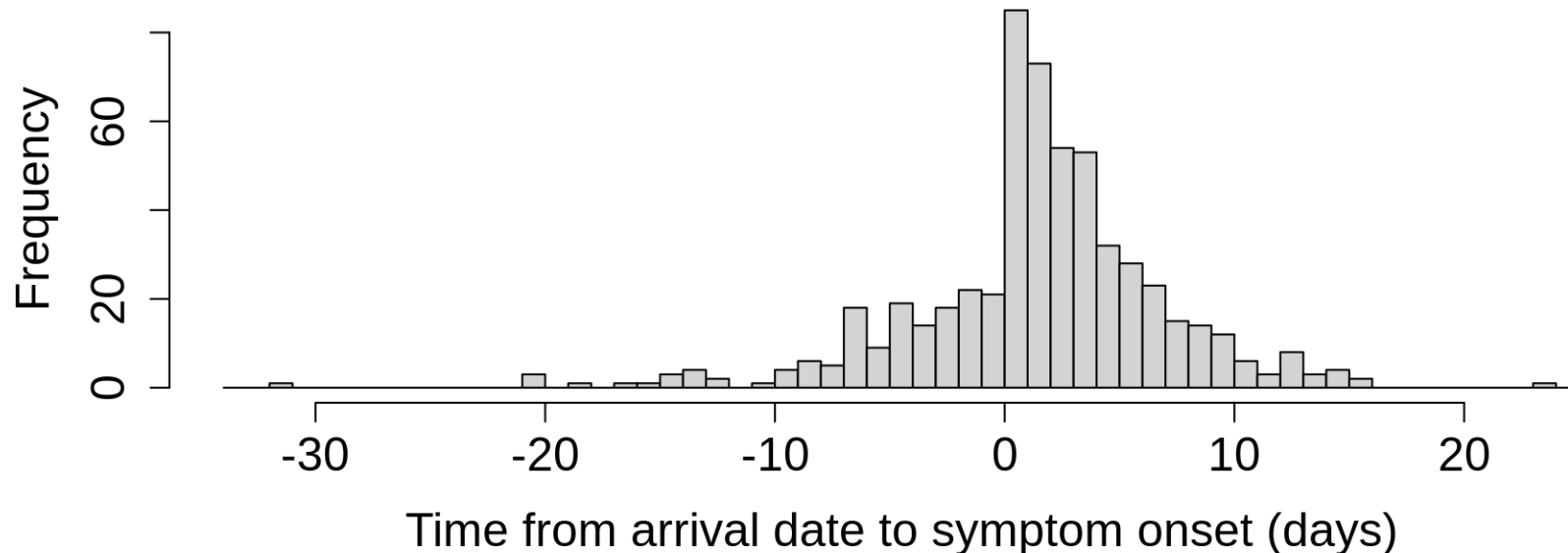
Source of acquisition



- The data are a bit noisy because many of our imported cases visited or transited through 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.

