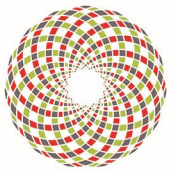

Te Pūnaha Matatini
Data ▪ Knowledge ▪ Insight

This paper has not yet undergone external peer review

FluTracking Incidence Calculation Methods

This version compiled: September 20, 2021
Author list alphabetical

Emily Harvey[1,3,*], Frank Mackenzie[2], Dion O'Neale[1,2], and Steven Turnbull[1,2]

[1]Te Pūnaha Matatini, University of Auckland, NZ
[2]Physics Department, University of Auckland, NZ
[3]M.E. Research, Takapuna, Auckland, NZ
[*]Corresponding author e-mail address: emily@me.co.nz

ABSTRACT

This report details the methods used for calculating the estimated weekly **incidence** of COVID-19-like and influenza-like illness in Aotearoa New Zealand, using data from the FluTracking weekly survey. In order to use FluTracking data to estimate symptom incidence relevant to surveillance for COVID-19, a number of steps are necessary. These key steps include:

1) We consider two new COVID-19-like illness (CLI) case definitions in addition to the influenza-like illness (ILI) case definition;
2) We adjust for reporting bias by restricting to responses where the participant had consistently responded for a number of weeks prior to the week of onset of incidence; and
3) We weight responses by age to account for the under- and over-representation of different age groups amongst the survey participants.

1 Introduction to FluTracking

FluTracking[1] is a participatory health surveillance system for Australia and New Zealand that uses an online, voluntary survey to detect the potential spread of Influenza[2], and more recently COVID-19. Volunteer participants from the general public receive a weekly email prompting them to fill out a survey which asks whether they have experienced any cold, flu, or COVID-19-like symptoms in the previous week.

FluTracking data is an incredibly useful resource for identifying patterns in symptom onset across the New Zealand population. It allows us to report on how symptom onset differs over time and between seasons, as well as across different regions in Aotearoa. However, there are limitations in this data that can reduce the utility of some results.

As participants of FluTracking are volunteers, responses are susceptible to a *selection bias* where individuals of a particular social location (i.e., age, sex, ethnicity) may be more likely to provide responses. FluTracking respondents are disproportionately New Zealand European and older, with Māori and Pacific Islanders and people under 30 years old being particularly under-represented (see Section 2.2).

Another factor is that there are various different combinations of symptoms, or *case definitions* that may characterise an illness. Since the advent of the first COVID-19 outbreak in New Zealand in early 2020, it has been important to allow flexibility with the case definition, including updating the case definition over time as new clinical data becomes available and as new Variants of Concern emerge.

This report details a methodology that can be used to mitigate some of the limitations in the FluTracking data, and provides case definitions that can be used to inform responses to outbreaks of infectious disease, such as COVID-19. This report also includes a brief summary of the latest (as of 2021) FluTracking estimates as an example of applying this new methodology.

2 Methodology

In this section we provide a brief summary of the FluTracking data and outline the steps necessary to calculate age weighted estimates of symptom incidence for both COVID and for the influenza specific case definitions historically used in FluTracking reporting[1].

For each survey week in a period of interest, we:

- create a set of *consistent respondents*, whose responses can be used to provide an indication of onset of new symptoms within the sample population.
- calculate the number of *Incidents* of onset of new symptoms, according to a specified *case definition*, in the given week.
- calculate an *age weighting factor* for each age (or age group) within the survey population. This can be calculated at either the whole of New Zealand level, or for sub-populations specified as sets of locations and ages.

All code and calculations used for our analysis of the FluTracking data can be found at: `https://gitlab.com/tpm-public-projects/fluTracking-data-analysis`.

2.1 Data

Raw data are obtained from FluTracking New Zealand[1] through the Ministry of Health. Data on the New Zealand population is obtained from Statistics NZ[3]. The six* symptoms included in the survey are: cough, fever, sore throat, shortness of breath, runny nose, and loss of taste or smell. All of these symptoms are part of the the Ministry of Health definition of COVID-like symptoms.

Participants are also asked about their vaccination status for COVID-19 and the annual influenza vaccine, and whether they have been tested for COVID-19 in the previous week. An example of the weekly survey is shown in Figure 1. If a respondent indicates that they are experiencing symptoms, they are then asked whether they sought healthcare, or missed work/usual activities as a result of the illness.

*A seventh symptom — headache — was added to the survey in the second half of 2021, to better capture the reported symptoms for the Delta VoC of SARS-CoV-2.

Figure 1. Example of the FluTracking weekly survey, sent to participants via email. Retrieved from https://www.flutracking.net/Demo/NZ[1]

Upon registration, respondents are asked to give demographic information including age, ethnicity, location (postcode), and gender. Population counts for the age weightings presented in this report use the 2021 population projections by age and District Health Board (DHB) of residence, though any other source of reference population data can be used, provided that it can be mapped on to the age (1-year age bands) and location (NZ postcodes) groupings used in the FluTracking data. In general, it is better to use higher levels of aggregation (e.g. 5-year age groups) and DHB in order to avoid the low response numbers per analysis unit that more granular aggregation will lead to.

2.2 Demographic details of FluTracking participants and responses

The average number of weekly responses over the period 27th April 2020 – 25th April 2021 was 44,575 responses from a population of 85,967 unique participants. That is, just over half of all registered FluTracking participants respond in a given week; though this number obviously varies over the course of the year, as shown in Figure 2.

Table 1 provides a summary of the demographic characteristics of the FluTracking population, for the period 27th of April, 2020 to 25th of April, 2021. This table lists the average weekly number of responses, and the number of unique

participants, for each demographic group, split by age, ethnicity, gender and region; and for both total participants and for only consistent respondents.

When compared against the demographic characteristics of the New Zealand population (as indicated by the 2018 census), we can see that the FluTracking population over-represents individuals who are 40–69 year olds, European, female, or from Wellington. It particularly under-represents 20–29 year-olds and Māori and Pasific Peoples.

