Comparing the Boundaries between Mobility-Identified Communities and Potential Administrative Definitions for COVID-19 "Protect Our Neighbors" Criteria

jimi adams, Jude Bayham, Tatiane Santos, Debashis Ghosh, Jonathan Samet, with the Colorado COVID-19 Modeling Group

2020 July 6

Summary

This report provides a description of how Coloradans mix with each other. Data on movement of mobile phones is analyzed to describe how people come into contact with each other within bounds of counties and across bounds of counties. This information is important to controlling the COVID-19 pandemic in Colorado as the state enters the next phase of control measures—Protect Our Neighbors. The jurisdictions making applications for changes in orders will be counties or groups of counties and the corresponding local public health agencies (LPHAs). Our analysis asks whether the resulting boundaries correspond to the actual mixing of people that is relevant to spread of the SARS-CoV-2 virus.

We find that there are 26 distinct mixing regions within the state, reflecting geography and urban districts. The overlap of these mixing regions with different jurisdictional zones varied among those considered: LPHA regions (administrative units proposed for Protect Our Neighbors), Planning and Management Regions, and Health Care Coalitions. The mixing regions described here may be useful for further refinement of planning for Protect Our Neighbors.

Introduction

With the move to the "Protect Our Neighbors" phase of COVID-19 curtailment,[1] a series of metrics have been identified that must be met for determining when locales will qualify for additional relaxation of social distancing requirements/recommendations. Thresholds have been developed that must be met with regard to 1) low disease transmission metrics; 2) local public health agency capacity for testing, case investigation, contact tracing, and outbreak response; and 3) hospital ability to meet the needs of all patients and handle the surge in demand for intensive hospital care. The application to move from Safer at Home to Protect Our Neighbors will be made at the level of counties or jurisdictions of local public health agencies (LPHA). Here, we address how well these administrative boundaries apply to the way populations actually mix. For example, a particular county might meet metrics while its neighbors do not and cross-boundary mixing could lead infections to spread across boundaries intended to be met for Protect Our Neighbors.

An important consideration is how well the boundaries of the administrative units that will be used to make the designation for moving into Protect Our Neighbors align with the population mixing patterns that likely underlie the transmissions of infection. It is these mixing patterns that will drive the course of the epidemic within specific jurisdictions as they are affected by the transition to Protect Our Neighbors. Essentially, the metrics proposed for tracking eligibility for

[1] https://covid19.colorado.gov/protect-our-neighbors.

transition to Protect Our Neighbors or to return to Safer at Home will be influenced not only by what is happening at the particular county or LPHA level but more broadly by the interactions of people within the jurisdiction with those outside. However, the social distancing-based strategies that are dependent upon those metrics are targeted at maintaining safe levels in the contact patterns that lead to potential transmissions between members of a population. Those could be well-aligned so that the places that people get infected may be the same places where cases are identified or those who are symptomatic seek care. However, mixing patterns may lead to many people becoming infected outside of the jurisdiction where they reside. Mountain communities are good examples of this phenomenon.

Methods

Therefore, we use the same mobility data as in our previous reports regarding social distancing changes and responsiveness to policy recommendations [1,2], to estimate the alignment between these two boundary definitions. Our analyses proceed in two steps. First, we identify the boundaries of mobility-based communities that represent the places where people are most likely to come in contact with others during activities that provide the context for potential transmission. To identify these boundaries, we use the volume of observed traversals between each pair of census block groups (CBGs) in Colorado. These pairwise data are used to build a mobility network between CBGs. We apply “community detection” methods to these networks. Community detection allows for the identification of “communities” within the network that indicate collections of CBGs where the majority of connections (here mobility traversals) are between CBGs than are *within*[2] That is, communities provide an empirical picture of the boundaries that provide the mixing opportunities to generate potentially transmitting social contacts—or the boundaries identifying which locales share the same “risk pool” of behavioral contacts. In other words, we identify those places where mixing among people can—and cannot—be expected to be constrained within the boundaries.

Once these mobility-based community boundaries have been estimated, we can examine how well they align with the potential boundary definitions determined by various administrative groupings. We present maps that illustrate these (mis-)alignments, and summarize the places where alignment is poor in table form.