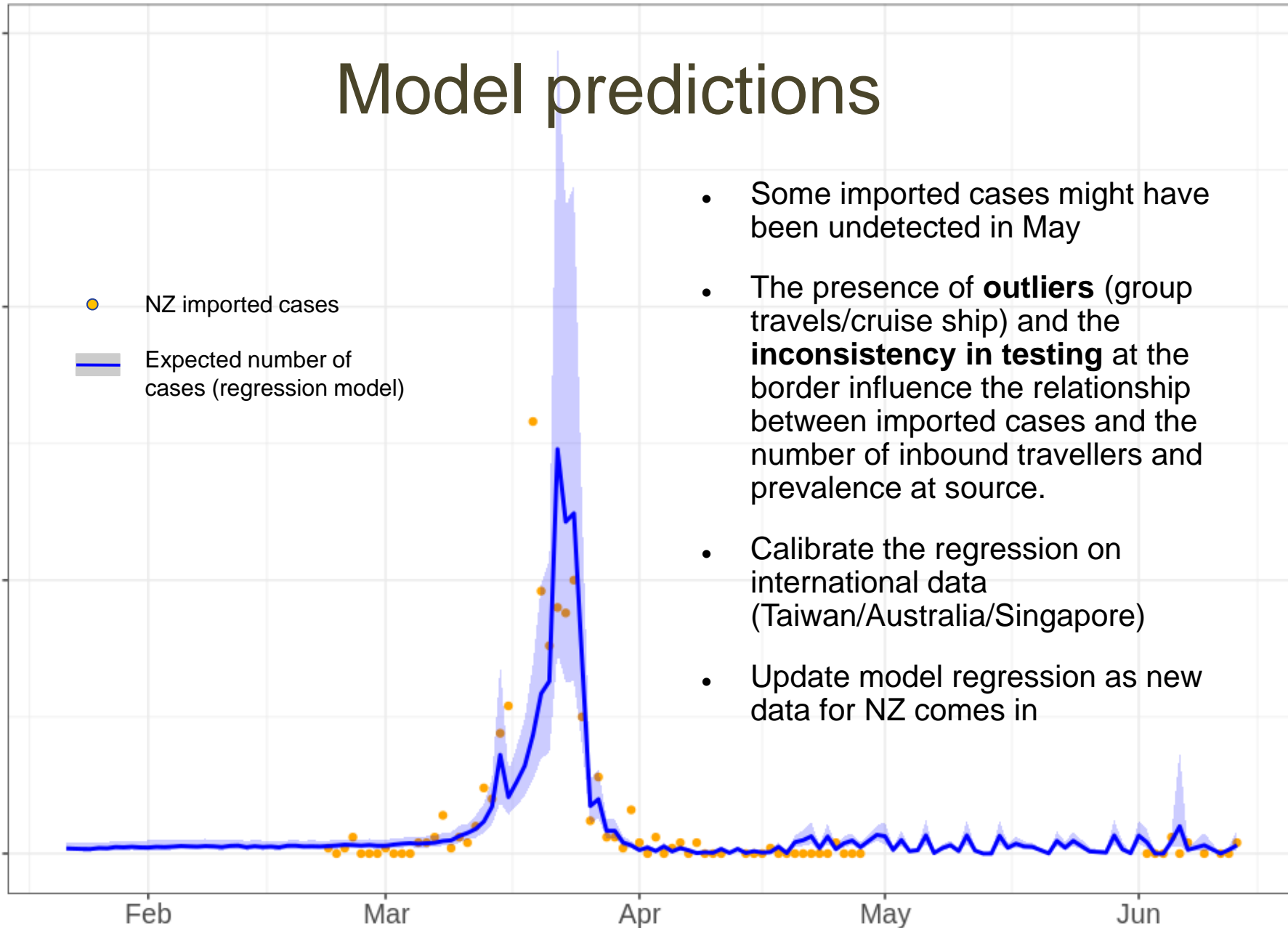


Model predictions

Number of imported cases of COVID-19

- NZ imported cases
- Expected number of cases (regression model)

