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Rapid Communication

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Potential for inter-state spread of Covid-19 from Arizona, USA: analysis of mobile device location and commercial flight data

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In June 2020, the USA reported rapidly increasing rates of Covid-19 cases nationally, with several states disproportionately affected. AZ currently has a high incidence of Covid-19, following the reopening of its economy on 8 May 2020. As of 15 July, AZ has reported 131 354 cases and 2434 deaths attributed to Covid-19 since the beginning of the outbreak.[1] Given the potential for human mobility to propagate Covid-19 transmission in new locations, we estimate recent and prospective mobility from AZ to other states in June 2020 and approximate the prospective air travel connectivity from July 2020.

To estimate recent connectivity from AZ to other regions of the USA, we used anonymized, population-aggregated, near-real-time, mobile device GPS location data provided by Veraset (Veraset, San Francisco, CA), a data-as-a-service vendor. We selected devices that were located anywhere in AZ from 31 May through 27 June 2020, and aggregated subsequent locations of those devices within two weeks of departure from AZ to the county level between 14 June and 27 June, inclusive. Each device was counted in every county where it had a minimum of two 30-min interval GPS 'check-ins' on a given day, even if a device was located across multiple counties within a single day. We defined 'check-in' as anonymized device locations identified in half hour windows. A device can have up to 48 check-ins per day. Data were suppressed for counties with <5 unique devices for any day during this 2-week period. Our primary outcome was cumulative device-days in a particular county (reflecting total days where devices were geo-located in a destination within 14 days of departing AZ).

To further evaluate prospective connectivity from AZ to the domestic USA, we evaluated commercial airline flight schedules published by CIRIUM (Portland, OR, USA) as of 1 June 2020. These data contain airport-level information on each scheduled flight and the associated aircraft seat capacity. Data were aggregated to the city and state level. For our analyses, we examined commercial flights scheduled to depart from AZ to any other US city for June and July 2020. We used the aircraft seat capacity on scheduled flights to approximate the potential maximum number of passengers travelling to a specific US state.

Figure 1 highlights the top destination US counties for all mobile devices originating in AZ between 14 June and 27 June 2020; the 10 most connected counties were within NV, CA, NM, TX and UT. NV's Clark county, which includes Las Vegas, had the highest domestic connectivity from AZ between 14 June and 27 June 2020. Our sample contributed at least one device-day to all 50 US states outside of AZ. The top 50 counties with the greatest number of device-days between 14 June and 27 June 2020 were located in the following states: NV, CA, NM, TX, UT, OK, IL, CO, MO and WA.

Appendix 1 presents the 10 counties outside of AZ with the highest cumulative device-days contributed by our sample, approximate number of unique mobile devices, and the