[2] There are numerous methods for analyzing community structure in networks. Here, we present results using [3], but we also ran the analyses using [4], which relies on an algorithm with substantially different maximization assumptions. While there are some marginal differences between the classifications provided across these 2 algorithms (e.g., in the number of communities, or classification for a few sparsely visited CBGs), the general fit [5] and overall patterns of alignment/misalignment reported are similar across the approaches (any differences are mentioned in footnotes).

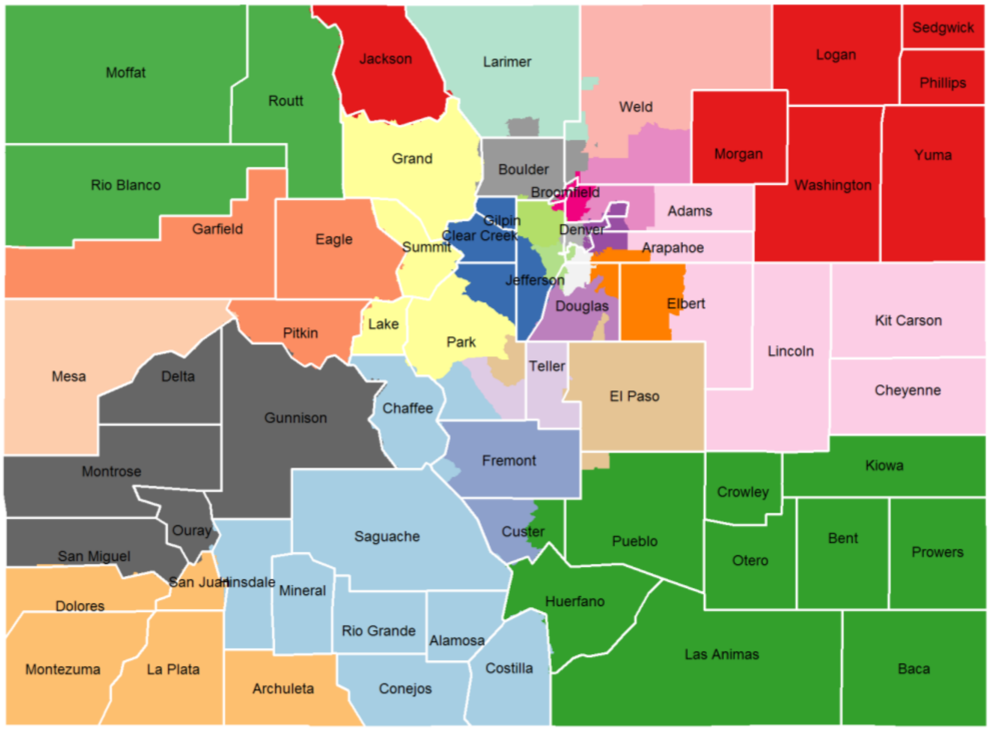

Figure 1. Boundary Alignment between Mobility-based Communities (color-fill) and county (white outlines, named). We also provide an interactive version of this visualization, which incorporates each of the boundary comparisons provided across the figures in this report, available at: https://jbayham.github.io/covid_community_detection/lpha_map.html

Results

This analysis leads to the identification of 26 different groupings of community block groups that bound populations that mix together but less external to the boundaries. Each grouping has a separate color in Figure 1, which illustrates how the 26 mobility-identified communities align with county boundaries in Colorado. The primary pattern observed is that most communities are well-bounded by a set of contiguous counties--for example, see the red community grouping spanning Sedgwick, Logan, Phillips, Yuma, Washington, and Morgan Counties in the northeast corner, noting that there are no segments with that same shading outside of those county boundaries. A secondary pattern illustrated in this figure, however, is that several communities bridge across county boundaries in non-contiguous ways, or counties have portions that are aligned with different communities. For example, Elbert County includes two distinct mixing communities, and each of those communities also include substantial portions of other counties. So, building from this example, if Elbert County's metrics revealed case growth that triggers more restrictive levels of social distancing, these may not sufficiently protect the county's residents if the primary mixing that drives potentially transmitting contacts takes place in the orange segments of Arapahoe or Douglas Counties, if similar protections are not in place. That is, the metrics identifying "unsafe" levels/trajectories of cases/hospitalizations are being measured with one set of boundaries, while the risk-driving social contacts span outside those boundaries--in which case, the interventions may therefore not have the intended consequences.