- 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



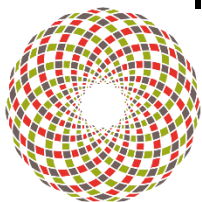
Managed isolation facilities

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

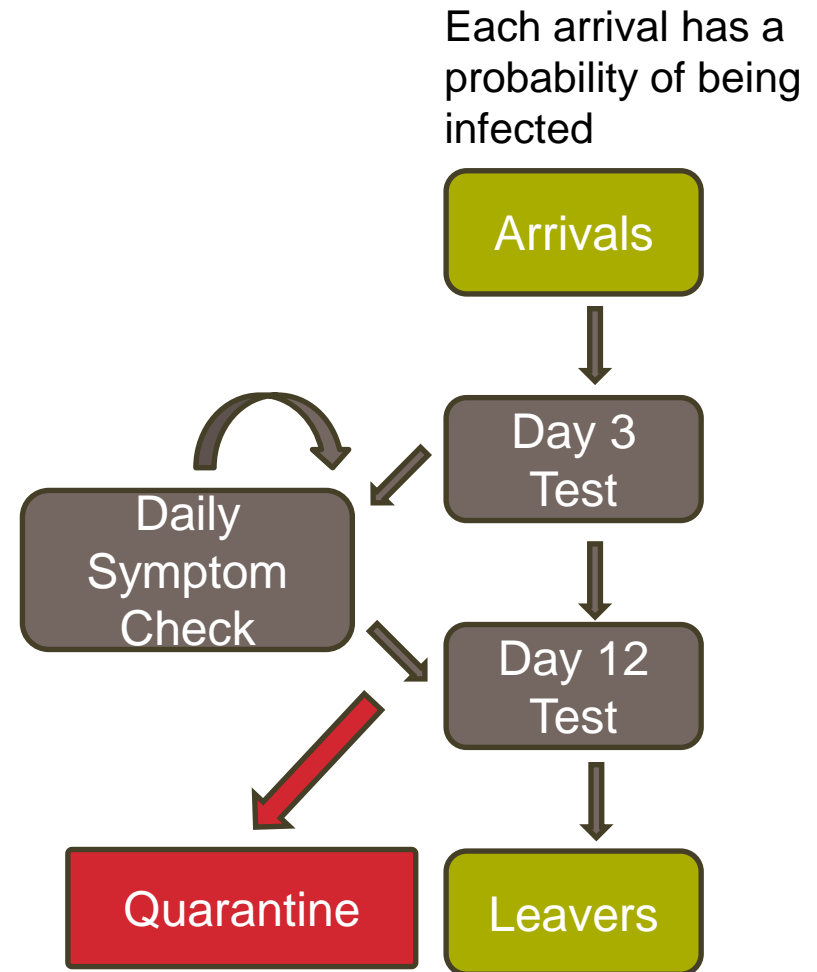
The mandatory 14-days is pretty good, but not impenetrable.

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?

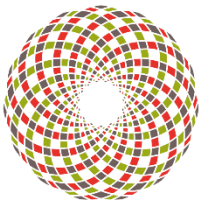
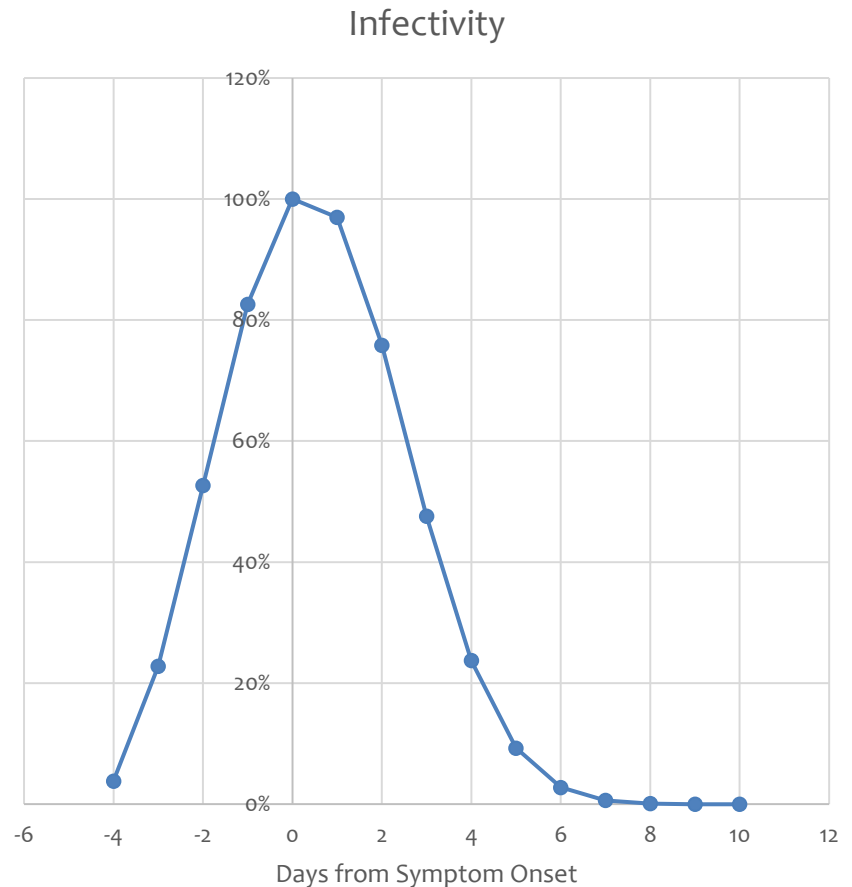