When considering only those participants who are classified as consistent respondents, we do not see any change in representation relative to total respondents, across any of the individual demographic factors.

Table 1. Demographic makeup of the FluTracking cohort over a year (27th April 2020 – 25th April 2021) as compared to the Aotearoa New Zealand population as of the 2018 census[3]. Note: the Aotearoa New Zealand level Ethnicity data from Census 2018 is percentage of total responses, whereas the FluTracking data uses Prioritised Ethnicity. The count and percentages of *Responses* are an average of the responses given per group across all survey weeks. The count and percentage of *Participants* represents the number of unique participants per group in the sample. $\%^a$ is the percentage of all responses across the whole year. n^b is the average weekly number of responses.

		All responses $\%^a$ **(**n^b**)**	**Consistent responses** $\%^a$ **(**n^b**)**	**All participants % (**n**)**	**Consistent participants % (**n**)**	**Aotearoa New Zealand %**
Age (years)	0-9	8.8% (3924)	8.6% (3510)	10.8% (9291)	10.5% (8203)	13.1%
	10-19	10.6% (4736)	10.5% (4271)	11.6% (9993)	11.6% (9036)	12.9%
	20-29	6.3% (2801)	6.1% (2507)	8.0% (6887)	7.6% (5933)	14.1%
	30-39	11.9% (5294)	11.7% (4776)	13.7% (11799)	13.3% (10390)	13.0%
	40-49	16.9% (7540)	16.8% (6866)	17.2% (14815)	17.5% (13611)	13.0%
	50-59	18.1% (8080)	18.3% (7467)	16.2%(13908)	16.6% (12946)	13.0%
	60-69	16.8% (7472)	17.1% (6967)	13.9% (11907)	14.2% (11051)	10.4%
	70-79	9.0% (4026)	9.2% (3765)	7.3% (6268)	7.3% (5718)	6.7%
	80+	1.5% (674)	1.5% (628)	1.3%(1099)	1.3% (992)	3.6%
	Total	(44547)	(40756)	(85967)	(77880)	
Ethnicity	Māori	6.6% (2931)	6.5% (2633)	7.8% (6723)	7.6% (5936)	14.7%
	Pacific	1.5% (658)	1.5% (591)	1.8% (1568)	1.8% (1394)	7.2%
	Asian	3.6% (1603)	3.5% (1434)	4.3% (3671)	4.0% (3094)	13.4%
	Other	4.9% (2176)	4.9% (1980)	5.2% (4445)	5.1% (3952)	2.4%
	European	83.5% (37178)	83.7% (34119)	80.9% (69572)	81.5% (63514)	62.3%
Gender	Female	55.7% (24808)	55.7% (22702)	55.5% (47689)	55.4% (43153)	50.6%
	Male	44.1% (19669)	44.1% (17995)	44.3% (38126)	44.4% (34585)	49.4%
	Other	0.2% (78)	0.2% (71)	0.2% (157)	0.2% (143)	No data
Region	Northland	2.8% (1268)	2.9% (1165)	2.9% (2466)	2.9% (2222)	3.8%
	Auckland	28.7% (12762)	28.5% (11630)	29.2% (25168)	29.0% (22612)	33.4%
	Waikato	7.4% (3312)	7.4% (3022)	7.6% (6500)	7.6% (5941)	9.8%
	Bay of Plenty	4.3% (1921)	4.3% (1747)	4.5% (3892)	4.4% (3452)	6.6%
	Taranaki	2.1% (930)	2.1% (843)	2.1% (1804)	2.10% (1615)	2.5%
	Gisborne	0.4% (176)	0.4% (160)	0.4% (380)	0.4% (338)	1.0%
	Hawke's Bay	3.2% (1433)	3.2% (1322)	3.2% (2740)	3.20% (2518)	3.5%
	Manawatū-Whanganui	3.8% (1692)	3.8% (1549)	3.8% (3283)	3.9% (3006)	5.1%
	Wellington	21.9% (9737)	22% (8950)	20.9% (17988)	21.0% (16382)	10.8%
	Marlborough	0.7% (321)	0.7% (293)	0.7% (602)	0.7% (547)	1.0%
	Nelson	1.4% (614)	1.4% (559)	1.4% (1172)	1.4% (1067)	1.1%
	Tasman	1.2% (529)	1.2% (485)	1.2% (1047)	1.2% (950)	1.1%

Continued on next page

Table 1 – continued from previous page

	All responses %[a] (n^b)	Consistent responses %[a] (n^b)	All participants % (n)	Consistent participants % (n)	Aotearoa New Zealand %
West Coast	0.5% (234)	0.5% (215)	0.6% (472)	0.5% (414)	0.7%
Canterbury	14.2% (6324)	14.3% (5809)	14.1% (12098)	14.2% (11066)	12.8%
Otago	5.9% (2626)	5.9% (2401)	5.8% (4995)	5.8% (4524)	4.8%
Southland	1.5% (660)	1.5% (600)	1.6% (1347)	1.6% (1213)	2.1%

Figure 2 shows the number of responses to FluTracking surveys from 2018 to April 2021. In 2018 and 2019, FluTracking New Zealand had around 4000 – 5000 participants, with little variation over the May – October period in which the survey was conducted. In early 2020, the survey was promoted by both New Zealand's Prime Minister and Director General of Health, resulting in a major increase in respondents, peaking at 76,000[4]. This number steadily decreased over the year until October, when respondents were sent an email with the option to pause their responses until the end of summer (February 2021) or the start of the next 'flu' season (April 2021). As a result, responses dropped to just over 20,000, before former respondents were prompted to resume again at several intervals in early 2021.