Comparing to other Administrative Aggregations

In the planned approach, counties are the primary administrative units used to assess eligibility for and continuation of “Protect Our Neighbors” metrics. The majority of Colorado’s 53 Local Public Health Agencies (LPHAs) have jurisdiction over one of the state’s 64 counties, with a few exceptions. While LPHAs could focus their planning and response efforts solely within counties under their jurisdiction, many recognize the potential value of regional planning because viral transmission is not restricted to county boundaries. Thus, LPHAs provide an important organizing potential for understanding the implications for transition to Protect Our Neighbors phase, and what would necessitate return to Safer at Home. We therefore demonstrate how LPHA region residents move within and across those administrative boundaries. In particular, these comparisons inform how closely these administrative boundaries (to which policies apply) are expected to align with the behavioral patterns supporting potential transmissions.

So we now turn to examining how these mobility-based communities align with other possible administrative boundaries. First, we compare to Local Public Health Agency (LPHA) region boundaries.[3] The Figure 2 map is similar to Figure 1, but the boundaries now represent the LPHA regions instead of counties. Then we summarize misalignments between these two sets of boundary definitions in Table 1.

3 https://www.colorado.gov/pacific/cdphe-lpha/colorado-public-health-structure-map

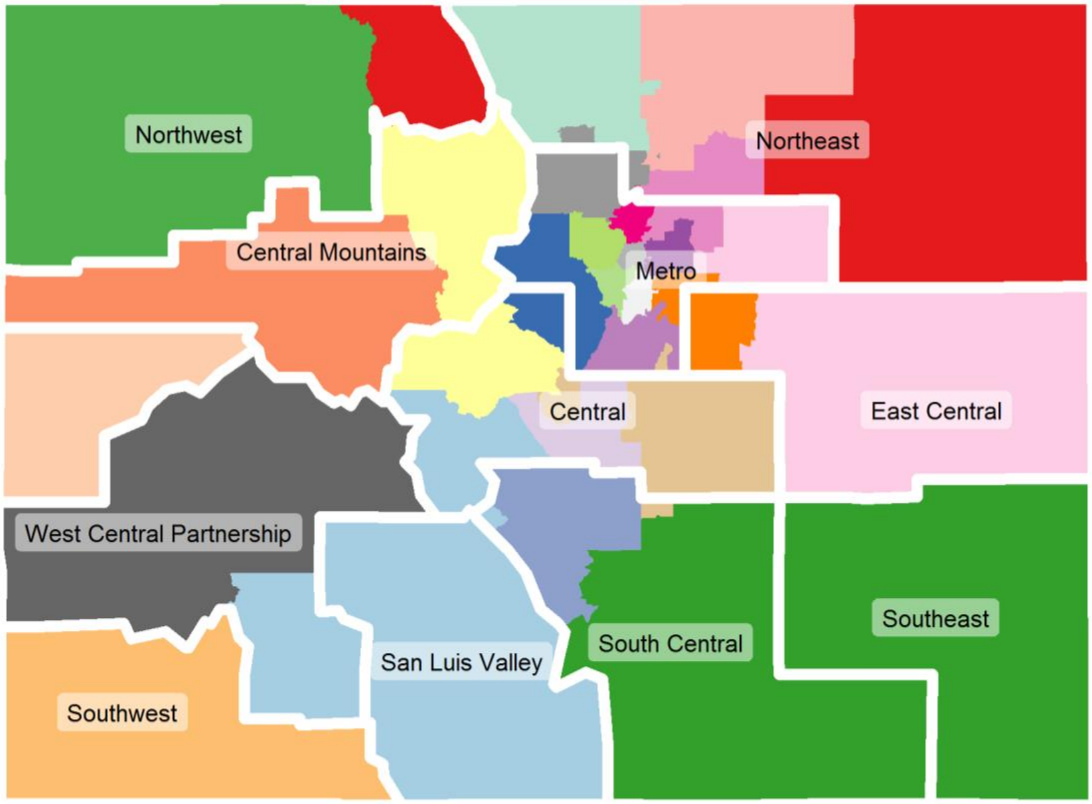

Figure 2. Boundary Alignment between Mobility-based Communities (color-fill) and LPHA Regions (white outlines, named).