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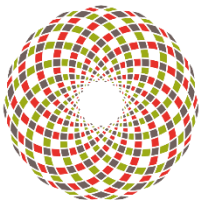
Missed cases

- 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



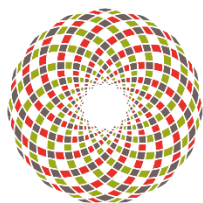
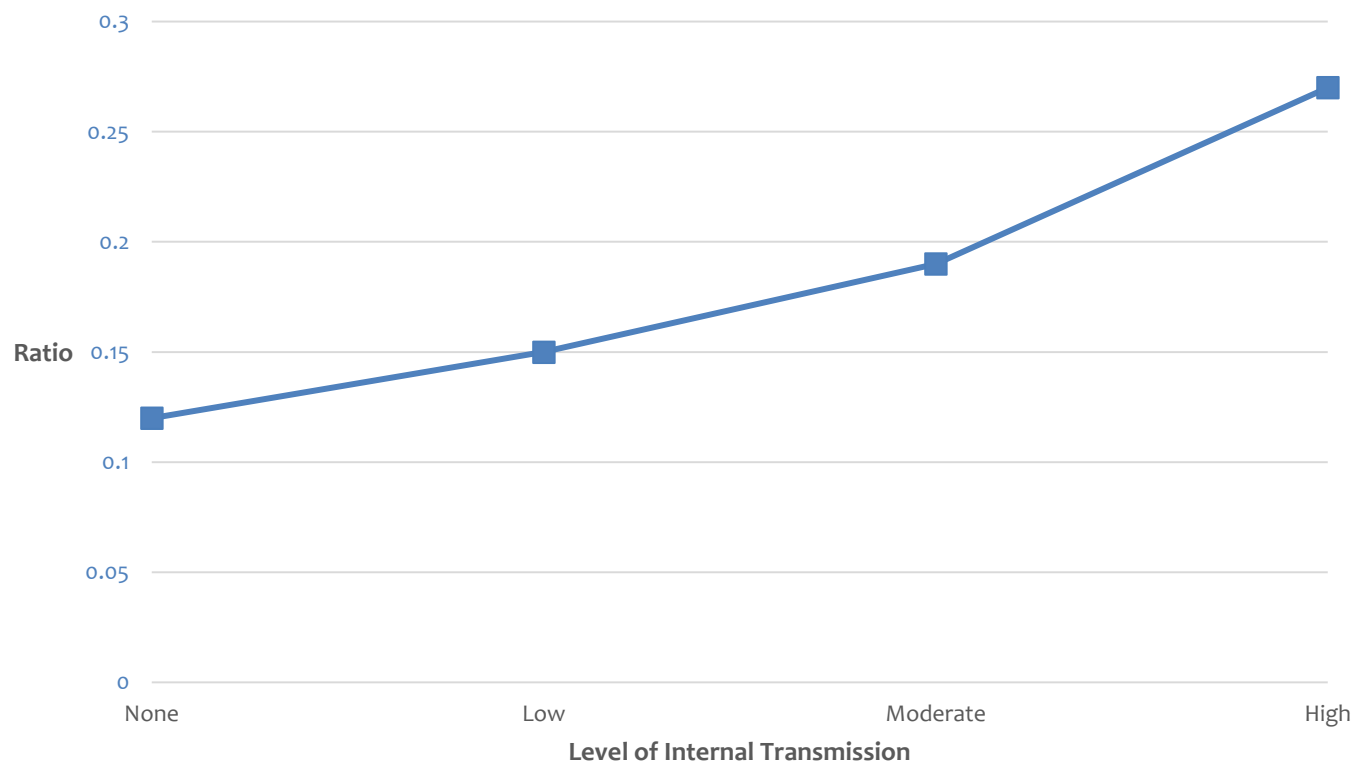
Internal Transmission

