Supporting Information for

Characterizing Spatial Epidemiology in a Heterogeneous Transmission Landscape Using the Spatial Transmission Count Statistic

Leke Lyu, Gabriella Veytsel, Guppy Stott, Spencer Fox, Cody Dailey, Lambodhar Damodaran, Kayo Fujimoto, Pamela Brown, Roger Sealy, Armand Brown, Magdy Alabady, Justin Bahl*

This PDF file includes:

Genome dataset and subsampling scheme

Supplementary Figure 1

Supplementary Table 1-3

Characterizing spatial transmission heterogeneity in subregions of Texas

Supplementary Figure 2-26

Supplementary Table 4-5

Sensitivity Analysis

Supplementary Table 6

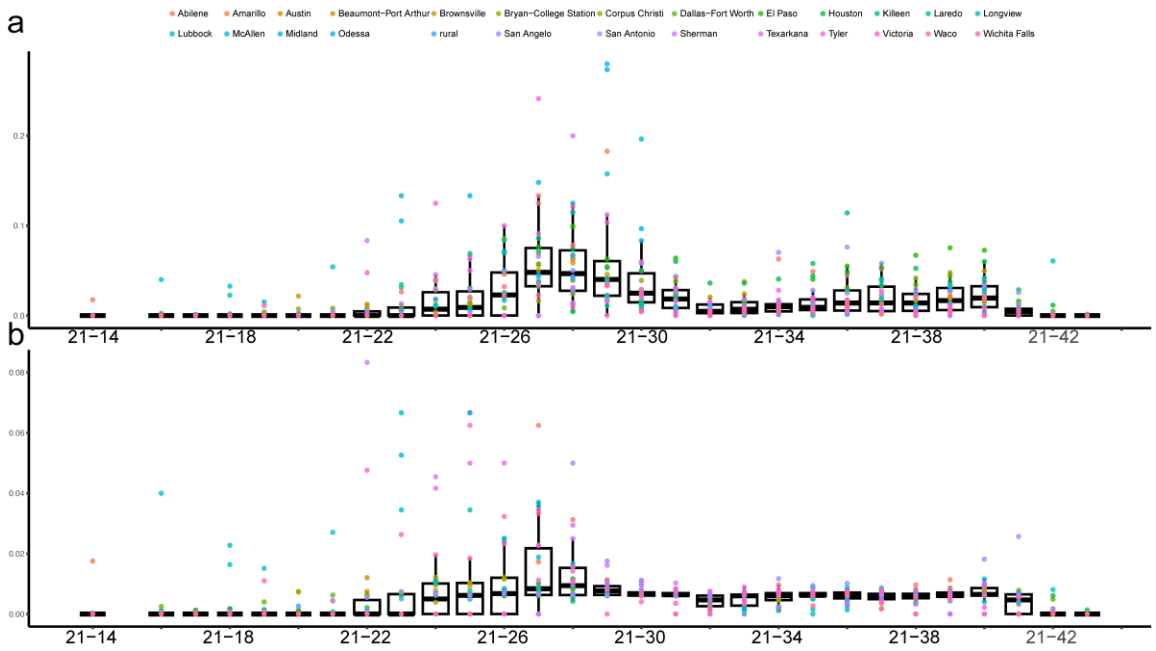
Genome dataset and subsampling scheme

In Supplementary Figure 1, we illustrate how our subsampling scheme reduces the sampling bias. Specifically: Supplementary Figure 1a depicts the sampling ratio of the unsampled dataset, categorized by metropolitan areas and segmented by Epi-Week; Supplementary Figure 1b shows the sampling ratio of the sampled dataset, also broken down by metropolitan areas.

In Supplementary Table 1, we provide the complete list of metropolitan areas with their population and RUCC assignment. The RUCC form a classification scheme that distinguishes metropolitan counties by the population size of their metro area. The latest update is RUCC 2013, based on the 2010 United States census. Here, we updated the RUCC classification using the 2020 United States census. Only one change occurred: Bryan-College Station moved from RUCC-3 to RUCC-2 due to a population increase from 228,660 to 268,248.

In Supplementary Table 2, we record the total case count, number of available genomes, and the number of sampled genomes from different subregions in Texas. The recorded time spans from Epi-Week 14 to Epi-Week 43.

In Supplementary Table 3, we record the genome counts by country in the global contextual dataset. The complete list of GISAID's accession IDs for SARS-CoV-2 sequences analyzed in this study is publicly available at https://github.com/leke-lyu/transmissionCount.



Supplementary Figure 1. Genome sampling ratio of the original Texas dataset vs the sampled Texas dataset

Supplementary Table 1. Population size of metropolitan areas in Texas and their corresponding RUCC

MAs	Population 2010	RUCC 2013	Population 2020	Updated RUCC
Dallas-Fort Worth	6987215	RUCC-1	7648780	RUCC-1
Houston	5920416	RUCC-1	7121540	RUCC-1
San Antonio	2141508	RUCC-1	2558143	RUCC-1
Austin	1706289	RUCC-1	2283371	RUCC-1
McAllen	774769	RUCC-2	870781	RUCC-2
El Paso	625739	RUCC-2	868859	RUCC-2
Killeen	405300	RUCC-2	475367	RUCC-2
Corpus Christi	428185	RUCC-2	445763	RUCC-2
Brownsville	406220	RUCC-2	421017	RUCC-2
Beaumont-Port Arthur	403190	RUCC-2	409782	RUCC-2
Lubbock	290805	RUCC-2	321368	RUCC-2
Waco	252772	RUCC-2	277547	RUCC-2
Amarillo	251933	RUCC-2	268691	RUCC-2
Bryan-College Station	228660	RUCC-3	268248	RUCC-2
Laredo	250304	RUCC-2	250304	RUCC-2
Tyler	209714	RUCC-3	233479	RUCC-3
Longview	214369	RUCC-3	217345	RUCC-3
Abilene	165252	RUCC-3	176579	RUCC-3
Midland	141671	RUCC-3	175220	RUCC-3
Odessa	137130	RUCC-3	165171	RUCC-3
Wichita Falls	148415	RUCC-3	148128	RUCC-3
Sherman	120877	RUCC-3	135543	RUCC-3
San Angelo	111823	RUCC-3	121516	RUCC-3
Victoria	94003	RUCC-3	98331	RUCC-3
Texarkana	92565	RUCC-3	92893	RUCC-3