Table 1 lists LPHA groupings for which the volume of mobility traversals—as identified with the mobility-based community detection and illustrated in Figure 1--substantially span outside the LPHA boundary. These comparisons are potentially asymmetric, given the differential volume of mobility originating within respective LPHA regions. For example, East Central and Northeast each (independently) overlap with Metro. This highlights that if either East Central or Northeast experienced case growth that sparked a return to Safer at Home, based solely on trends from within the LPHA region, this change would not alter Metro's status, where their residents mix. Such a misalignment suggests that if these LPHA regions make decisions independently from one another, they would be ignoring the mixing overlaps between their residents that provide the potential for transmissions. The shift back to Safer at Home would therefore have no effect on reducing the potential of "importing" cases from neighboring locales (e.g., from Metro) where their residents have regular contact beyond the LPHA boundaries. These overlaps point to regions that may benefit from coordinating, rather than differentiating, their response strategies.

Table 1. LPHA Groupings with more than 5% of Mobility volume from other LPHA Regions

• East Central → Metro (25% of mobility volume)
• Northeast → Metro
• South Central → South East

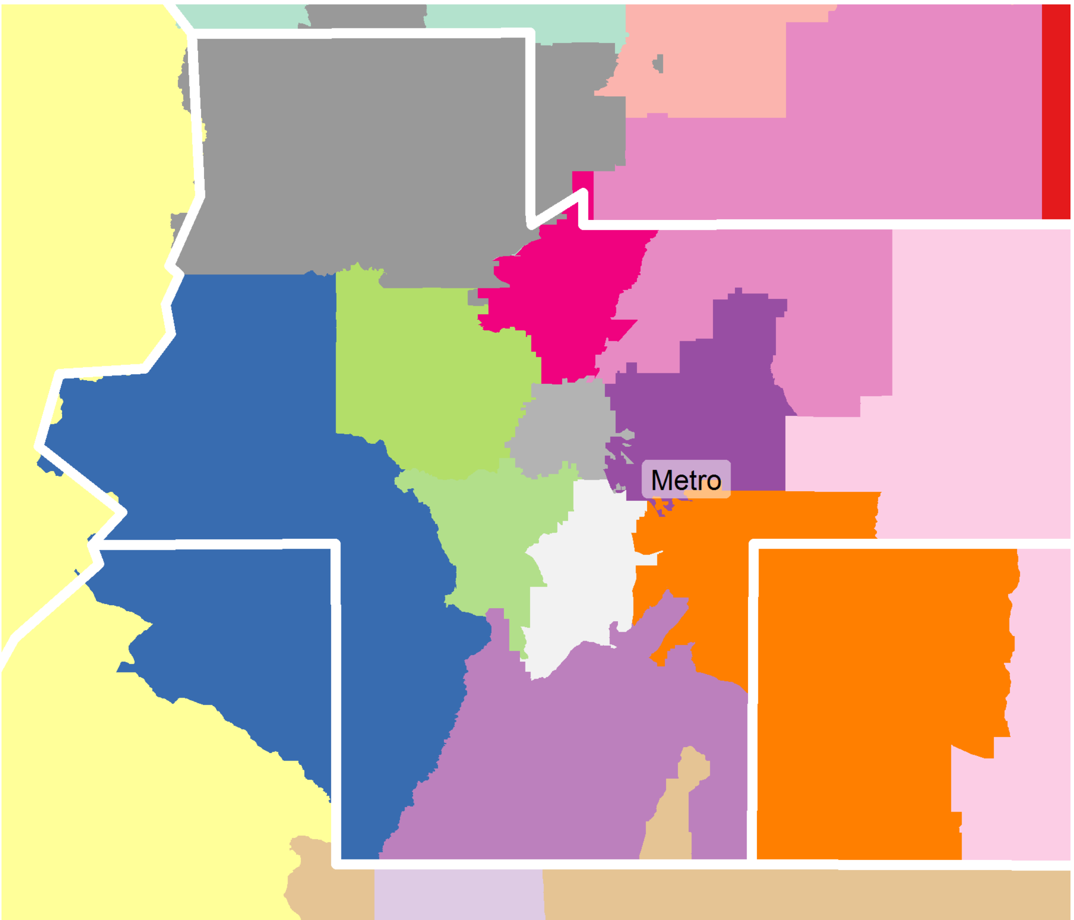

Figure 2a. Denver-area Focus - Boundary Alignment between Mobility-based Communities (color-fill) and LPHA Regions (white outlines, named).

