Work Package 3: Review border measures & arrivals pathways in context of revised risk tolerance

Key question: How can arrivals caps and pathways be safely modified in the context of the changing risk environment as population vaccine coverage increases?

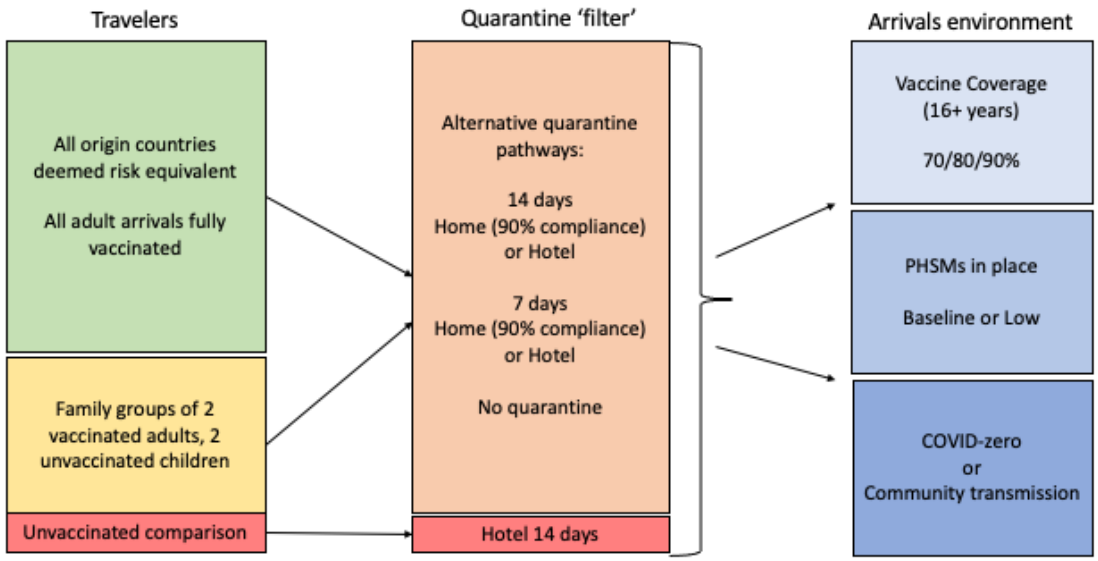
Overview: This work package extends on earlier models of quarantine and importation risk assessment to consider alternative arrivals arrangements for vaccinated individuals including family quarantine, and the impact of increased arrivals caps on outbreak risk during Phases B and C of the National Plan.

The purpose of this report is to:

1. Review the quarantine pathways risk assessment using our updated parameters for vaccine effectiveness against the Delta strain, including assessment of family pathways, reduced quarantine durations and alternative testing regimens;
2. Demonstrate the relative infection risk associated with hypothesised arrivals scenarios developed in consultation with PM&C, Home Affairs and Treasury, based on pre-COVID-19 travel volumes for Australian citizens and permanent residents into a large and medium jurisdiction;
3. Demonstrate the local epidemiological impact associated with these arrivals scenarios for jurisdictions where COVID-19 transmission is established (endemic cases) or absent (COVID-zero) for different vaccine coverage levels and application of public health and social measures (PHSMs).

Figure 1 shows an overview of the risk assessment pathway by which the influence of arrivals on local epidemiology will be characterised in this reporting phase. In the first instance, we will assume uniform risk of exposure in the country of origin for travellers from the majority of destinations, deemed 'green'. We will consider the relative effectiveness against importations of alternative quarantine approaches, applied to fully vaccinated travellers and partially vaccinated families. Consequences of importations are determined by three characteristics of the arrivals environment: vaccine coverage, the level of intensity of public health and social measures (PHSMs) and the level of pre-existing transmission of COVID. 'Partial' or 'optimal' test-trace-isolate-quarantine (TTIQ) responses are assumed to be ongoing.

Figure 1: Overview of the risk assessment pathway



1. Updated quarantine pathways risk assessment

In previous work we defined the *force of infection* associated with quarantine breach events as the number of days an infectious individual is in the community adjusted for their relative infectiousness. It can be interpreted as the expected number of secondary cases produced per infected arrival through a given quarantine pathway in a *fully susceptible* community. It exceeds one for an unvaccinated infected individual without quarantine or testing. This metric also allows comparison of the relative risks posed by vaccinated and unvaccinated travellers, given that we assume vaccinated breakthrough infections are less infectious per unit time.

Hotel quarantine is modelled as previously, with a 14-day duration as the benchmark, for comparison with a 7-day stay. Compliance in this system is assumed to be 100% due to oversight. Testing is an important risk mitigation measure for both travellers and workers, the former according to a fixed schedule (days 1, 5 and 13 for 14-day duration; days 1 and 5 for 7-day duration), the latter corresponding to their days of work. Confirmed cases are removed to an isolation facility for 10 days, and the quarantine duration of their travelling party contacts is extended by 14 days in situ. All measures are implemented in accordance with the national minimum standard, which may be exceeded by some jurisdictions to further reduce risks.

Home quarantine is modelled as previously, with a 14-day duration as the benchmark, for comparison with a 7-day stay. The household unit is assumed to be bound by the restrictions imposed for the same duration as the arriving traveller, whether they have returned together from overseas or represent the home-based contacts of a returning single traveller. Testing is conducted according to the same schedule as hotel quarantine. We consider a range of compliance levels:

- 100% compliance with social restrictions, allowing quantification of the additional risks of transmission within the hotel quarantine system to other travellers (and workers);
- 90% compliance with social restrictions, deemed reasonably achievable by jurisdictions who have offered this arrivals pathway to exempt travellers;
- 75% compliance with social restrictions.