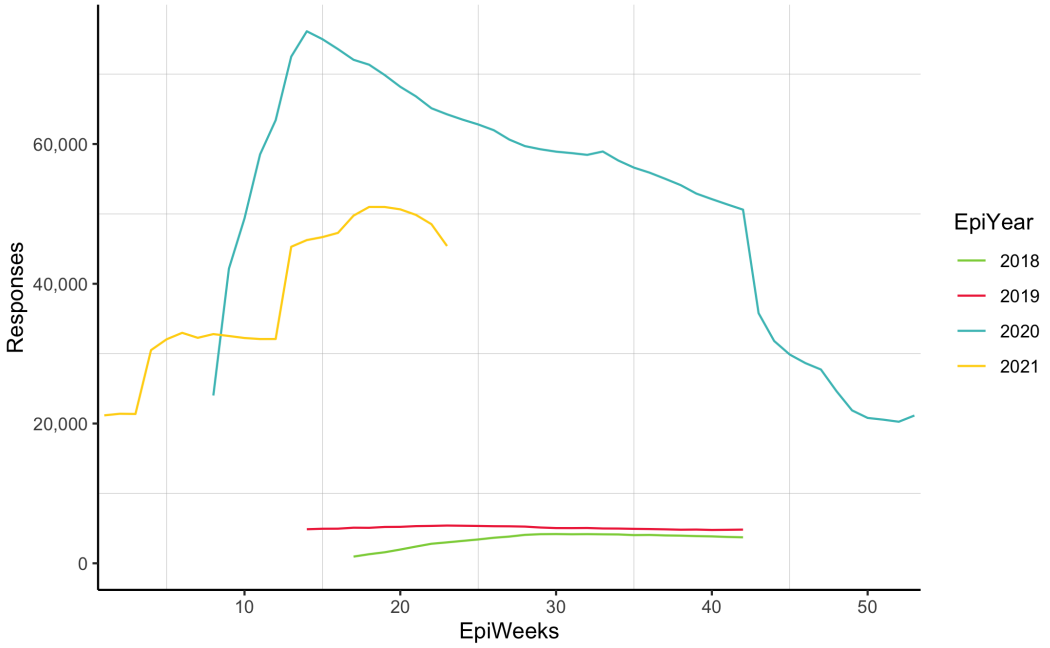

Figure 2. Number of FluTracking responses by epidemiological week (EpiWeeks) from 2018 to 2021. We observe that the number of responses is substantially higher for 2020 and 2021 compared to the years prior to the COVID-19 pandemic.

While similar online health surveillance platforms report that the average participant fills out a low number of surveys over the period of interest[5], this is not the case for FluTracking. Figure 3 shows that the most common number of responses over the course of a year is 52, with many respondents never missing a week. This may be aided by the fact that respondents can submit surveys up to 4 weeks in arrears. The spikes around 28 and 38 weeks worth of responses are likely to correspond to the emails encouraging people to opt in or out for the 'flu' season, as mentioned above.

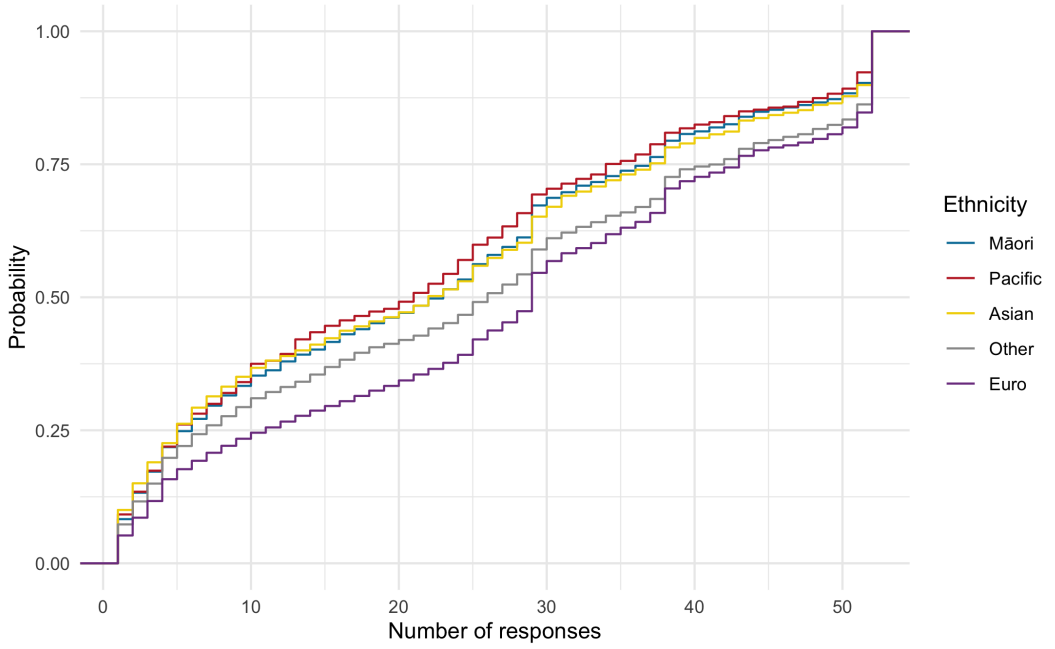

Figure 3. Cumulative probability of a FluTracking respondent having responded to x or more surveys over the year between 27th April 2020 and 25th April 2021 by prioritised ethnicity.

2.3 Consistent Respondents

FluTracking participants are more likely to fill out a survey when experiencing symptoms than when they are well. This can result in overestimating rates of incidence[6]. Additionally, participants may respond to the survey one week, but not in the weeks preceding and following. Both of these factors make it difficult to accurately determine the onset of symptoms or to distinguish a low level of responses from a low level of symptom incidence, at a population level.

To address these issues, we determine a set of consistent respondents for each week of interest. We define consistent respondents as those respondents who filled out *at least three of the four surveys during the four week period preceding the survey week being considered.* A respondent's 'consistent' status can therefore change from week to week. We provide two examples using hypothetical cases illustrated in Figure 4.

The aim of defining a set of consistent respondents is to minimise reporting bias due to symptom presence, while maximising the number of participants in the data set. We find that increasing the number of weeks required to qualify as a consistent respondent not only reduces the size of the eligible cohort, but also increases the over-representation of some groups of participants — specifically older Pākehā cohorts. Increasing the number of weeks of responses required to be considered 'consistent' lowers the incidence rate, which we attribute to reduced reporting bias. Making the consistent response criteria too stringent reduces the sample size, potentially introducing other biases due to specific traits of consistent respondents.