Supplementary Table 2. Genomic sampling ratio by subregions in the Texas dataset

Reported Cases		Available genomes (var = 5.74e-05)		Sampled genomes (var = 7.56e-07)	
Regions	Case Count	Genome Count	Ratio	Genome Count	Ratio
Dallas-Fort Worth	331624	6621	0.020	1835	0.006
Houston	284582	10724	0.038	1523	0.005
San Antonio	108685	1922	0.018	593	0.005
rural	101957	958	0.009	516	0.005
Austin	88138	1329	0.015	465	0.005
McAllen	24147	245	0.010	113	0.005
Killeen	19473	393	0.020	78	0.004
Corpus Christi	17951	328	0.018	102	0.006
Beaumont-Port Arthur	14444	206	0.014	84	0.006
Bryan-College Station	13979	100	0.007	60	0.004
El Paso	13918	328	0.024	57	0.004
Brownsville	12961	222	0.017	66	0.005
Lubbock	10247	244	0.024	48	0.005
Laredo	8451	73	0.009	32	0.004
Waco	8045	113	0.014	48	0.006
Amarillo	7526	124	0.016	38	0.005
Tyler	7196	138	0.019	43	0.006
Wichita Falls	5972	41	0.007	26	0.004
Victoria	5502	29	0.005	21	0.004
Longview	5407	40	0.007	23	0.004
Odessa	4789	86	0.018	24	0.005
Midland	4436	100	0.023	29	0.007
Sherman	4315	58	0.013	25	0.006
Abilene	3487	87	0.025	22	0.006
Texarkana	2453	30	0.012	15	0.006
San Angelo	1870	54	0.029	13	0.007

Supplementary Table 3. Genome counts by country in the global contextual dataset

Europe		Asia		North America		South America		Oceania		Africa	
United Kingdom	1849	Japan	265	USA	2231	Brazil	78	Australia	41	South Africa	18
Germany	265	India	111	Canada	200	Chile	13	New Zealand	2	Nigeria	4
Denmark	214	Indonesia	14	Mexico	47	Peru	7				
France	177	Malaysia	12	Sint Maarten	2	Aruba	2				
Sweden	93	Thailand	9								
Switzerland	83	Philippines	7								
Netherlands	79	Qatar	3								
Italy	78	Vietnam	3								
Spain	78	Bangladesh	1								
Belgium	63	China	1								
Ireland	58	Israel	1								
Norway	43										
Austria	25										
Slovenia	19										
Finland	18										
Poland	17										
Slovakia	17										
Bulgaria	15										
Croatia	14										
Czech Republic	14										
Lithuania	13										
Estonia	12										
Iceland	10										
Russia	10										
Romania	8										
Greece	6										

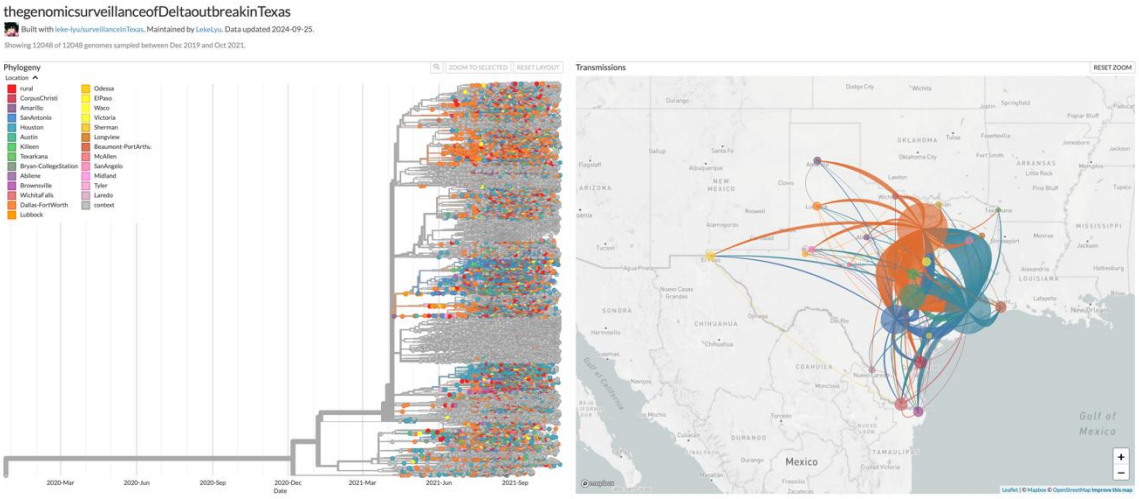
Characterizing spatial transmission heterogeneity in subregions of Texas

In Supplementary Figure 2, we present the time-adjusted phylogeny with branches colored based on ancestral trait reconstruction. The nextstrain build is available in: https://nextstrain.org/community/leke-lyu/deltaoutbreak/texas.

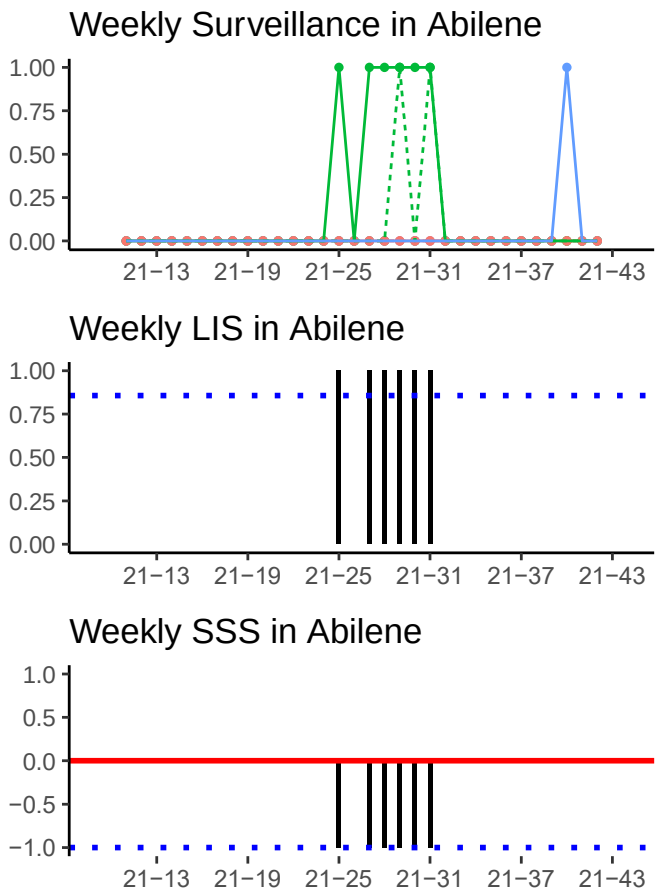
In Supplementary Figure 3-26, we summarized the epidemic trends in these subregions by utilizing the spatial transmission counts. The layout for the figures is as follows: the first row shows epidemic trends, the second row displays the Local Import Score, and the third row presents the Source Sink Score. Green lines represent importation, blue lines indicate local transmission, and pink lines signify exportation.

In Supplementary Table 4, we present the complete centrality analysis of metropolitan areas in Texas using betweenness, connectedness, and degree measures.

In Supplementary Table 5, we provide the complete set of Source Sink Scores and Local Import Scores for all subregions in Texas.