In addition, this report includes evaluation of 2 or 3-day home quarantine durations, with rapid antigen testing (RAT) on days 0,1 or 0,1,2 respectively.

No quarantine is modelled as previously, with no constraints placed on arrivals. Polymerase Chain Reaction (PCR) testing is the only substantive risk mitigation measure, with tests required on days 1 and 5. Testing is an important risk mitigation for arrivals through the 'no quarantine' pathway, reducing the force of infection by about four times compared with the 'no testing' option, which is now also shown in the pathway for reference.

Our updated calculations include assessment of the risks posed by family groups composed of adults and children, understanding that children less than 12 years are currently ineligible for vaccination. Vaccination reduces infectiousness and hence the risk posed by quarantine breach events from immunized travellers. In this way it mitigates against the observed increase in community exposure days resulting from shorter duration stays. Given the anticipated intensity of transmission pressure within the confined family group, we assume all members are equally infectious and susceptible in the quarantine environment.

Updated estimates for the force of infection per infected arrival are shown in Tables 1.1 and 1.2 for adult arrivals and families, respectively, by vaccination status, quarantine pathways and testing regimens.

Table 1.1: Force of infection contributed by an infected adult arriving in a group of four travellers, by vaccination status, quarantine pathway and testing regimen

Pathway	Duration (days)*	Vaccinated	Compliance (%)	Force of infection per infected arrival	Force of infection relative to baseline
Hotel	**14**	**No**	**100**	**0.042**	**1**
		Yes		0.013	0.31
	7	No		0.17	4.05
		Yes		0.081	1.93
Home	14	No	100	0.019	0.45
			90	0.123	2.93
			75	0.283	6.74
		Yes	100	0.008	0.19
			90	0.076	1.81
			75	0.167	3.98
	7	No	100	0.119	2.83
			90	0.219	5.21
			75	0.371	8.83
		Yes	100	0.07	1.67
			90	0.133	3.17
			75	0.225	5.36
Home (daily RAT)[#]	3	Yes	100	0.597	14.21
			90	0.641	15.26
			75	0.695	16.55
	2	Yes	100	1.207	28.74
			90	1.236	29.43
			75	1.282	30.52
No quarantine	0	No	NA	1.121	26.69
		Yes		0.69	16.43
No quarantine or testing	0	No	NA	4.85	115.48
		Yes		2.807	66.83

**For quarantine durations of 14 days, arrivals are PCR tested on days 1, 5 and 13; for quarantine durations of 7 or 0 days, arrivals are PCR tested on days 1,5.*

[#]For 2-3 day home quarantine options, individuals are rapid antigen tested (RAT) on days 0,1 (2 day stay) OR days 0,1,2 (3 day stay)

Table 1.2: As for Table 1.1 but for family group arrivals comprising 2 vaccinated adults and 2 unvaccinated children aged <12 years

Pathway	Duration (days)*	Vaccinated	Compliance (%)	Force of infection per infected arrival	Force of infection relative to baseline
Hotel	14	No	100	0.048	1.14
		Yes		0.035	0.83
	7	Yes		0.125	2.98
Home	14	Yes	100	0.024	0.57
			90	0.086	2.05
			75	0.181	4.31
	7	Yes	100	0.114	2.71
			90	0.175	4.17
			75	0.267	6.36
No quarantine	0	Yes	NA	0.73	17.38
No quarantine or testing	0	Yes	NA	2.89	68.81

**For quarantine durations of 14 days, arrivals are PCR tested on days 1, 5 and 13; for quarantine durations of 7 or 0 days, arrivals are PCR tested on days 1, 5*

Key differences for family groups are that children are not protected by vaccination but if they do contribute a quarantine breach are assumed to be intrinsically less infectious in the community than adults. In addition, if a child is identified as infected in quarantine they will be isolated with a parent and not alone, so there is an ongoing risk of infection transmission within the isolation facility/medi-hotel that would not apply to adult travellers.

Figure 2: Force of infection per infected arrival in home quarantine, for unvaccinated arrivals, family units containing vaccinated parents and unvaccinated children, and unvaccinated arrivals. Results are shown by duration of stay (14 or 7 days) and compliance with quarantine (100%, 90% or 75%)