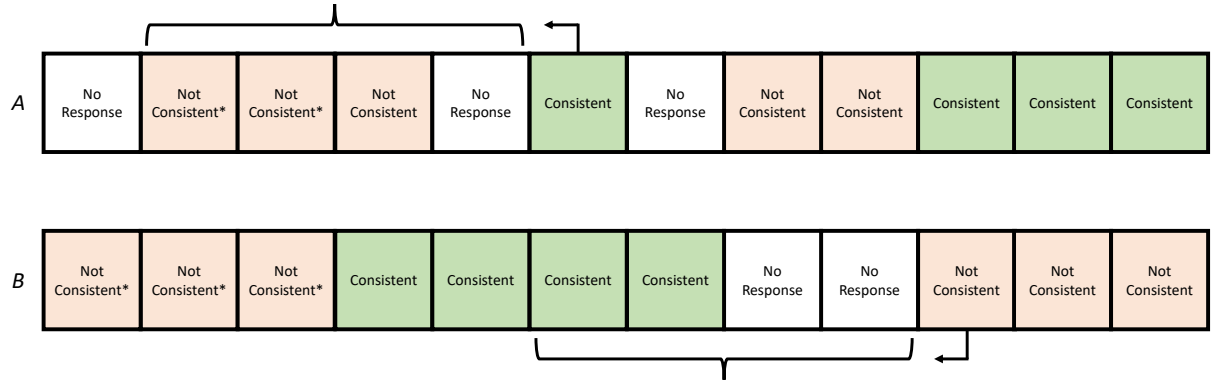

Figure 4. Hypothetical examples of consistent and not consistent respondents. The illustration above shows two examples of survey respondents *A* and *B*, where a response for a given survey week can be defined 'no response', 'not consistent', or 'consistent'. We can see that for respondent *A*, the highlighted survey week is considered consistent as 3 of the previous 4 survey weeks contain a response (even if for each of those previous survey weeks, a response was considered not consistent). For respondent **B**, we can see that the highlighted survey week is considered inconsistent, since 2 out of the previous 4 survey weeks did not contain a response. * indicate that the survey weeks covering the respondents first three weeks of participation are considered inconsistent, due to the fact that they have not yet answered enough surveys to meet the threshold of consistency.

2.4 Case definitions

We apply three different case definitions:

- **CLI1+**. Responses indicate any one or more of the included *COVID-like* symptoms. CLI1+ meets the Ministry of Health advice to seek a COVID-19 test.
- **CLI2+**. Responses indicate two or more symptoms. CLI2+ allows us to be slightly more discerning given that many non-infectious illnesses (allergies, asthma, etc) can cause some of the symptoms in the survey.
- **ILI**. Responses indicate at least both *cough* and *fever* which are symptoms of *influenza-like illness*. This case definition is used for public FluTracking reporting[1].

2.5 Incidence calculation

We wish to estimate 'incidence', not 'prevalence' from the FluTracking data. Specifically, we wish to identify any new onset of symptoms that meet the threshold for an 'Incident' according to a chosen case definition. The method we use follows that employed by Ministry of Health NZ and FluTracking Australia for estimating incidence of ILI (cough and fever), but extended to the case definitions CLI1+ and CLI2+ above, in addition to the case definition for ILI.

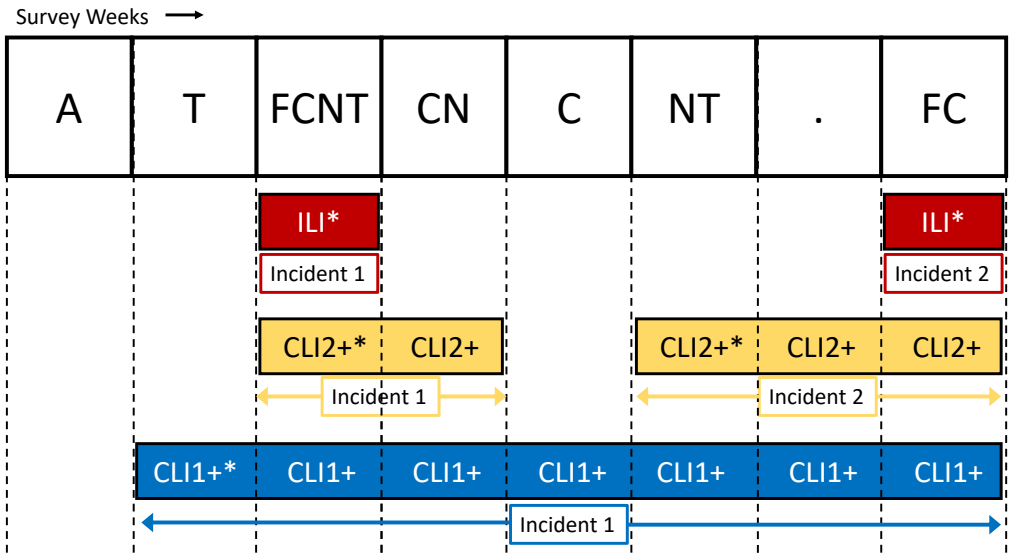

Figure 5. Example of case definitions for one hypothetical respondent. This illustration shows a period of 8 survey weeks, with reported symptoms (or non-response) indicated for each week. These symptom definitions include **A** Asymptomatic (i.e. a response indicating no symptoms), **C** Cough, **F** Fever, **N** runny Nose, and **T** sore Throat. A dot indicates the respondent did not answer the survey that week. In this hypothetical case we see how the responses given can fall under each case definition, and that these *Incidents* cover different survey weeks depending on the patterns of symptoms. As CLI1+ has the most lenient definition, it includes more survey weeks and is considered a single Incident, while ILI and CLI2+ would be split into two separate Incidents during the same time period. We can also see that CLI1+ and CL2+ (but not ILI) span a period including one week where no response was given. This is because we assume that the missing week would be a continuation of the same Incident, provided it meets the same case definition. * indicates the week that will be included as the onset of the incident.