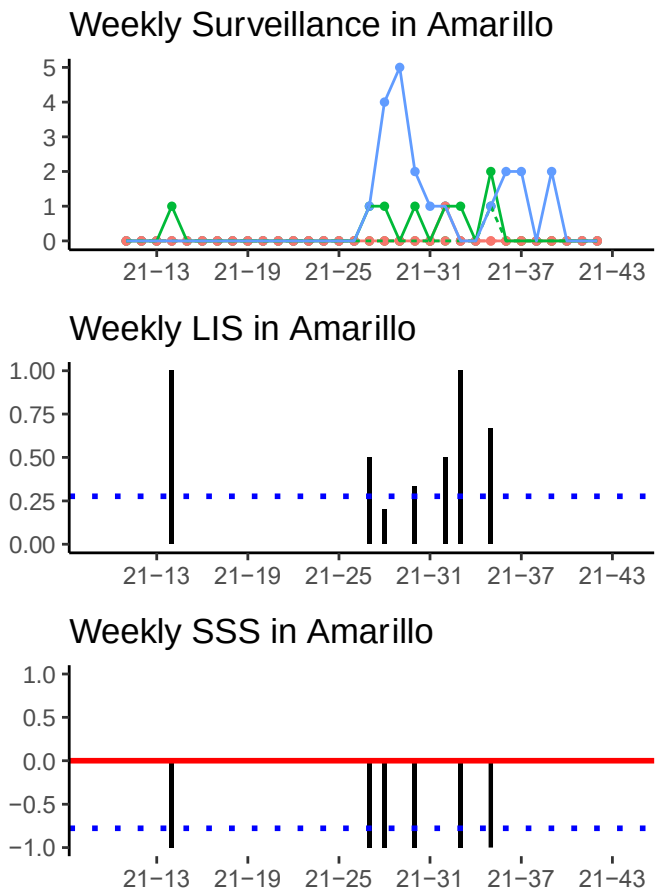
Supplementary Figure 2. The time-adjusted phylogeny with branches colored based on ancestral trait reconstruction



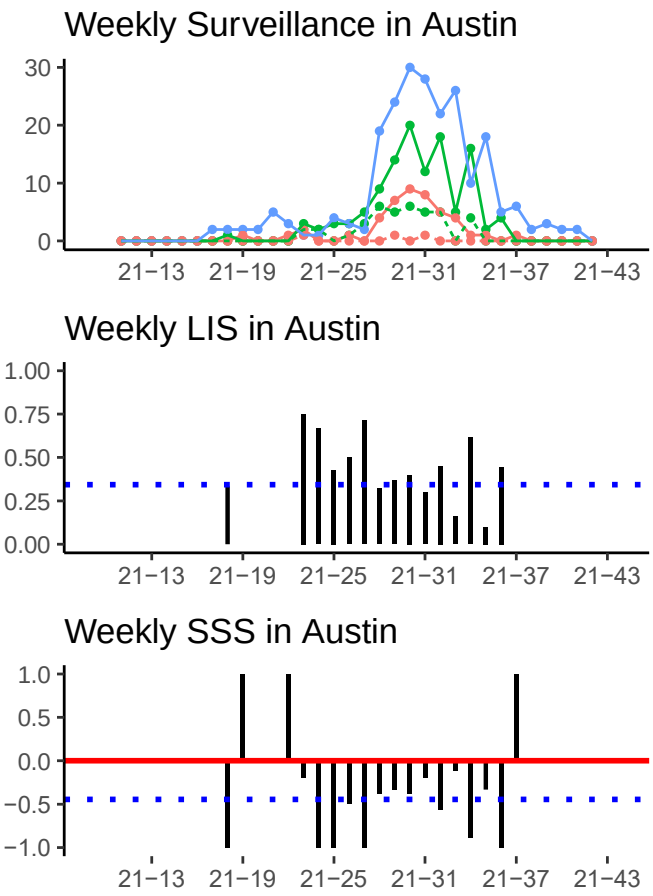
69

70 **Supplementary Figure 3. The epidemic trend in Abilence**

71



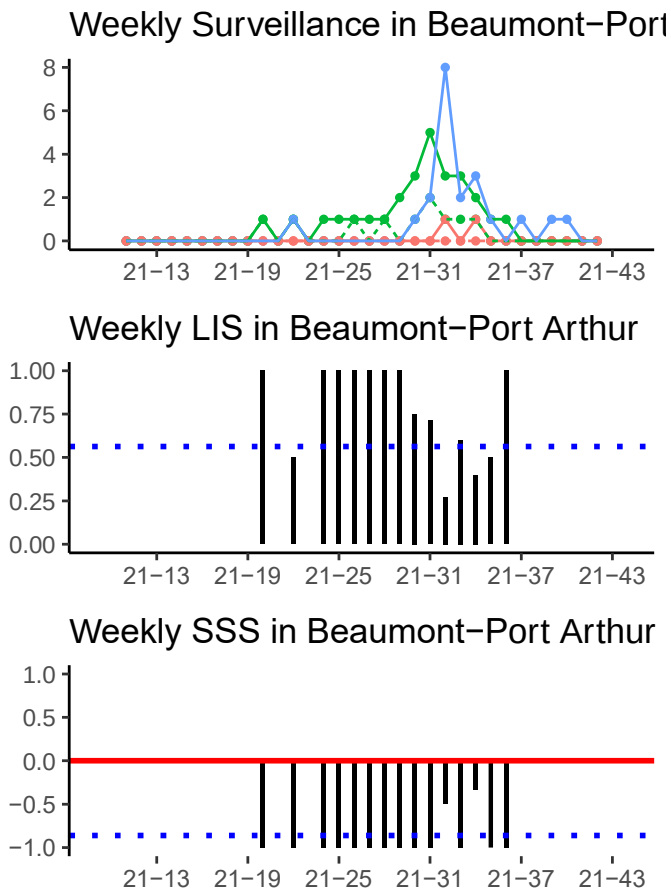
Supplementary Figure 4. The epidemic trend in Amarillo