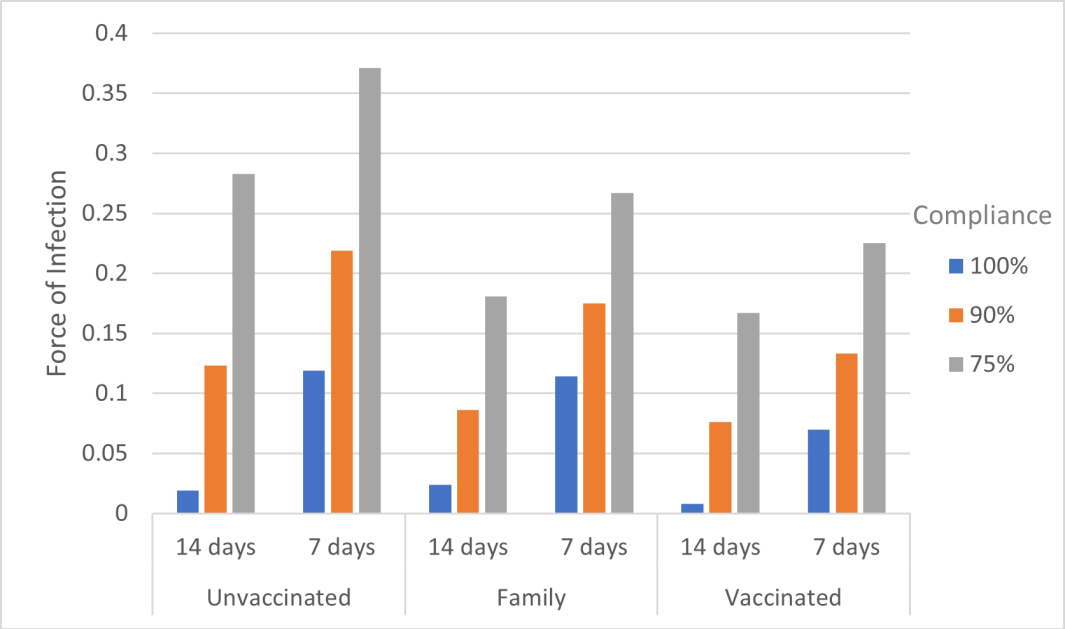


Figure 2 demonstrates the drivers of risk associated with quarantine breaches. Longer quarantine stays reduce breach risk. Lower compliance with quarantine requirements is more influential at increasing risk for a given length of stay. And vaccination reduces risks across the board. Families contribute an overall risk that is between fully vaccinated and unvaccinated arrivals.

2. Aggregate force of infection associated with hypothesised arrivals scenarios

Importation risks associated with alternative arrival scenarios can be readily calculated by grouping different volumes of arrivals into their allocated quarantine pathways. Given uncertainty about the true risks of infection across all potential countries of origin, we have assumed 1% of travellers are exposed to infection but remain undetected on embarkation. Vaccination reduces the likelihood that 'exposed' travellers will arrive infected by 80% (ie to 0.2%). This percentage is used to calculate the absolute number of infected arrivals entering the quarantine system for given traveller volumes. The quarantine pathways through which they are processed will determine the aggregate weekly force of infection imposed on the arrival jurisdiction.

We have devised arrivals scenarios in consultation with PM&C, Home Affairs and Treasury that allow us to calculate the aggregate weekly force of infection for different numbers of vaccinated adult and family group arrivals 'filtered' through alternative quarantine pathways. The total number of arrivals is calculated as a proportion of 2019 Australian citizen and permanent resident traveller volumes to inform scenarios representative of large and medium sized jurisdictions. Based on the threshold age for vaccine eligibility, we use numbers of travellers up to the age of 12 years from these data to allocate 'family groups' incorporating a corresponding proportion of adults in units of size four (two vaccinated parents, two unvaccinated children).

Scenario 1 – Endemic cases

Table 2.1: Calculated force of infection resulting from breaches in the quarantine system, assuming weekly arrivals of 65,534 or 32,767*, with 17.9% of travellers arriving in family units. The first five scenarios assume that all adult arrivals are fully vaccinated and compare different lengths of stay in home or hotel quarantine. 90% compliance is assumed for all home quarantine pathways. Regular PCR testing increases infection ascertainment on days 1, 5 and 13 for 14 day stays, and days 1 and 5 for 7 day stays and 'no quarantine'. Forces of infection through these pathways are compared with the previous policy of 14 days' hotel quarantine for unvaccinated travellers.

		14d home	14d hotel	7d home	7d hotel	None	Unvaccinated
80% **65,534 weekly arrivals**	**Adult FOI**	8.17	1.40	14.31	8.71	70.24	22.59
	Family FOI	6.06	2.47	12.34	8.81	45.55	5.64
	Total FOI	**14.24**	**3.87**	**26.65**	**17.53**	**115.79**	**28.23**
40% **32,767 weekly arrivals**	**Adult FOI**	4.09	0.70	7.15	4.36	35.12	11.29
	Family FOI	3.03	1.23	6.17	4.41	22.78	2.82
	Total FOI	**7.12**	**1.93**	**13.32**	**8.76**	**57.90**	**14.11**

**Arrivals figures represent 80% and 40%, respectively, of 2019 Australian citizen/Permanent resident arrivals into NSW in 2019*

All pathways other than 'no quarantine' (None) are associated with a lower aggregate force of infection than 14 day hotel quarantine for unvaccinated arrivals, which was the requirement prior to the era of vaccination. It should be noted that incursion risks in the absence of a quarantine stay are mitigated by testing on days 1 and 5 and are four times higher if no tests are performed. Doubling the number of arrivals from 40% to 80% doubles the force of infection per unit time, *noting that this aggregate force of infection estimate applies to an unvaccinated population.*

Scenario 2 – 'COVID-zero'

Table 2.2: As above, but assuming weekly arrivals of 20,726 or 10,363*, with 18.2% of travellers arriving in family units.

		14d home	14d hotel	7d home	7d hotel	None	Unvaccinated
80% **20,726 weekly arrivals**	**Adult FOI**	2.58	0.44	4.51	2.75	22.14	7.12
	Family FOI	1.95	0.79	3.96	2.83	14.61	1.81
	Total FOI	**4.52**	**1.23**	**8.47**	**5.57**	**36.76**	**8.93**
40% **10,363 weekly arrivals**	**Adult FOI**	1.29	0.22	2.26	1.37	11.07	3.56
	Family FOI	0.97	0.40	1.98	1.41	7.31	0.90
	Total FOI	**2.26**	**0.62**	**4.23**	**2.79**	**18.38**	**4.47**

**Arrivals figures represent 80% and 40%, respectively, of 2019 Australian citizen/Permanent resident arrivals into WA in 2019*

Consistent with findings above, reduced traveller volumes for this example jurisdiction are associated with a lower overall risk of infection importation.