FluTracking data contains each respondent's reported symptoms for a given survey week. For a selected case definition, we first check whether an individual's symptoms in the given week meet the criteria for that case definition, and if so, we mark it as an Incident. For example, if we wanted to investigate the number of CLI1+ Incidents, we would record as an Incident all weeks where an individual recorded one or more of the six COVID-like symptoms.

Figure 5 provides a hypothetical example of a respondent who reported different symptoms over the course of 8 weeks.

To distinguish new onset of illness from the continuation of a previously reported Incident, each Incident is assigned a unique ID, with this same Incident ID given to all consecutive weeks that meet the case definition. If there is no response for one week between two weeks in which the case definition was met, it is assumed that the interstitial week is a continuation of the first week's Incident and it is allocated the same Incident ID. Any gaps between Incidents longer than one week imply that the second Incident would be preceded by two or more missed responses and would hence fail to meet the consistent respondent criteria.

The incidence calculation is done independently for each case definition. This means that if a respondent reported one symptom in their first week of illness, and two or more symptoms in the second week, the second week would be recorded as an 'Incident' of CLI2+, as though it were the onset of a new illness. It also means that if a participant met the criteria for CLI1+ for three consecutive weeks, but met the criteria for CLI2+ only in the first and last weeks, this would be recorded as two Incidents of CLI2+. This is useful information, on the basis that someone with new or worsening symptoms should seek a COVID-19 test.

2.6 Age Weighting

There are several demographic biases in the FluTracking cohort with *participation rates* differing by age, ethnicity and location of respondents. If any of these participation biases also aligns with a corresponding variation in *incidence rates* along the same demographic factor then it will contribute to an under- or over-estimate of incidence for the total population.

The strongest factor affecting incidence is age (see Figure 6), with younger ages, particularly 0-4 years, tending to have higher incidence across CLI1+, CLI2+, and ILI case definitions. We therefore adjust our incidence estimates to account for age of respondents in the survey population.

In order to adjust for age we assign a weighting coefficient to each response based on whether their five year age group is over- or under-represented in the cohort that week. This is done at a level that depends on the aggregation required in the results. For example, if we are aggregating on a sub-national spatial level, we consider the over- or under-representation of that age group across all ages *within the chosen location*. Similarly, if we are aggregating to specific age-bands, the over- or under-representation of that age group is calculated within the chosen age-bands.

Given a specified set of Locations, $L = \{l_1, l_2, \ldots l_n\}$, and Ages[†], $A = \{a_1, a_2, \ldots a_m\}$, we calculate the weighting factor $W_{L,A}(a)$ for an individual age group, $a \in A$, as

$$W_{L,A}(a) = \frac{P_{L,A}(a)}{Q_{L,A}(a)} \tag{1}$$

where $P_{L,A}(a)$ is the proportion of age group a within the reference population for L and A, as specified for a reference population, and where $Q_{L,A}(a)$ is the proportion of age group a within the population of FluTracking consistent respondents for L and A on a specified week of interest. The resulting age weighting factors can then be multiplied by incidence numbers for the corresponding sub-populations to provide incidence estimates that are more representative of the general New Zealand population.

There is also significant selection bias in the ethnicity of respondents. While there is a relationship between ethnicity and incidence of several respiratory illnesses[7,8], ethnicity is not necessarily causative. Socioeconomic deprivation, household crowding, and housing quality, are all associated with increased incidence and outcomes from respiratory infections[8–10], and are also related to ethnicity[9], and may also contribute to selection bias. Due to the low response rate for ethnic groups other than NZ European, it is unlikely that the sampled population within each ethnic group is representative of that group in the New Zealand population. Therefore, weighting based on ethnicity alone may actually

[†]Since the reference population data we use from Statistics NZ is specified in 5-year age groups, sets of ages must also consist of combinations of 5-year age groups. In general any age groups can be used as along as they are applied consistently for the reference and the survey populations.