- 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



Internal Transmission

Modelled Results (too early to use current data):



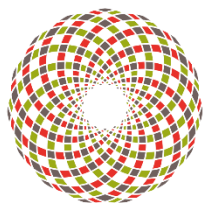
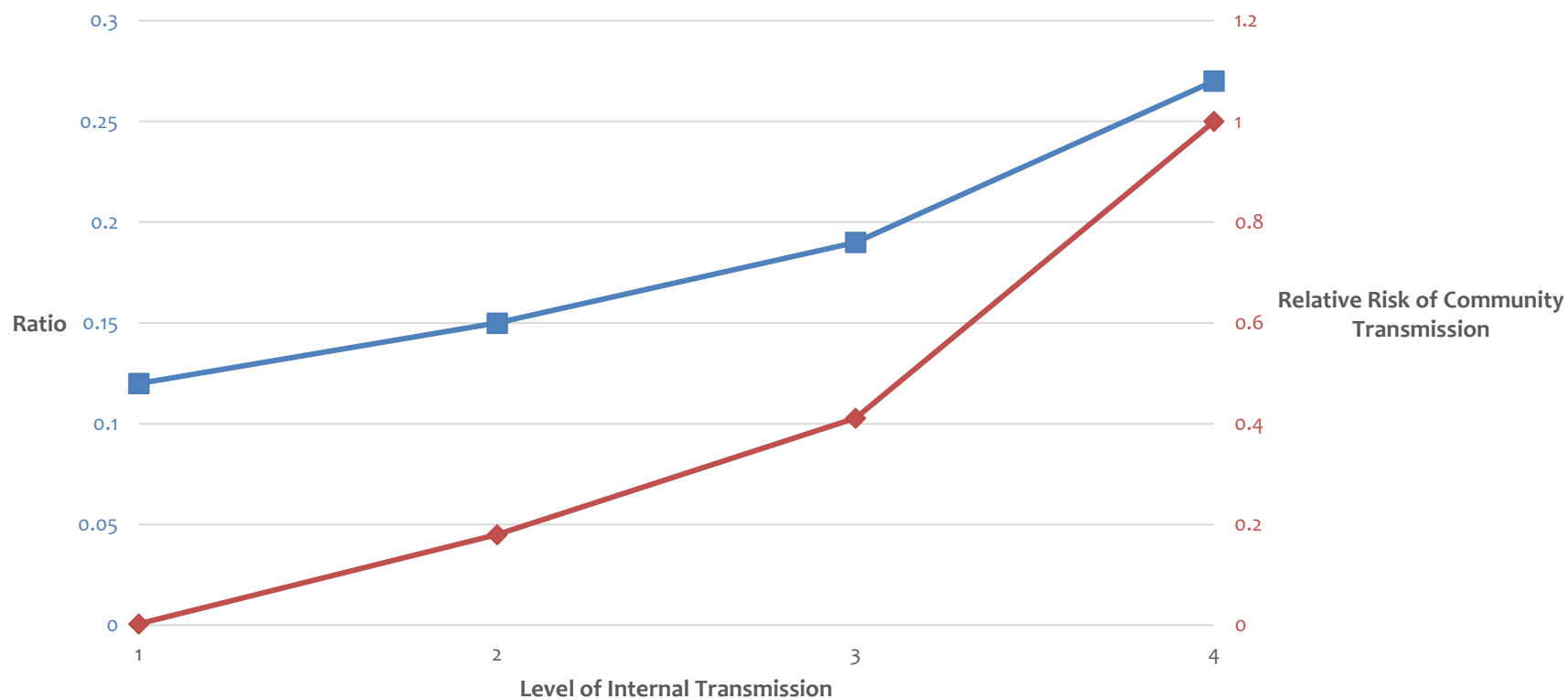
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—■ Ratio