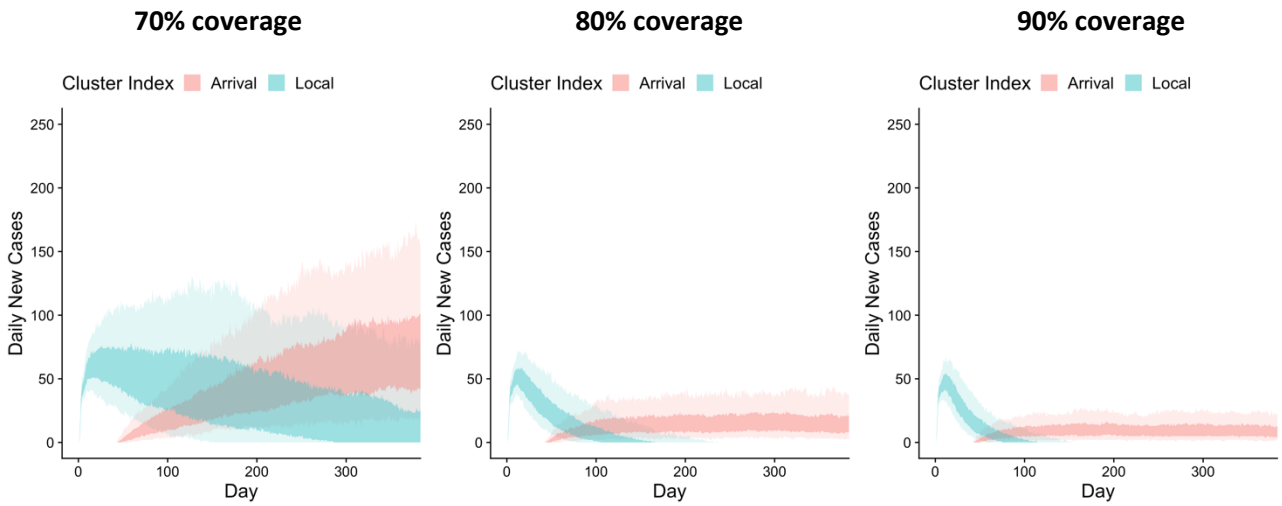
3. Consequences of importations for local epidemiology

Scenario 1 – Endemic cases

Epidemiological consequences of the arrivals scenarios above are demonstrated in Figures 3.1.1, 3.1.2 and 3.1.3. The 'vaccine coverage' (16+ years) in these simulations is fixed at the beginning of the simulations, with no ongoing vaccine rollout assumed. We include additional coverage of the 12-15 years age group at the time of achieving the threshold, based on estimates provided by the Quantium team in Health. 200 'local' infections are seeded on day 0 to establish a local epidemic, with travellers beginning to arrive on simulation day 40.

At 70% vaccine coverage, ongoing transmission of local strains occurs and is gradually superseded by new infections resulting from imported strains. For 80% and 90% coverage, locally transmitted strains become extinct at around 100 days. Ongoing importation of strains is a continuous source of newly seeded infections, but transmission is sufficiently constrained by vaccination that large outbreaks do not occur.

Figure 3.1.1: Impact of incursions on endemic cases given differing vaccine coverage in the arrivals environment. Partial TTIQ and ongoing 'low' PHSMs are additional constraints on transmission. Travellers (vaccinated adults and families) are managed through a 7 day home quarantine pathway, with 90% compliance and PCR testing on days 1 and 5. Traveller volumes are 40% of 2019 citizen/PR values.



Shaded areas denote uncertainty across multiple simulations. Teal shading reflects new cases resulting from local strains present at the beginning of the simulation. Salmon/pink shading denotes cases resulting from transmission chains seeded by importations.

Figure 3.1.2: As for Figure 3.1.1 but comparing 40% (left) and 80% (right) of 2019 arrivals, 80% coverage

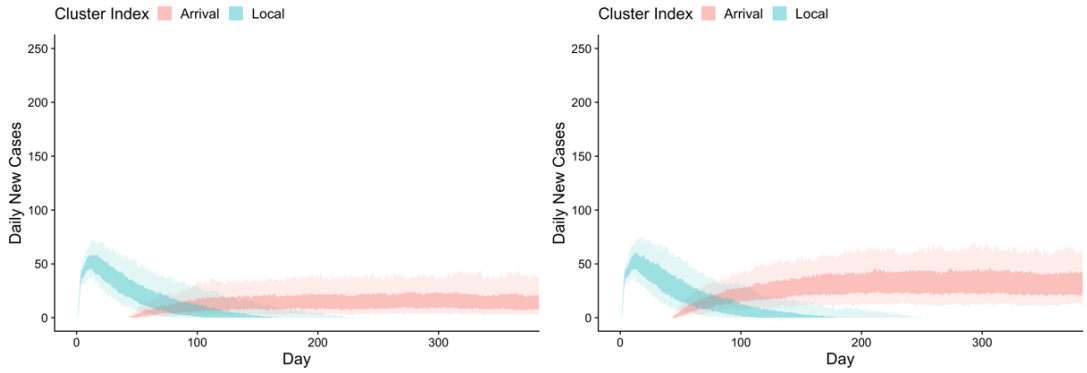


Figure 3.1.3: As for Figure 3.1.1, with 80% vaccine coverage but for different quarantine requirements