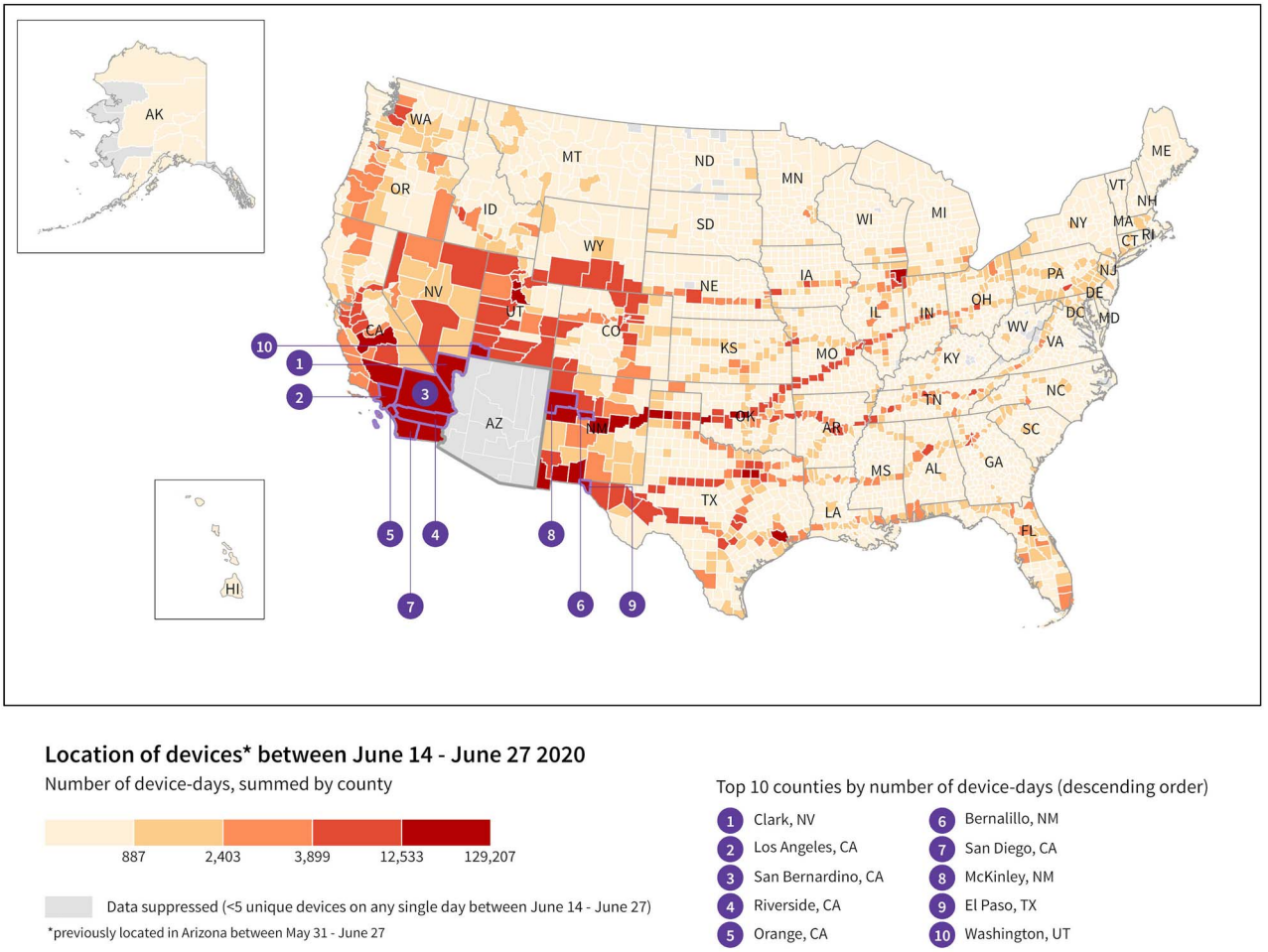

Figure 1. Dispersion of anonymized mobile device locations previously located in AZ between 31 May and 27 June 2020 and subsequently located across the domestic USA by county, measured in device-days, between 14 June and 27 June 2020. Intervals used to rank counties are reflective of the 75th, 90th, 95th, 99th percentile, and maximum value by number of device-days. Patterns of device counts for adjacent counties approximate ground travel on interstate highways

number of Covid-19 cases in those counties. Notable counties include Clark (NV), Los Angeles (CA) and San Bernardino (CA) with 66 979, 65 761 and 47 911 unique mobile devices from AZ and 129 207, 123 935 and 94 585 cumulative device days, respectively.

The top 10 flight destination cities originating from AZ, based on maximum seat capacity on scheduled flights, in descending order, are Los Angeles (CA), San Francisco (CA), San Diego (CA), Dallas/Fort Worth (TX), Houston (TX), Denver (CO), Chicago (IL), Las Vegas (NV), Seattle (WA) and Salt Lake City (UT). All of these destinations demonstrated a rise in confirmed COVID-19 case counts between June and July 2020.

Covid-19 cases continue to rise in the USA, and while the reasons for this are multifactorial, human mobility is likely a contributing factor.[2] Evaluating human mobility patterns through several mechanisms (e.g. mobile devices, social media, commercial air travel) may predict the spread of infectious diseases.[3,4] AZ is a heavily impacted state, and connectivity patterns can help inform where future disease activity may occur. Connectivity patterns along interstate highways indicate substantial ground travel originating from AZ across the country. Some states (e.g. NY, NJ, CT) implemented a 14-day quarantine on travellers from AZ, however the highly interconnected states such as NV or CA do not have such a policy. Recent public health measures in AZ may help slow down transmission in the weeks ahead. For example, on 29 June, the Governor ordered all bars, movie theatres, gyms and waterparks to close again for at least 30 days. Public gatherings are limited to 50 and gatherings in swimming pools are limited to 10 people. While there has not been a state mandate for masks, the Governor allowed local officials to determine ordinances, which most have put into place throughout the state as of 23 June 2020.[5]

Limitations to this analysis include considerations of representativeness of 'smart device' users in the USA and potential for sampling bias in the anonymized device-level data.[6] Another limitation relates to the GPS locations provided at irregular intervals dependent on user action, which may also

systematically bias the outcome towards higher frequency device users. Additionally, the flight data are prospective, and do not account for the actual number of completed flights after cancellations or other dynamic changes in flight schedules take place. Scheduled flight data may over-represent travel volumes but still demonstrate general patterns in connectivity and final destination of passengers, and interconnected cities likely saw a rise in Covid-19 cases for several reasons including imported cases from AZ and elsewhere in the country.

Evaluating human mobility from high burden settings may illuminate where new cases of Covid-19 will likely be introduced and highlight where public health interventions can be focused to help curb future outbreaks.

Author contributions

A.W., A.T.B. and I.I.B. conceived the idea. N.H.A., J.F. and M.O. conducted data analysis;

A.W., A.T.B., I.I.B. and S.P. interpreted data and contributed to writing.

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Conflict of interest/disclosure

A.W., N.H.A., A.T.B., J.F. and M.O. are employed at BlueDot, a social enterprise that develops digital technologies for public health. I.I.B. has consulted for BlueDot. S.P. has no conflicts to declare.

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