*Ratio approximate and depends on parameters

Internal Transmission

Modelled Results (too early use real data):



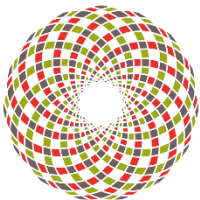
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—■— Ratio —◆— Relative Risk

*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)

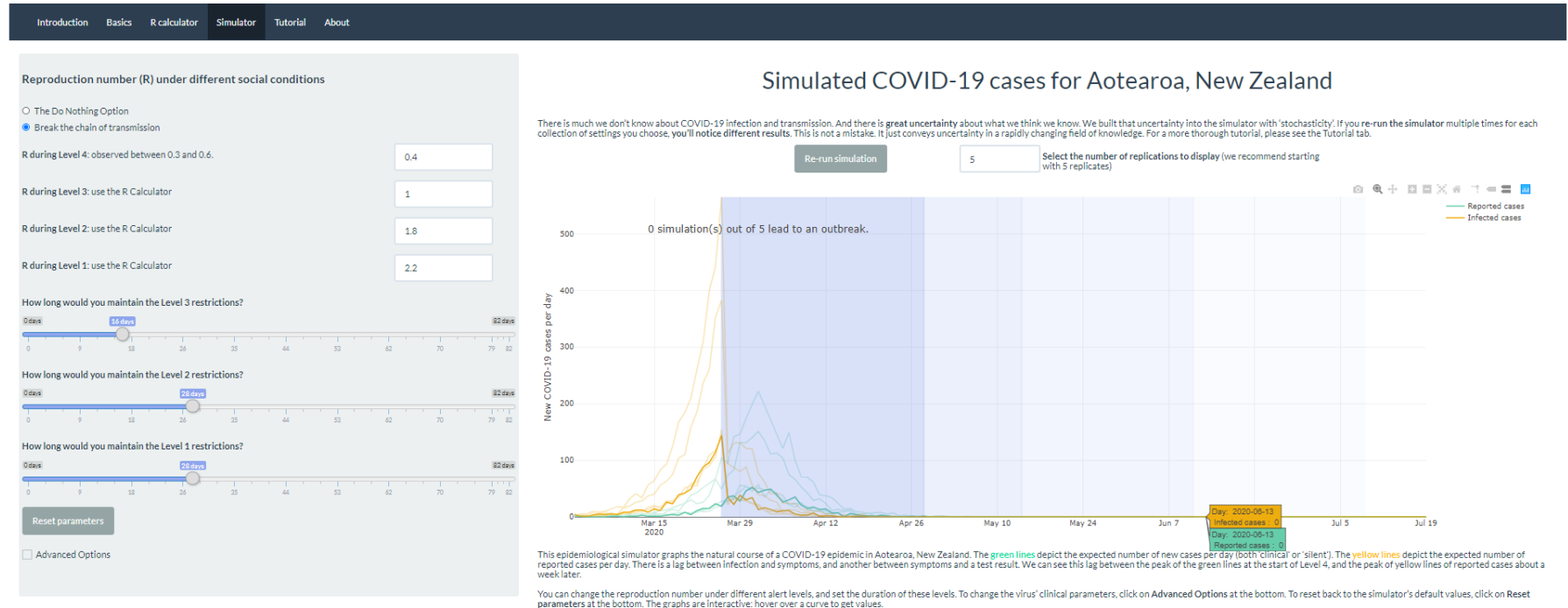


Thank you for listening

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

COVID-19 Take Control simulator

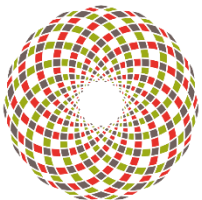
Disclaimer: This simulator is intended for research and educational purposes only, not for decision-making. It simulates the natural course of a COVID-19 epidemic in Aotearoa, New Zealand. This work is licensed under the GNU General Public License v3.0 (GNU GPLv3)



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