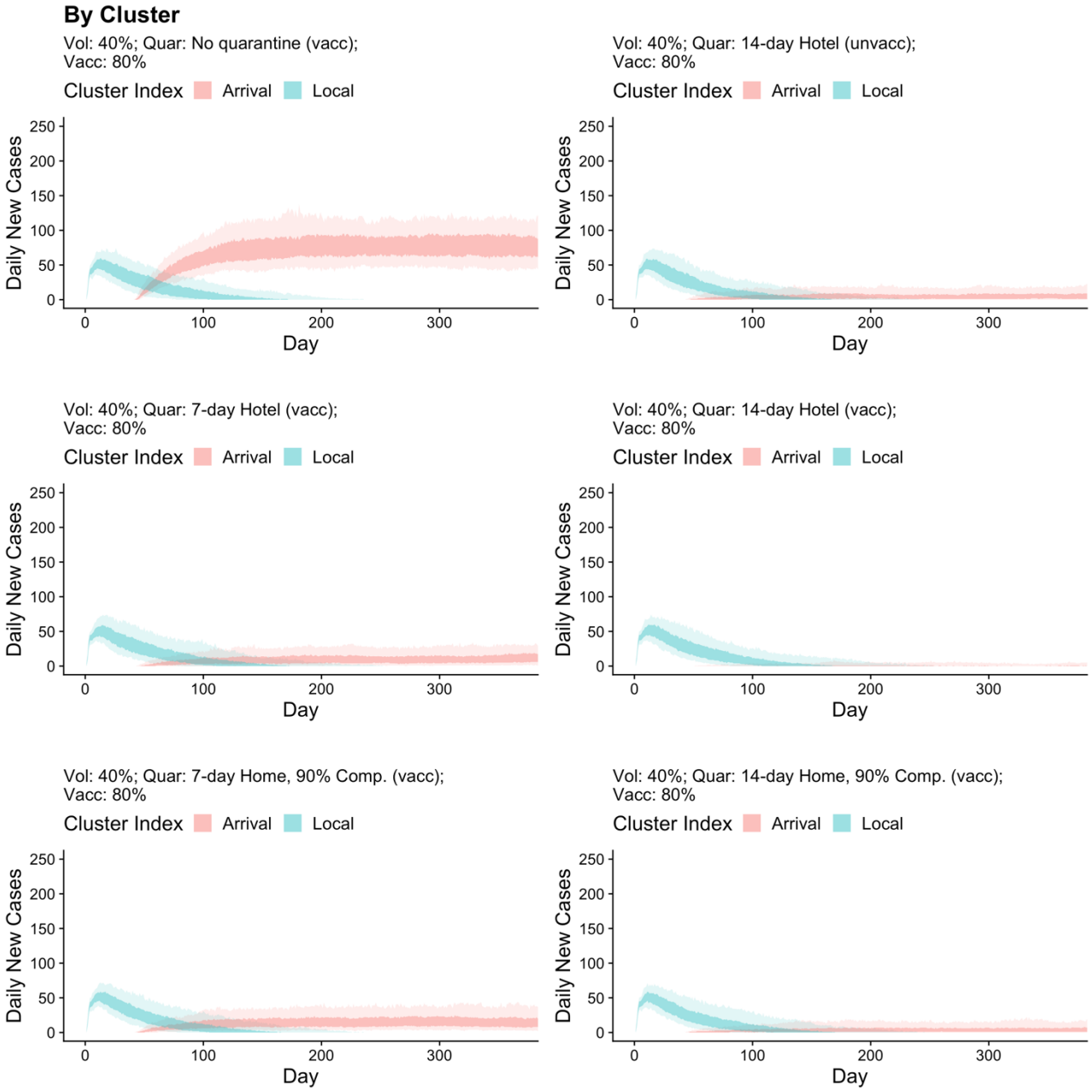


Figure 3.1.2 shows an approximate doubling of set point infection prevalence as traveller volumes increase. Figure 3.1.3 demonstrates that the 'no quarantine' pathway is associated with approximately a three to four fold increase in daily incident infections resulting from importations. This difference is explained by the higher aggregate force of infection associated with this pathway in Table 2.1. However, as in all simulations with vaccine coverage of 80% or more transmission is strongly constrained, preventing explosive outbreaks.

The importance of controls in place in the arrivals environment is demonstrated (Figure 3.2.1) by an additional scenario for endemic cases considering the impact of partial TTIQ with only *baseline PHSMs* in place, for all the same arrivals considerations as above (Figures 3.2.1, 3.2.2 and 3.2.3). Note the marked difference in axes between these two sets of figures. **At 80% coverage, thousands of incident cases are expected daily with only baseline PHSMs in place, compared with fewer than 100 when ongoing low PHSMs are maintained.**

Such rapidly escalating infections are driven by 'local' cases which far exceed the rate of importation. Incursions do not materially impact on the established local epidemic. This scenario is demonstrative only, as an outbreak of the size shown for the 70% and 80% coverage examples would require imposition of additional measures to reduce disease burden and impacts on the health system and society.