75

76 **Supplementary Figure 5. The epidemic trend in Austin**

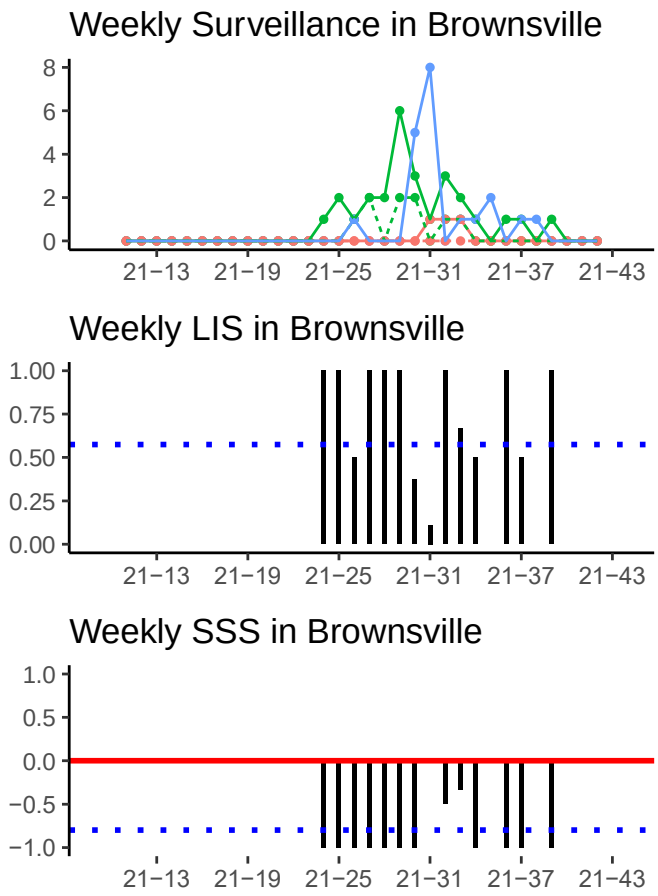
77



78

79 **Supplementary Figure 6. The epidemic trend in Beaumont-Port Arthur**

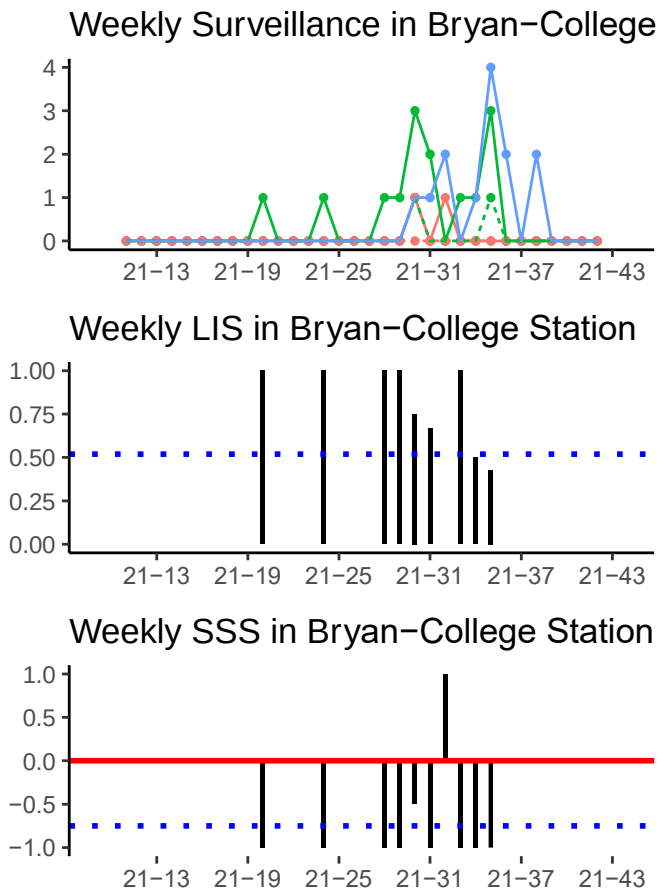
80



81

82 **Supplementary Figure 7. The epidemic trend in Brownsville**

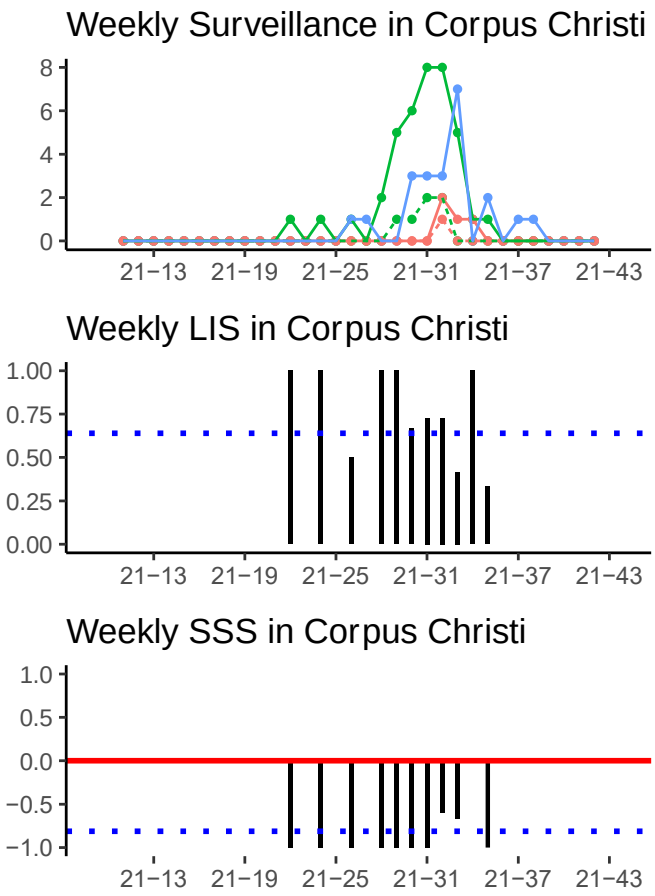
83



84

85 **Supplementary Figure 8. The epidemic trend in Bryan-College Station**