Next, we compare to Colorado Planning and Management Region boundaries,[4] in Figure 3, and again summarize the misalignments in Table 2. These comparisons reveal that the Planning and Management Regions provide boundaries that are more comparable to the observed mobility patterns identified with network communities. Regions 2, 5, and 12 each have substantial mobility overlaps with Region 3, as seen in the community colors that span across these boundaries in Figure 3--colored grey and hot pink (Region 2→3), orange and pale pink (Region 5→3), and dark blue (Region 12→3), respectively.

[4] https://www.colorado.gov/pacific/sites/default/files/Caro%20Brochure%20and%20Directory%20Link.pdf

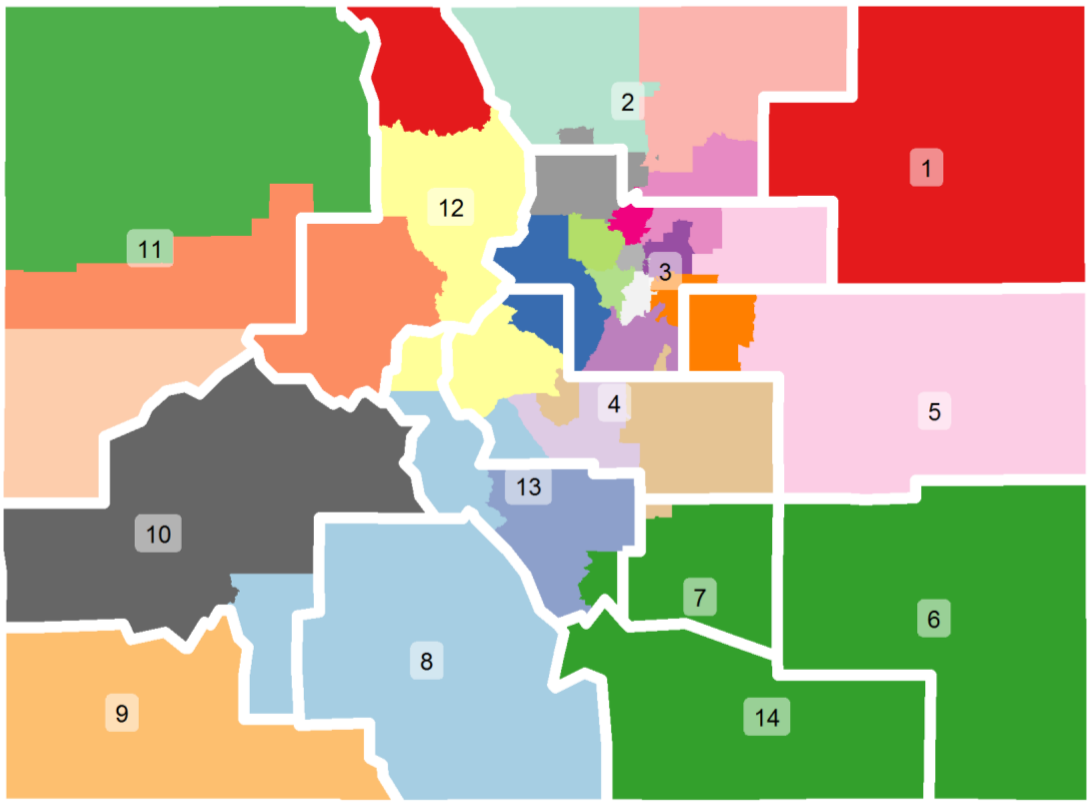

Figure 3. Boundary Alignment between Mobility-based Communities (color-fill) and Planning & Management Regions (white outlines, named).