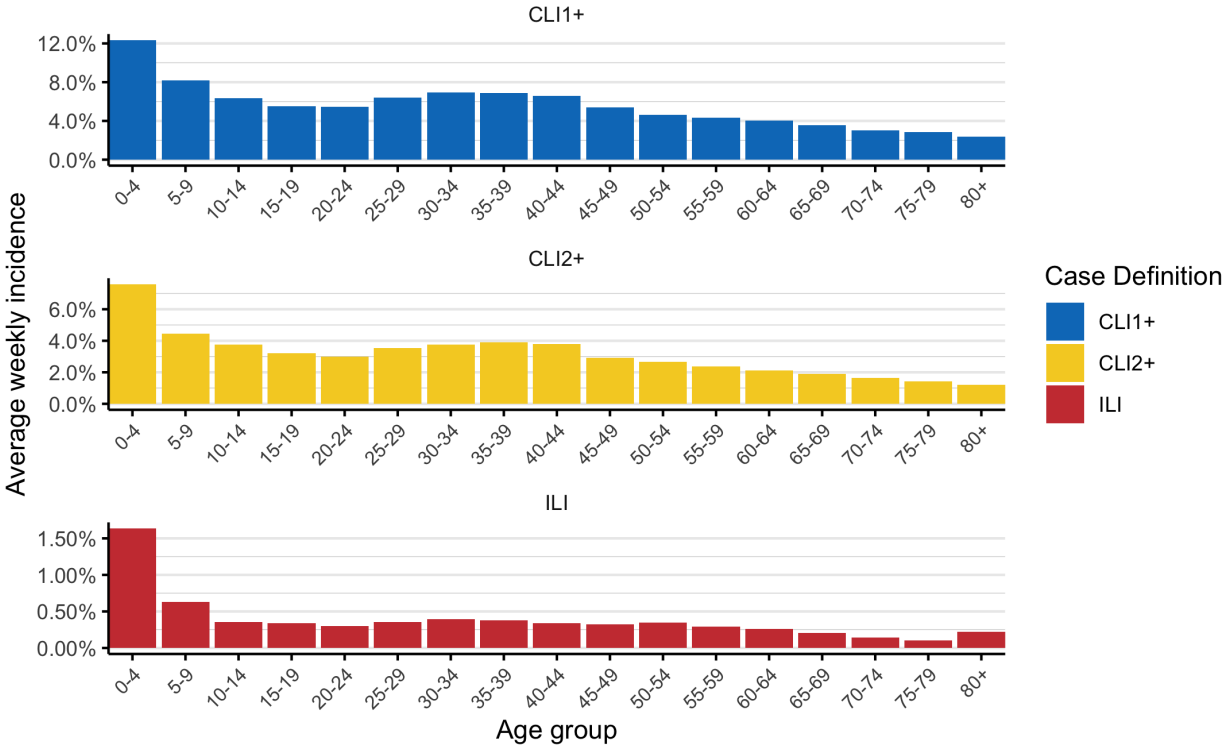

Figure 6. Average weekly incidence for the year between 27th April 2020 and 25th April 2021, by five-year age groups. This only considers respondents who submitted at least 50 surveys over the year. In terms of case definitions, overall we see that reports of CLI1+ are more common than CLI2+ and ILI. We can also see that the higher average level of incidence, across all three case definitions, is experienced by those individuals in the 0-5 year range.

amplify selection bias rather than mitigate it. For this reason, incidence was not adjusted for ethnicity. This is very likely to affect the applicability of these results to some ethnic groups within Aotearoa.

3 Incidence estimates

We demonstrate the method outlined above by applying it to FluTracking data from the period from the survey week ending Sunday 3rd May 2020 to the survey week ending Sunday 25th April 2021.

Figure 7 presents the weekly incidence estimates for the whole of Aotearoa and for the CLI1+, CLI2+, and ILI case definitions. The effect of Alert Level interventions (indicated on the chart as shaded regions) are clearly seen in the reduction of symptom incidence, particularly for CLI symptoms.

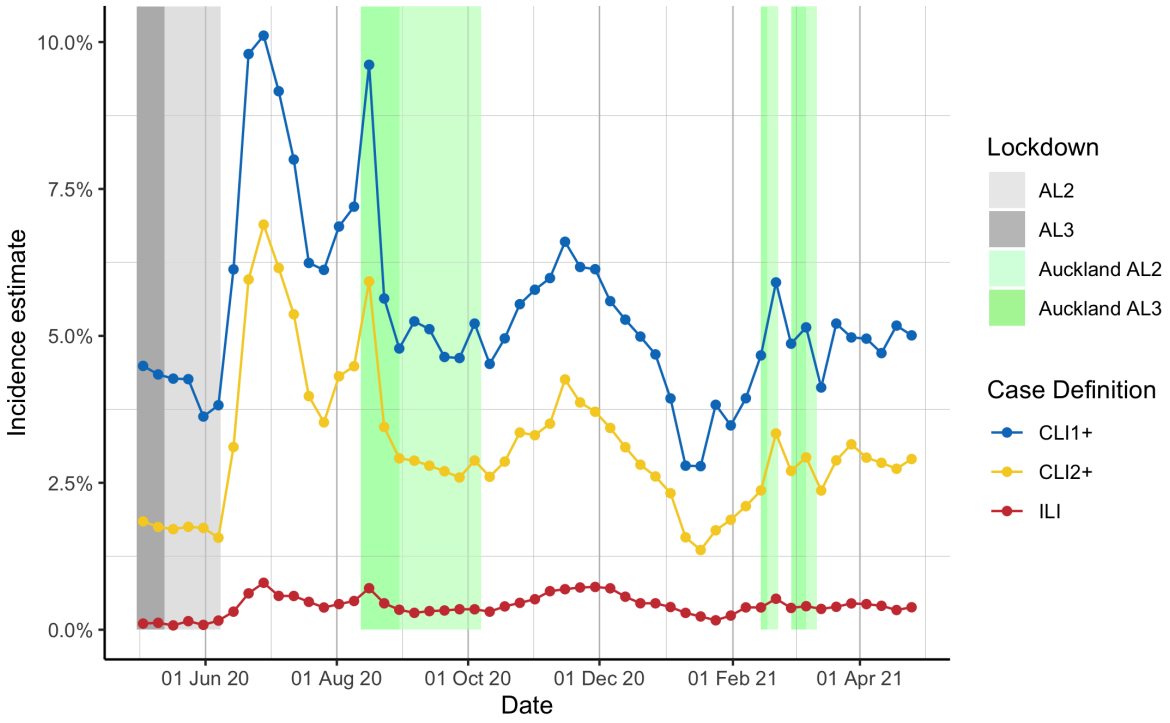

Figure 7. Weekly incidence estimates for the whole of Aotearoa NZ, for three different case definitions (CLI1+,CLI2+, and ILI) for the year between 27th April 2020 and 25th April 2021. Alert levels are shaded. We observe periods of reduced incidence during these alert levels, as well as some spikes in incidence when alert levels of not in effect (e.g., July).

Figure 8 show the effect of adjustments to the incidence estimates for consistent respondents and age weighting. Adjusting incidence estimates to account for only the population of consistent respondents shows an almost universal reduction in incidence rates, by around 5%–10%. This is due to the removal of Incidents for respondents who preferentially (or exclusively) completed the survey when symptomatic[6]. It is interesting to note that this effect decreases in early 2021, coinciding with a very stable population of FluTracker respondents in this period.

Age-weighted adjustments to the incidence estimates vary over the period shown in Figure 8. The initial half of the survey period saw a high number of responses from younger participants, who tend to have higher rates of symptom incidence. Adjusting for this increase in young respondents results in a decrease in the overall incidence rate across all age groups. Conversely, the latter half of the survey data in Figure 8 showed a marked decrease in the number of younger participants, and hence a positive adjustment in the estimated incidence rate for the overall population. When adjustments for consistent respondents and age-weighted participation are both included we see a slight reduction in weekly incidence rate — around 5% relative to all responses.