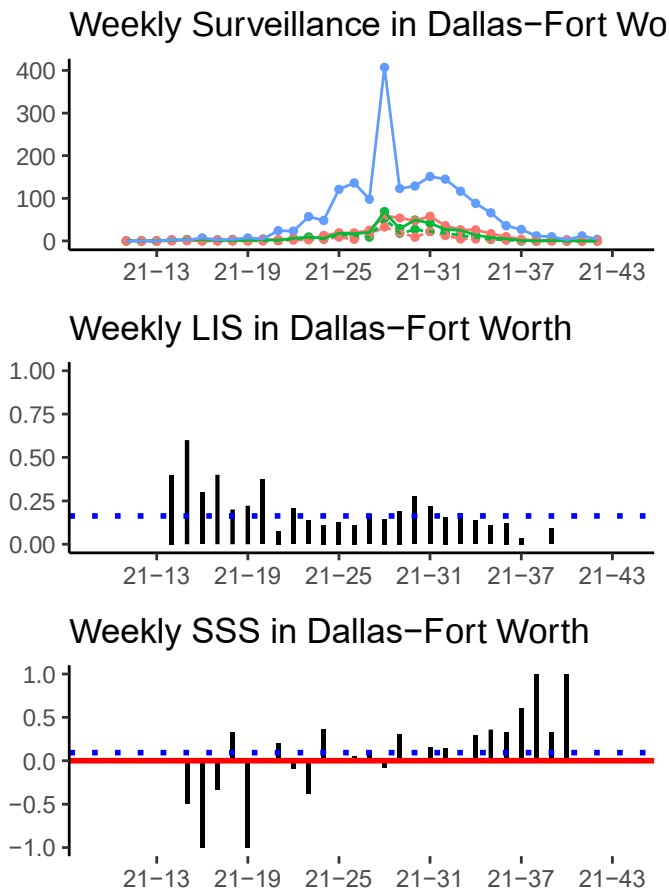
86



87

88 **Supplementary Figure 9. The epidemic trend in Corpus Christi**

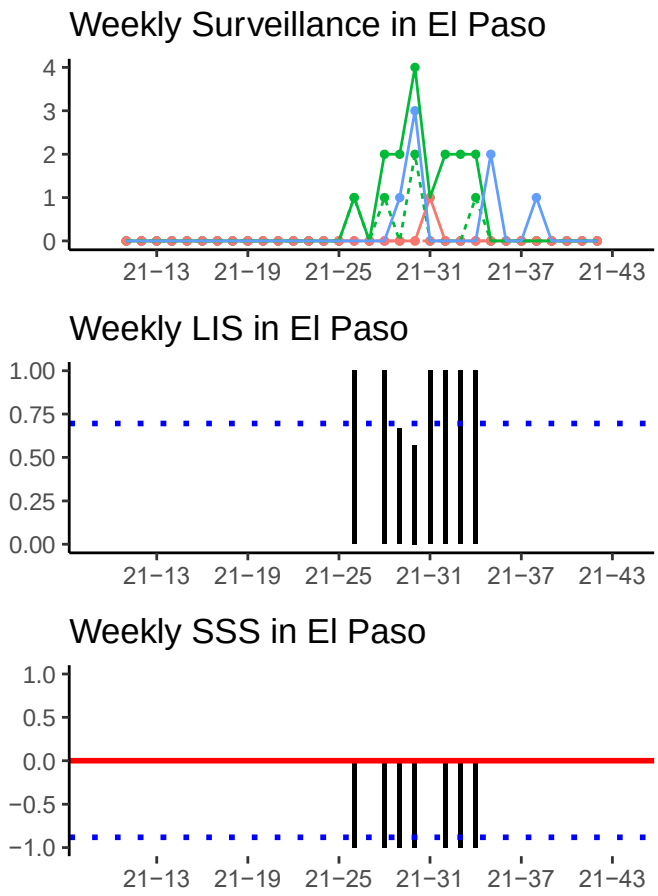
89



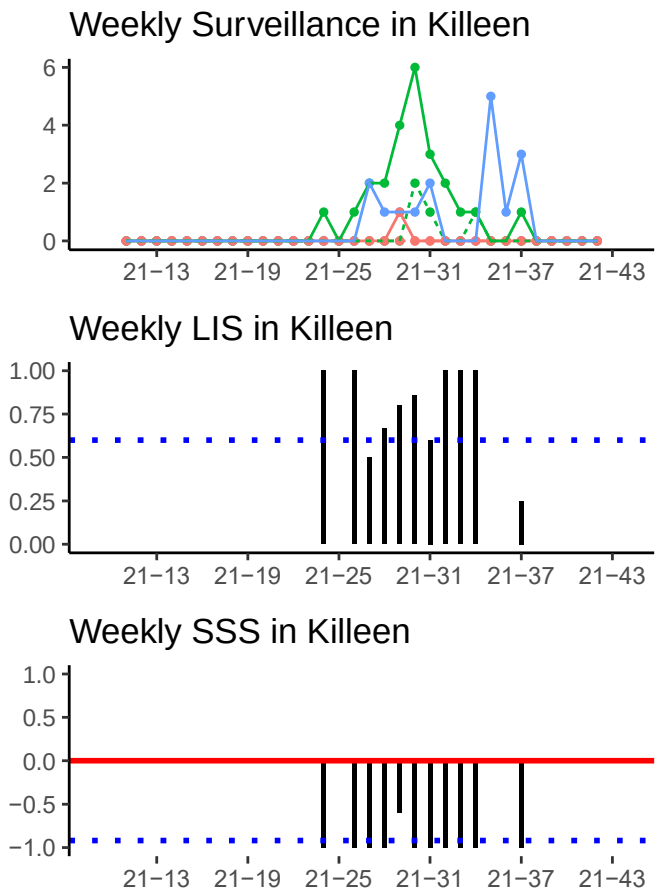
90

91 **Supplementary Figure 10. The epidemic trend in Dallas-Fort Worth**

92



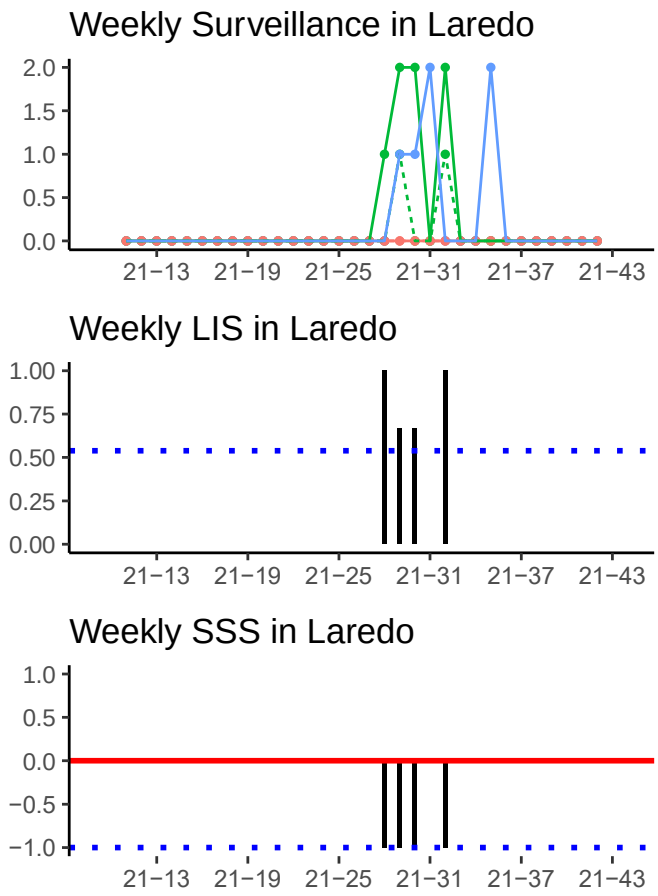
Supplementary Figure 11. The epidemic trend in El Paso