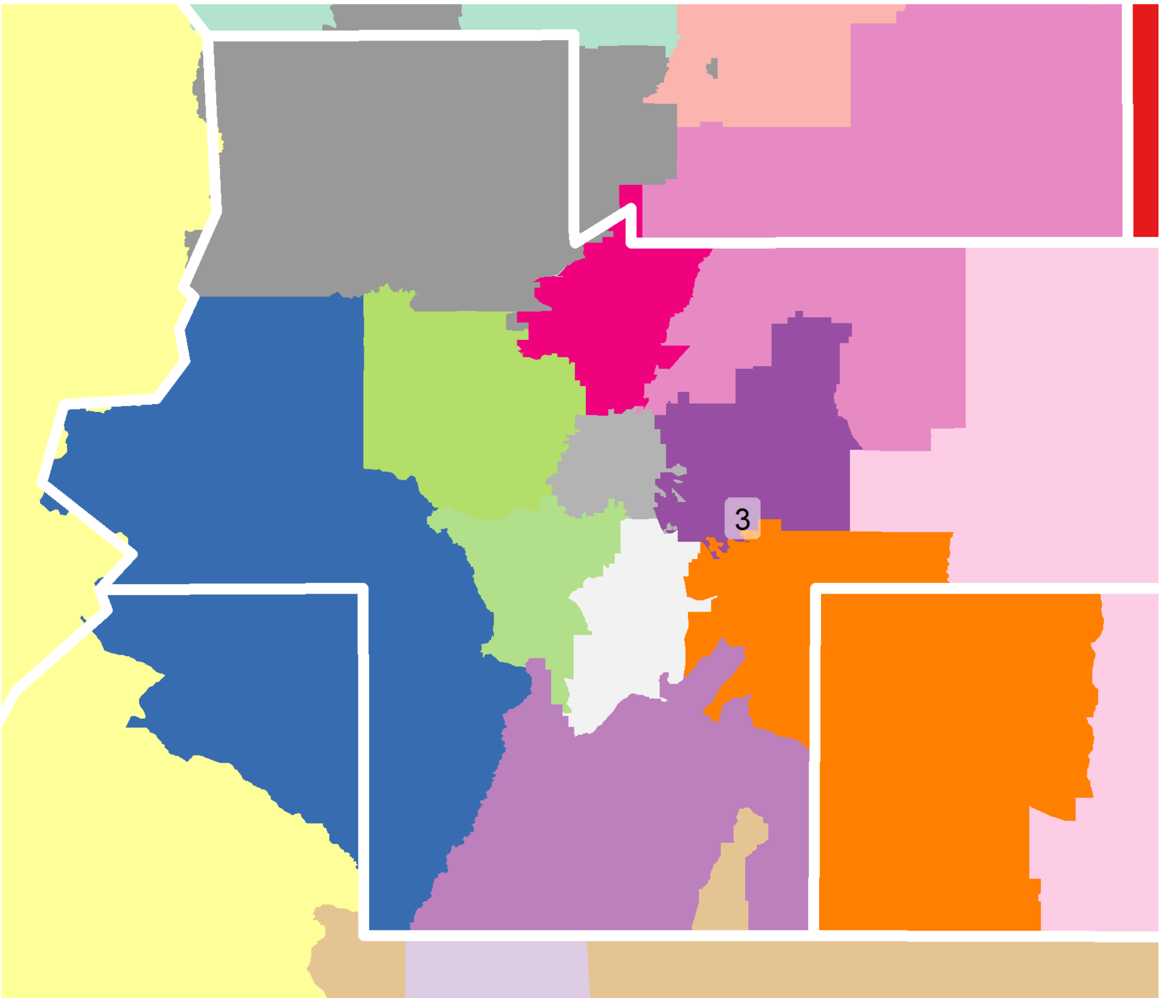

Figure 3a. Denver-area Focus - Boundary Alignment between Mobility-based Communities (color-fill) and Planning & Management Regions (white outlines, named).

Table 2. Planning & Management Regions with Substantial Mobility-based Community Overlap

• Regions 2, 5, 12 → 3
• Regions 6, 14 → 7

Finally, we compare to Health Care Coalition boundaries,[5] in Figure 4, and summarize the misalignments in Table 3.