While the relative adjustments for the CLI incidence rates are mostly smoothly varying over time, the weighting factors applicable to the ILI case definition are more stochastic due to low total rates of ILI symptoms from early 2020 onwards.

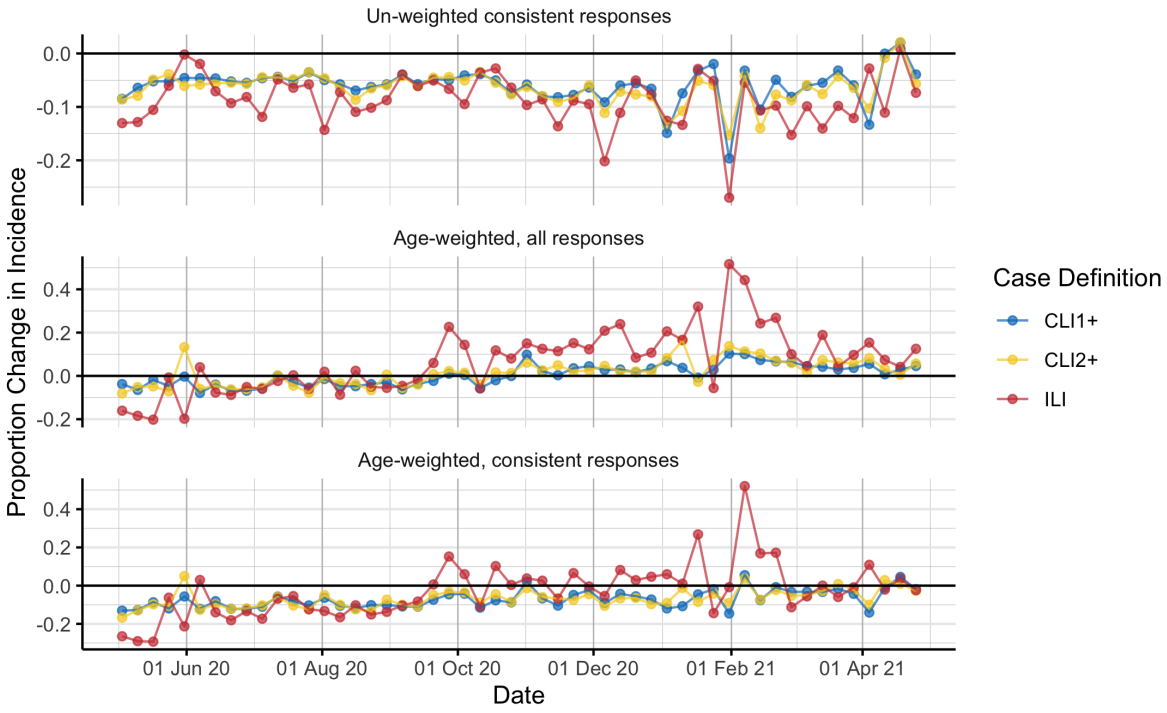

Figure 8. Change in weekly incidence estimates, due to adjusting for consistent respondents (top), age weighting (middle), and both (bottom) effects, relative to weekly incidence estimates from all respondents.

Figure 9 shows incidence of CLI1+, CLI2+, and ILI symptoms, broken down by age. The higher rates of incidence for younger age bands in clearly seen for both CLI case definitions, with under-fives being particularly high at 1.5–2 times the incidence rate of even the next highest incidence age band.

Figure 10 shows weekly incidence estimates for CLI2+ split by location for Auckland Region and Rest of New Zealand. Alert Level interventions, including those that applied principally only to Auckland are indicated by shaded regions. The effect of these regional interventions is clearly seen in the difference in incidence estimates with Auckland region having much lower incidence numbers during periods of elevated Alert Levels, relative to the rest of the country.

Acknowledgements

We wish to thank New Zealand FluTracking, which is a collaborative initiative between the Ministry of Health (NZ) and Hunter New England Health (NSW, Australia) for the provision of FluTracking data.

References

1. FluTracking.net. https://info.flutracking.net/about/.
2. Dalton, C. *et al.* Flutracking: a weekly Australian community online survey of influenza-like illness in 2006, 2007 and 2008. *Commun. diseases intelligence quarterly report* **33**, 316–322 (2009).
3. National population projections, by age and sex, 2020(base)-2073 information on table. http://nzdotstat.stats.govt.nz/wbos/Index.aspx# (2021).
4. Mau, A. Coronavirus: Dr Ashley Bloomfield loves it, but what is the flu tracker? *Stuff.co.nz* https://www.stuff.co.nz/national/health/coronavirus/120746580/coronavirus-dr-ashley-bloomfield-loves-it-but-what-is-the-flu-tracker, 2020-04-02.