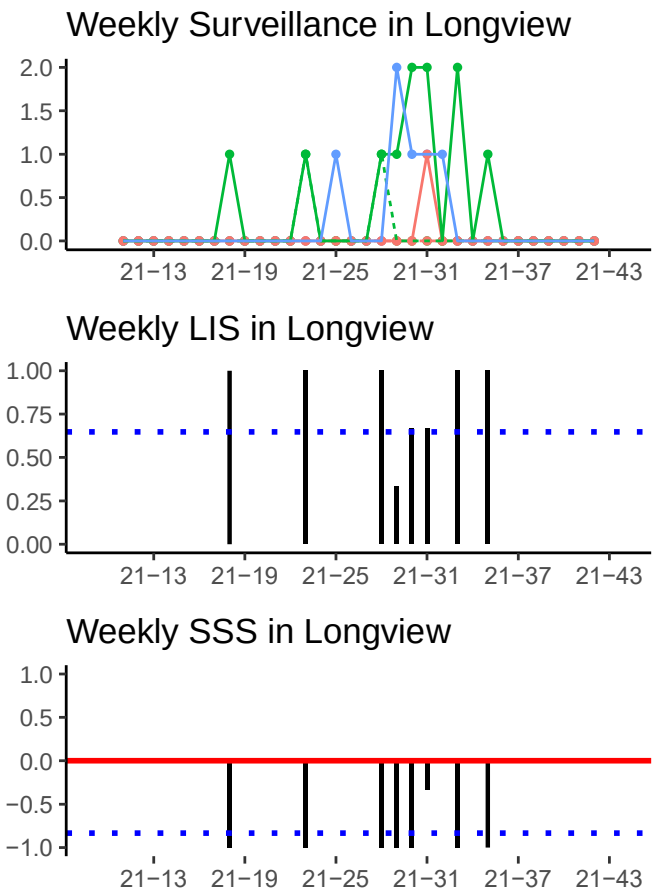
96

97 **Supplementary Figure 12. The epidemic trend in Killeen**

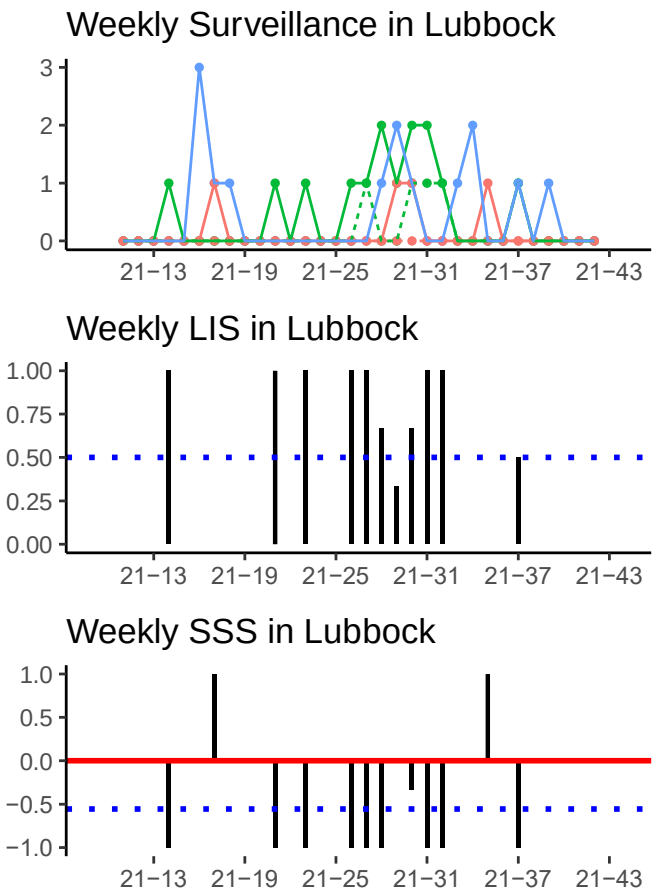
98



Supplementary Figure 13. The epidemic trend in Laredo



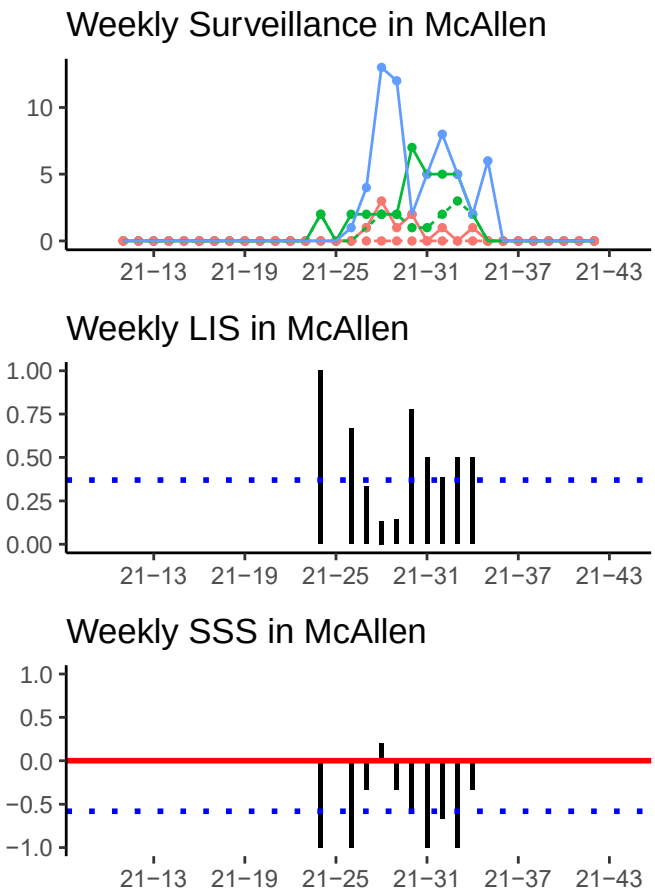
Supplementary Figure 14. The epidemic trend in Longview