Figure 3.2.1: As for Figure 3.1.1 but assuming Partial TTIQ and 'baseline' PHSMs in place

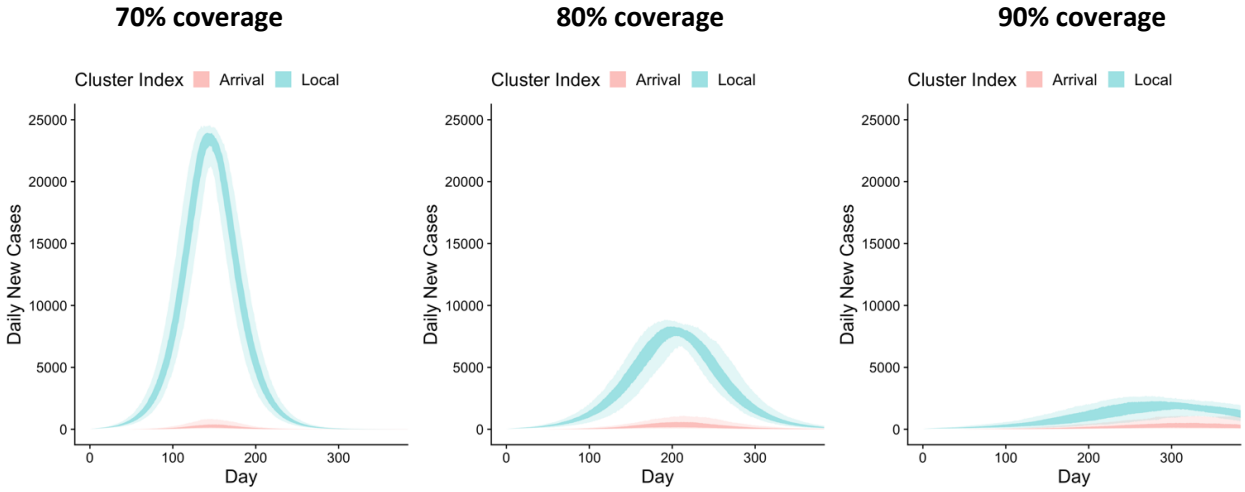


Figure 3.2.2: As for Figure 3.2.1 but comparing 40% (left) and 80% (right) of 2019 arrivals, 80% coverage

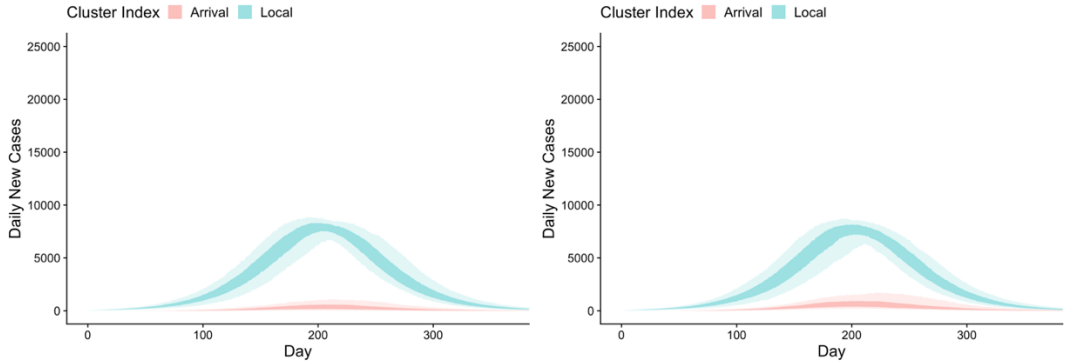
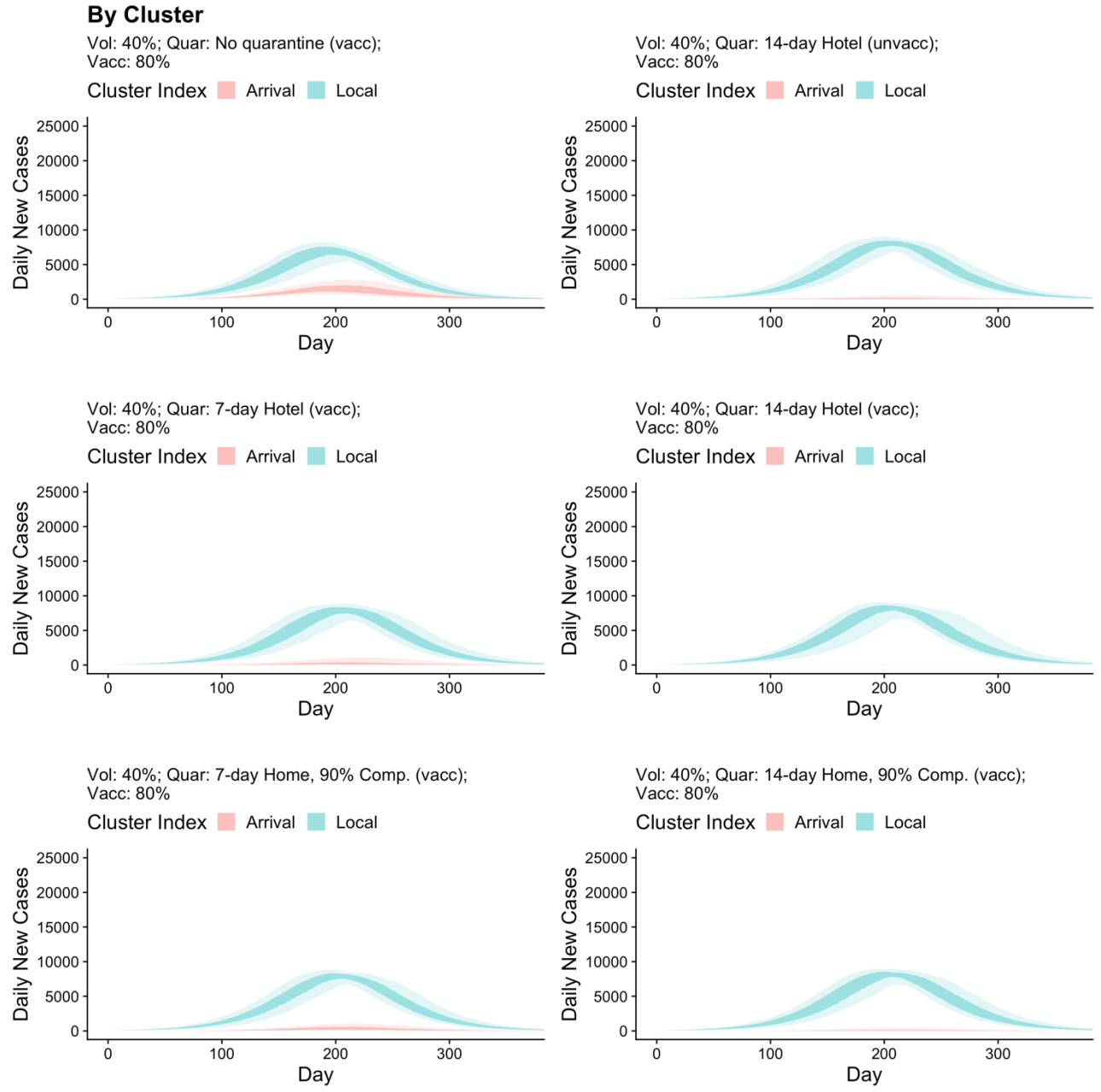