5 https://www.colorado.gov/pacific/cdphe/health-care-coalitions

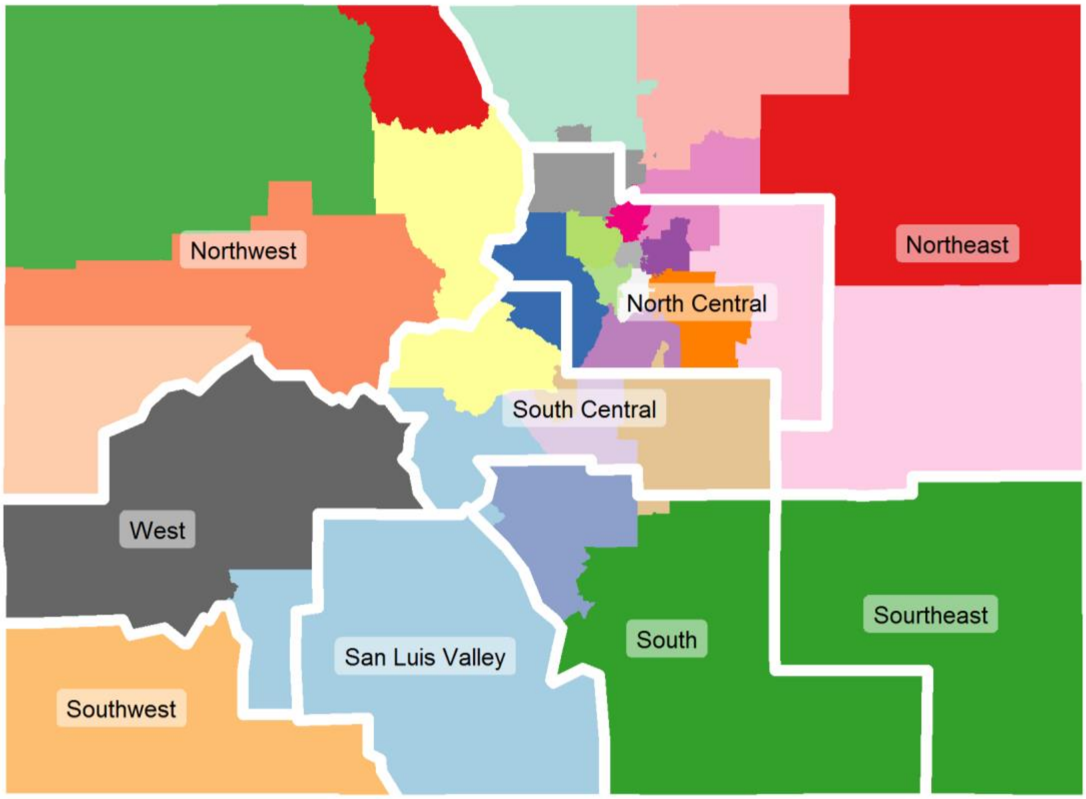

Figure 4. Boundary Alignment between Mobility-based Communities (color-fill) and Health Care Coalitions (white outlines, named).

Table 3. Health Care Coalitions with Substantial Mobility-based Community Overlap

• Southeast → South
• Northeast → Northcentral

Implications

This representation of mobility patterns suggests that for some parts of Colorado, if interventions are designed by various administrative units to reduce social contacts that potentially transmit SARS-COV-2, they could target behavioral changes in locales that do not align with the boundaries of the units making those decisions. While the vast majority of the comparisons provided here *are* in alignment, we have noted some of the particular limitations that arise from using a range of potential administrative groupings. These findings should be considered as Protect Our Neighbors is implemented and its consequences monitored.

References

1. Bayham J, adams j, Ghosh D, Jackson P, with the Colorado COVID-19 Modeling Group. Colorado Mobility Patterns During the COVID-19 Response. Colorado School of Public Health; Published online May 14, 2020. http://www.ucdenver.edu/academics/colleges/PublicHealth/coronavirus/Documents/Mobility%20Report_final.pdf

2. Buchwald A, Carlton E, Ghosh D, et al. The current state of COVID-19 in Colorado and projected course of the epidemic in the coming weeks. Colorado School of Public Health; Published online May 29, 2020. https://drive.google.com/file/d/1ZCX_mloh0kQS-c9-UdPjqlBRVAovQnJl/view

3. Blondel VD, Guillaume J-L, Lambiotte R, Lefebvre E. Fast Unfolding of Communities in Large Networks. *Journal of Statistical Mechanics.* 2008;10:10008-10020. doi:10.1088/1742-5468/2008/10/P10008

4. Newman ME, Girvan M. Finding and evaluating community structure in networks. *Physical Review E*. 2004;69:no.026113.

5. Danon L, Díaz-Guilera A, Duch J, Arenas A. Comparing community structure identification. *Journal of Statistical Mechanics: Theory and Experiment*. 2005;2005(09):P09008-P09008. doi:10.1088/1742-5468/2005/09/p09008