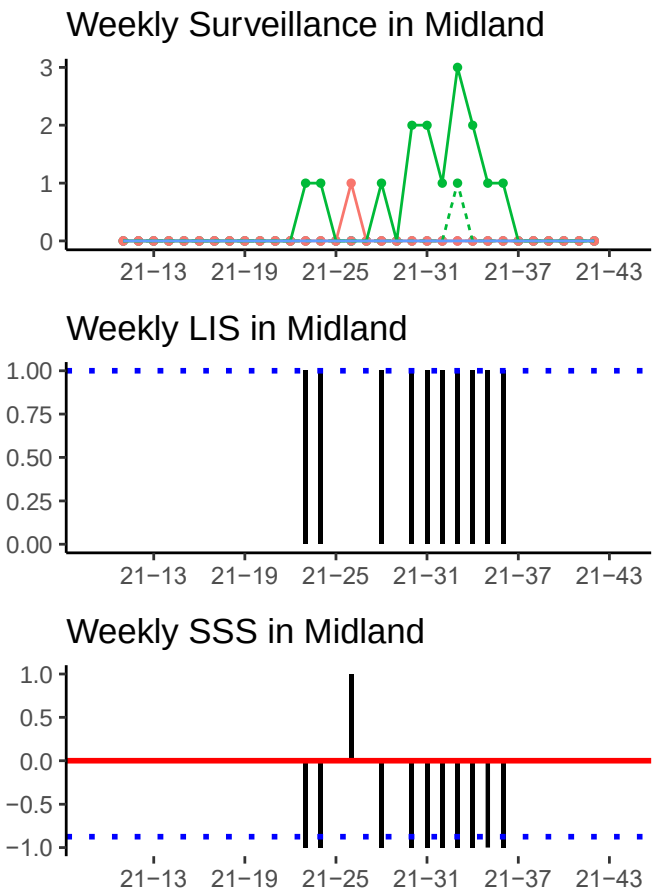
105

106 **Supplementary Figure 15. The epidemic trend in Lubbock**

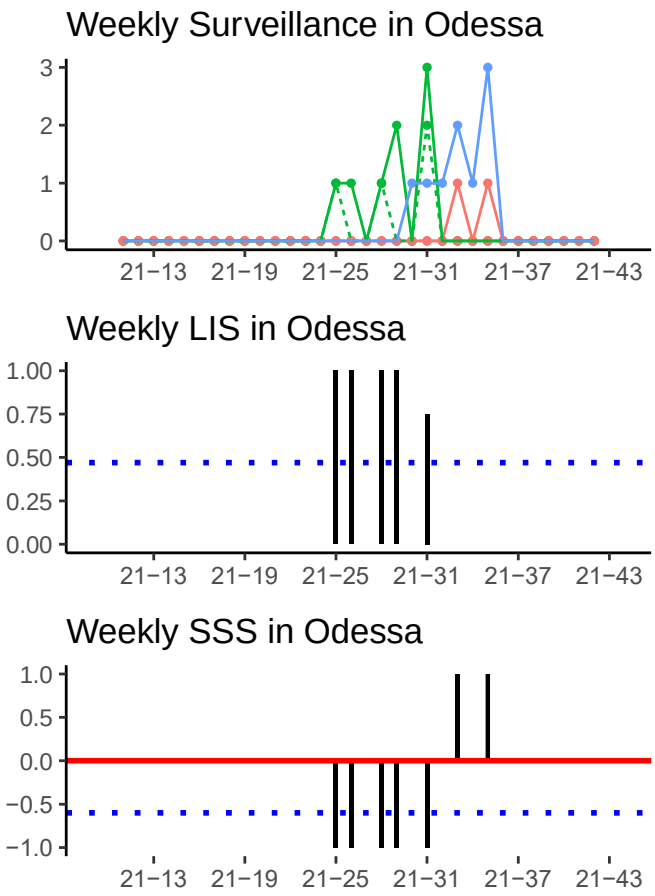
107



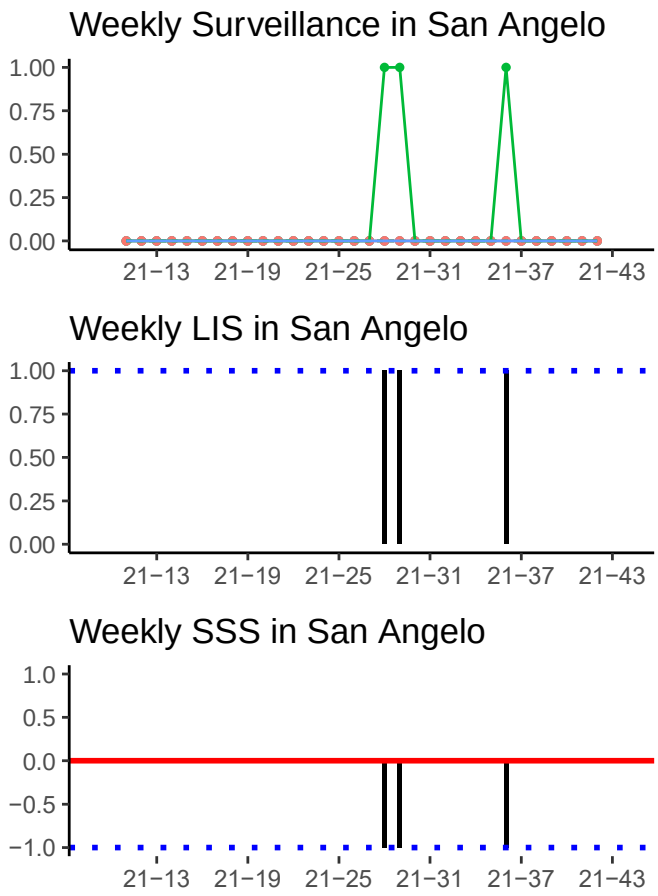
Supplementary Figure 16. The epidemic trend in McAllen



Supplementary Figure 17. The epidemic trend in Midland



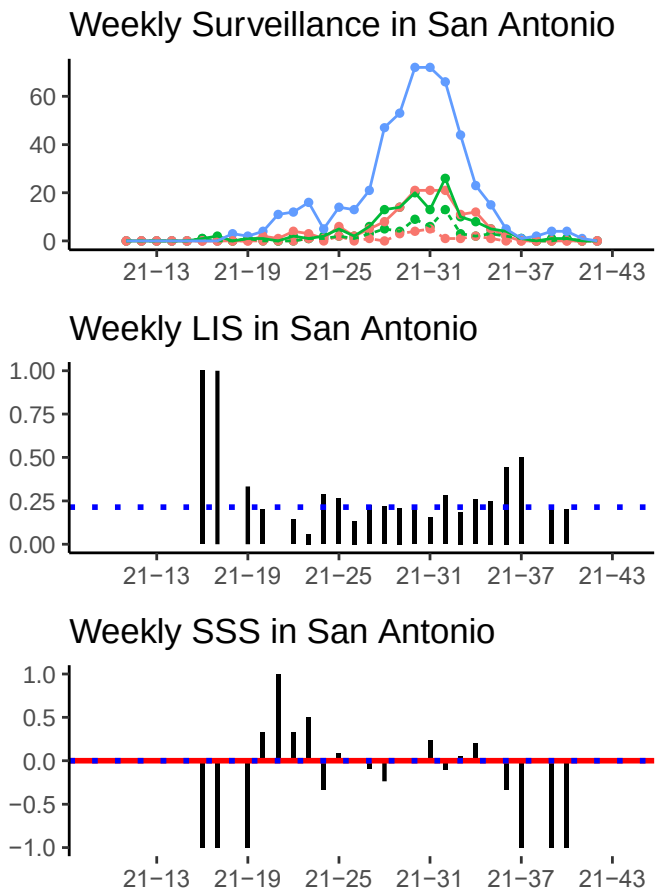
Supplementary Figure 18. The epidemic trend in Odessa