Figure 3.2.3: As for Figure 3.2.1, with 80% vaccine coverage but for different quarantine requirements



Scenario 2 – 'COVID-zero'

The simulations in Figures 3.3.1, 3.3.2 and 3.3.2 share most of the same assumptions as previously but with *optimal TTIQ and baseline PHSMs* in place in a 'COVID-zero' jurisdiction. These differences account for the enhanced epidemic growth most apparent in the 70% coverage case, noting that the y axes in these figures are in the 1,000s compared with the first Scenario 1 example (maximum 125).

The seeded epidemics grow slowly initially because the transmission potential is just above one but escalate within a few months at 70% coverage. At 80% or higher coverage epidemic growth is slower as further constrained. Because all infections are seeded by 'arrival' strains only one colour is shown on the plots, but in reality it is implausible that only internationally seeded infections would circulate over the one year time frame of the simulations.

Figure 3.3.1: As for Figure 3.1.1 but for 'COVID-zero', and assuming optimal TTIQ and 'baseline' PHSMs.

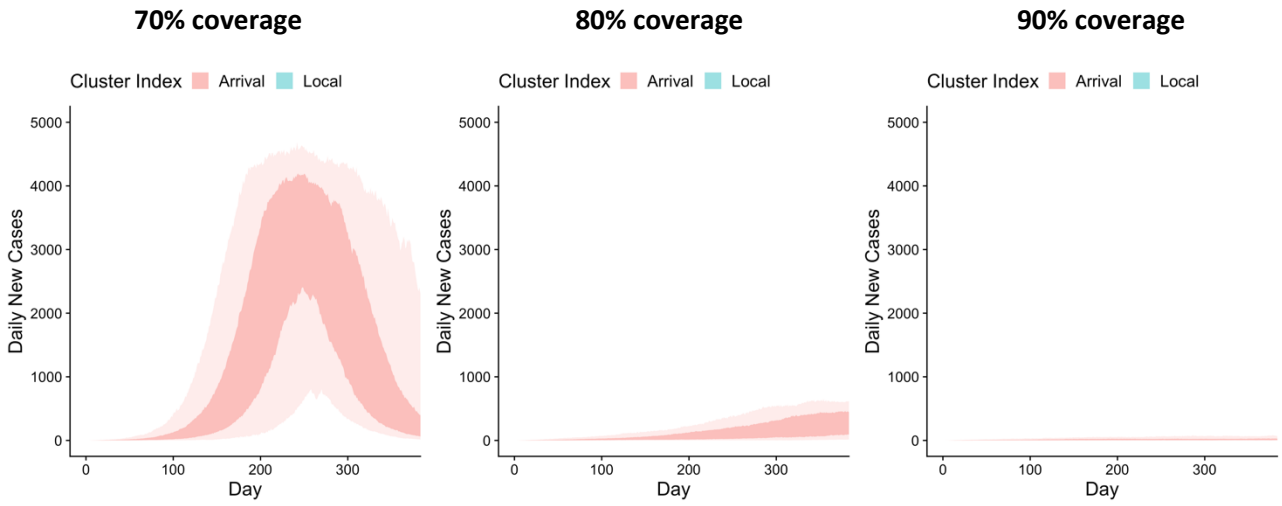
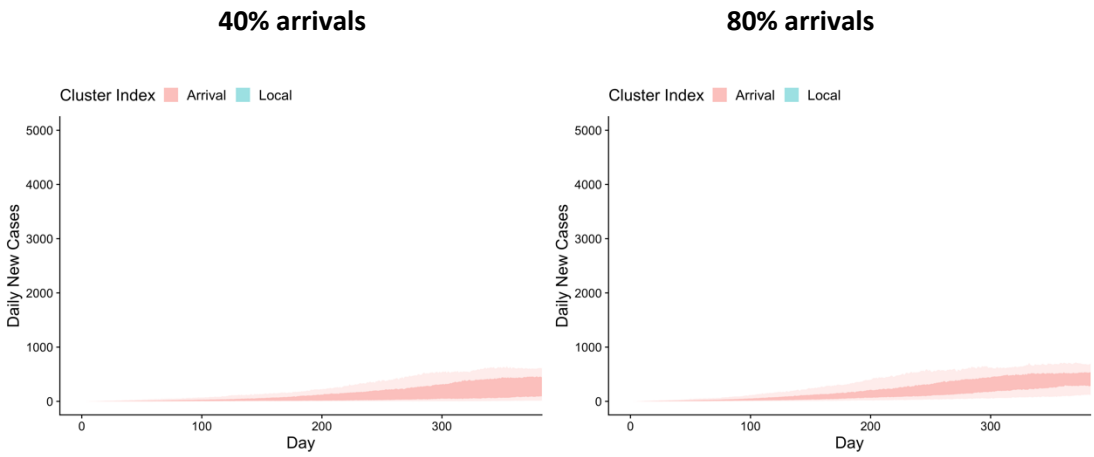
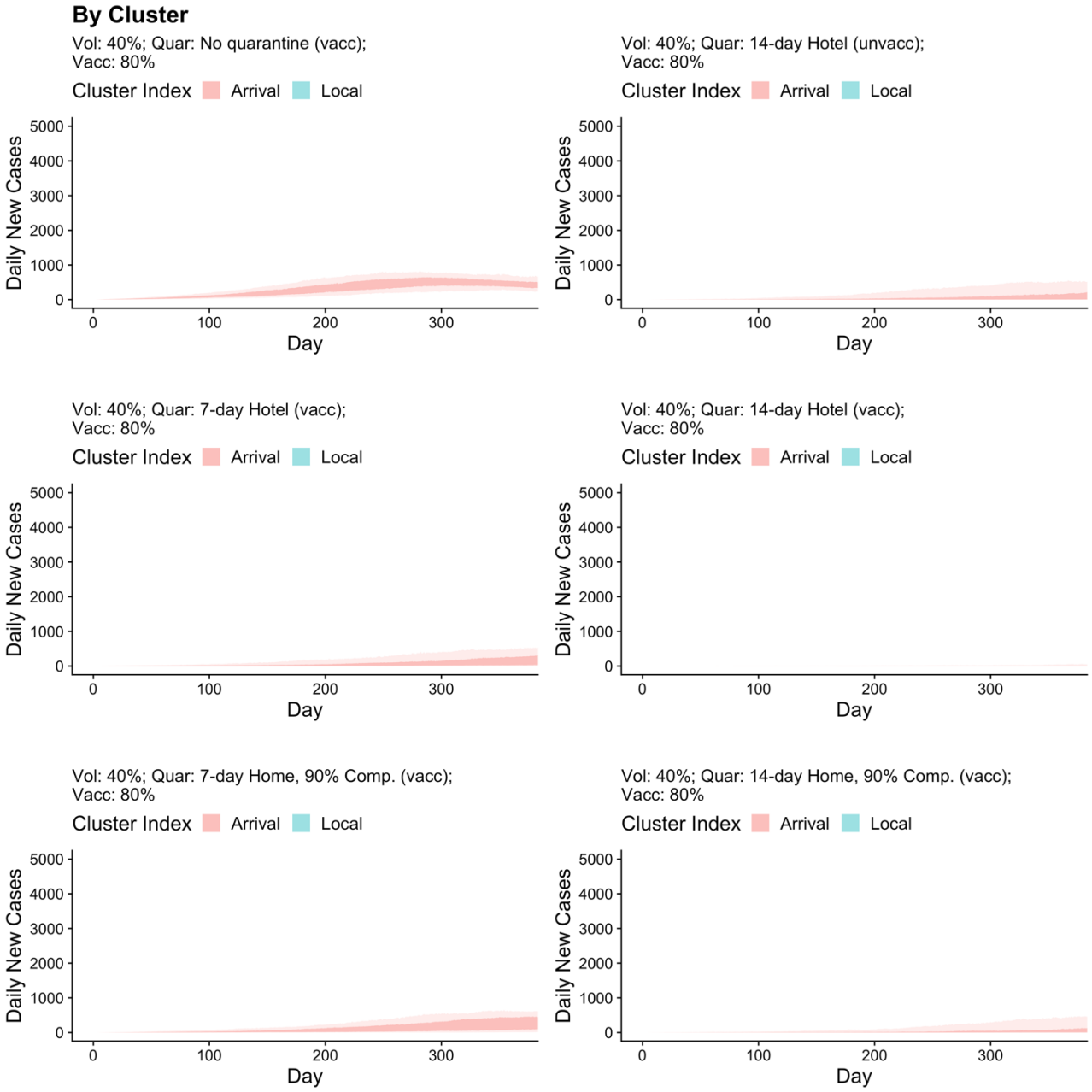


Figure 3.3.2: As for Figure 3.3.1 with 80% vaccine coverage, comparing 40% and 80% of 2019 arrivals



Doubling the number of arrivals at 80% coverage results in a modest increase in the number of infections anticipated on a given day in this scenario (Figure 3.2.2) but less than the difference with 'no quarantine' for 40% of arrivals (Figure 3.2.3). In all cases, the timing of epidemic growth is not materially different and case numbers escalate over several months, allowing time for situational assessment.

Figure 3.3.3: As for Figure 3.3.1 with 80% vaccine coverage, but for different quarantine requirements



Note that all of these simulations assume consistent vaccine protection over time (ie immunity does not wane) and that the characteristics of imported strains are identical to those initially present in the population (ie they are not more transmissible and are equally preventable by vaccination).