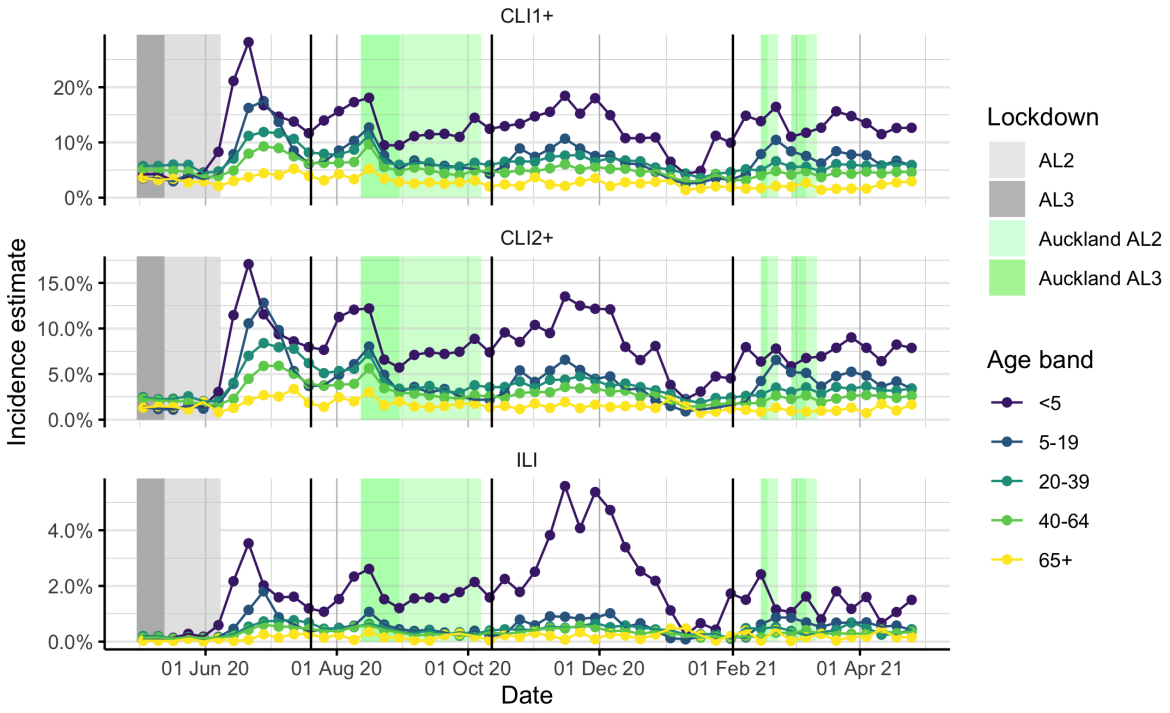

Figure 9. Weekly incidence estimates by selected age bands, for the whole of Aotearoa, for the CLI1+, CLI2+, and ILI case definitions. Alert levels are indicated by shaded regions. Black lines indicate the beginning of school term periods.

5. Smolinski, M. S., Crawley, A. W., Olsen, J. M., Jayaraman, T. & Libel, M. Participatory disease surveillance: Engaging communities directly in reporting, monitoring, and responding to health threats. *JMIR Public Heal. Surveillance* **3**, e62, DOI: 10.2196/publichealth.7540 (2017).

6. Liu, D., Mitchell, L., Cope, R. C., Carlson, S. J. & Ross, J. V. Elucidating user behaviours in a digital health surveillance system to correct prevalence estimates. *Epidemics* **33**, 100404, DOI: 10.1016/j.epidem.2020.100404 (2020).

7. Baker, M. G. *et al.* Increasing incidence of serious infectious diseases and inequalities in New Zealand: a national epidemiological study. *The Lancet* **379**, 1112–1119, DOI: https://doi.org/10.1016/S0140-6736(11)61780-7 (2012).

8. Baker, M. G., McDonald, A., Zhang, J. & Howden-Chapman, P. Infectious diseases attributable to household crowding in New Zealand: A systematic review and burden of disease estimate (2013).

9. Ingham, T. *et al.* Damp mouldy housing and early childhood hospital admissions for acute respiratory infection: a case control study. *Thorax* **74**, 849–857, DOI: 10.1136/thoraxjnl-2018-212979 (2019).

10. Zhang, J. & Telfar Barnard, L. The impact of respiratory disease in new zealand: 2020 update (2021).

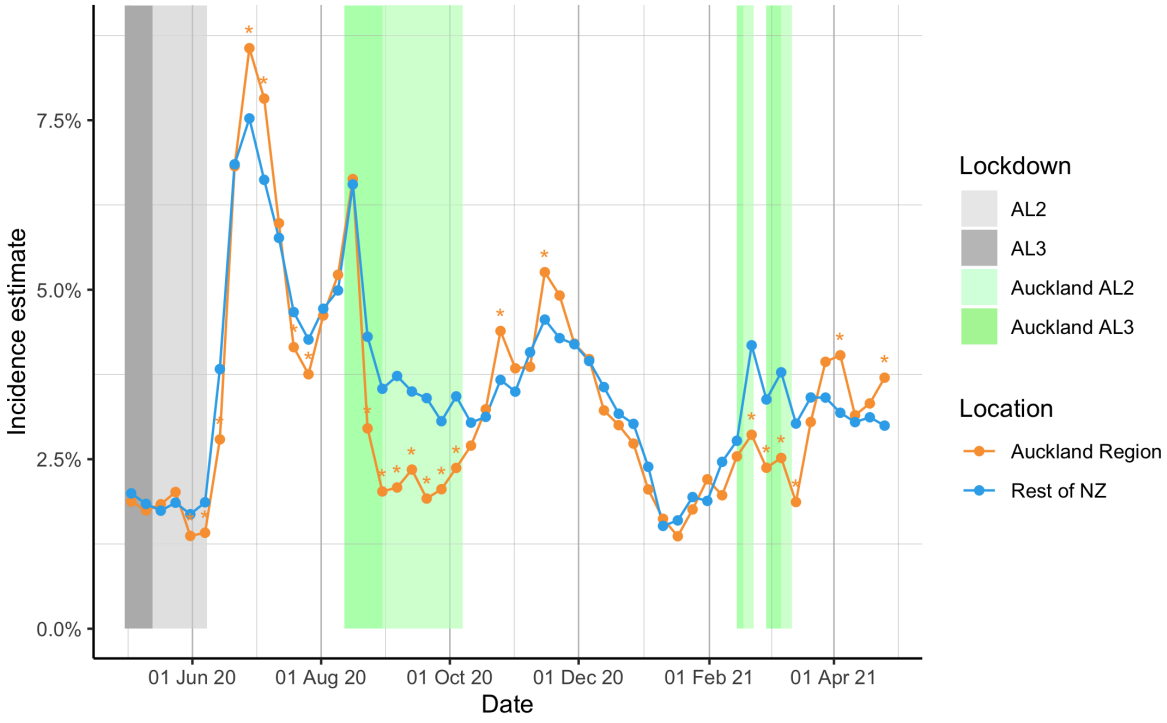

Figure 10. Weekly incidence estimates for the CLI2+ case definition split by location (Auckland Region and Rest of New Zealand). Stars indicate weeks when the difference in incidence estimate is statistically significant for Auckland Region, relative to the rest of New Zealand. Alert levels are indicated by shaded regions.