117

118 **Supplementary Figure 19. The epidemic trend in San Angelo**

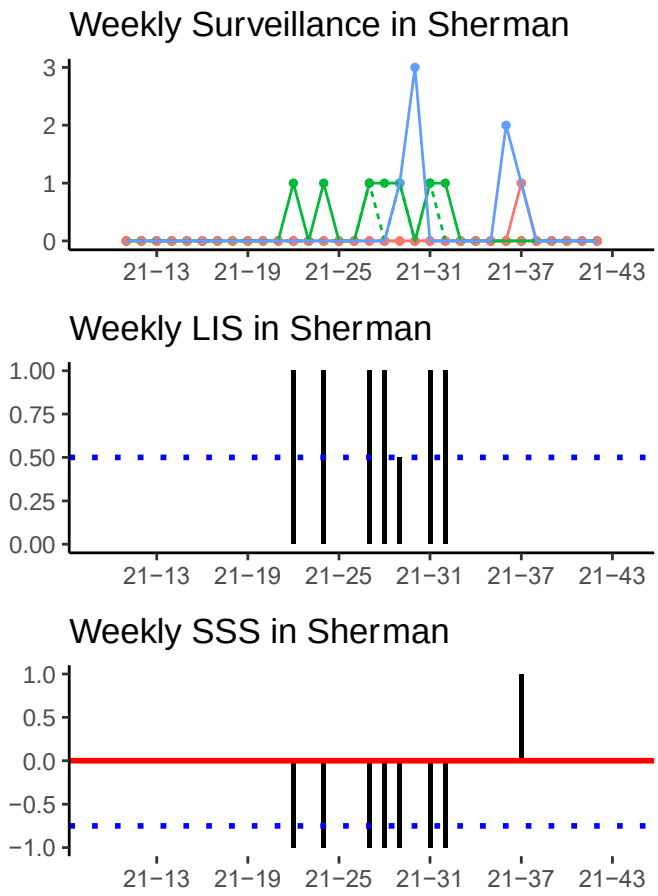
119



120

121 **Supplementary Figure 20. The epidemic trend in San Antonio**

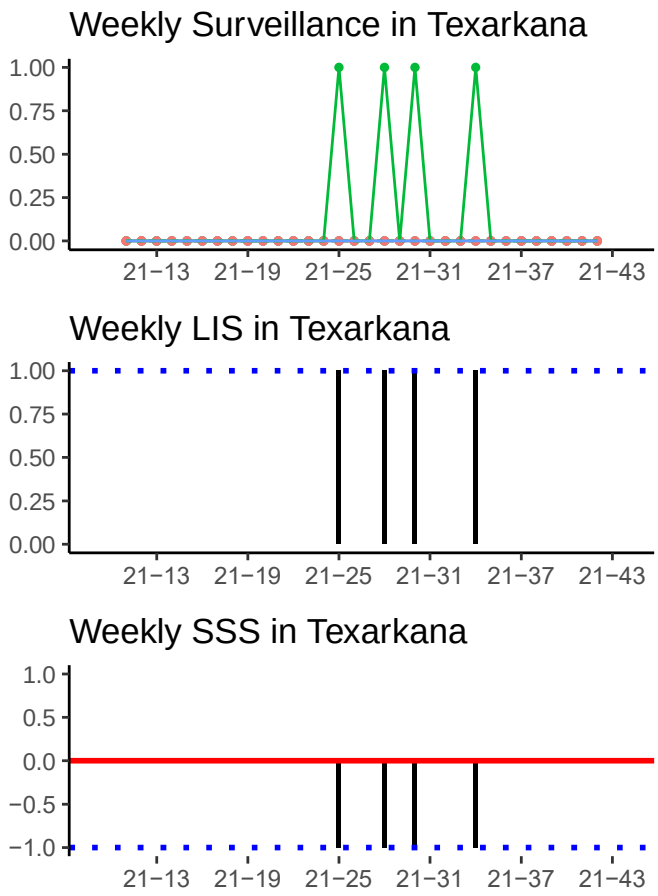
122



123

124 **Supplementary Figure 21. The epidemic trend in Sherman**

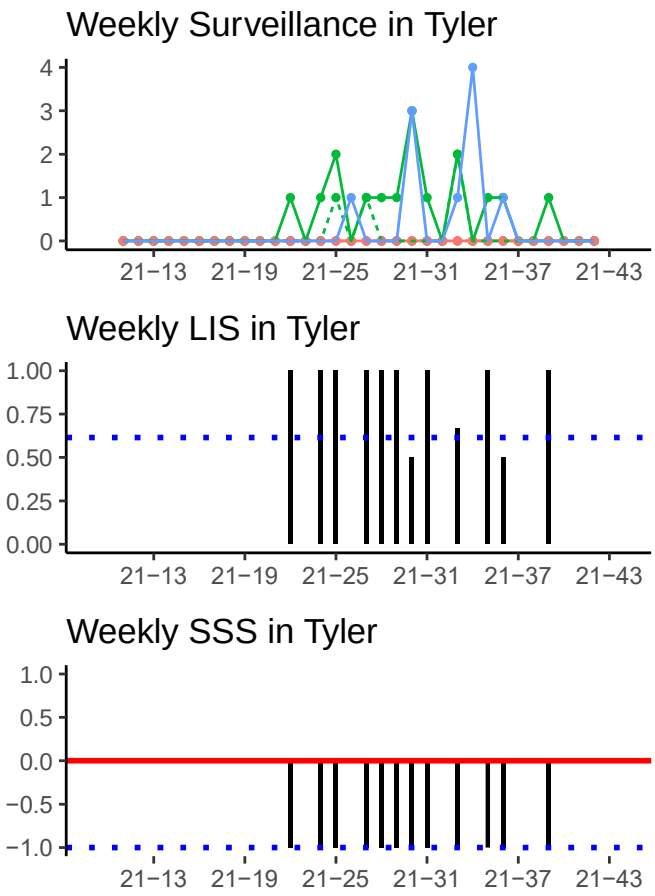
125



126

127 **Supplementary Figure 22. The epidemic trend in Texarkana**

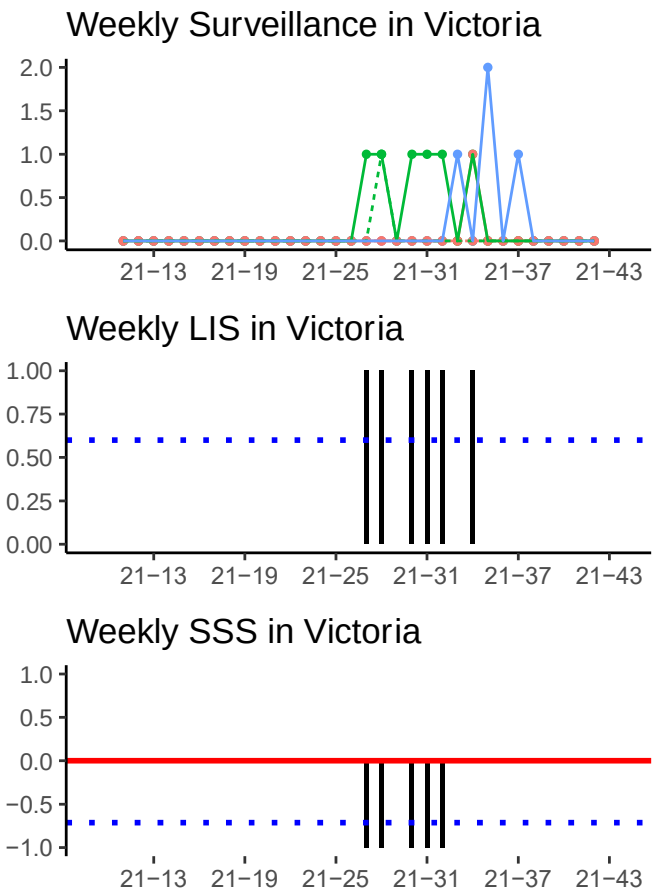
128



129

130 **Supplementary Figure 23. The epidemic trend in Tyler**

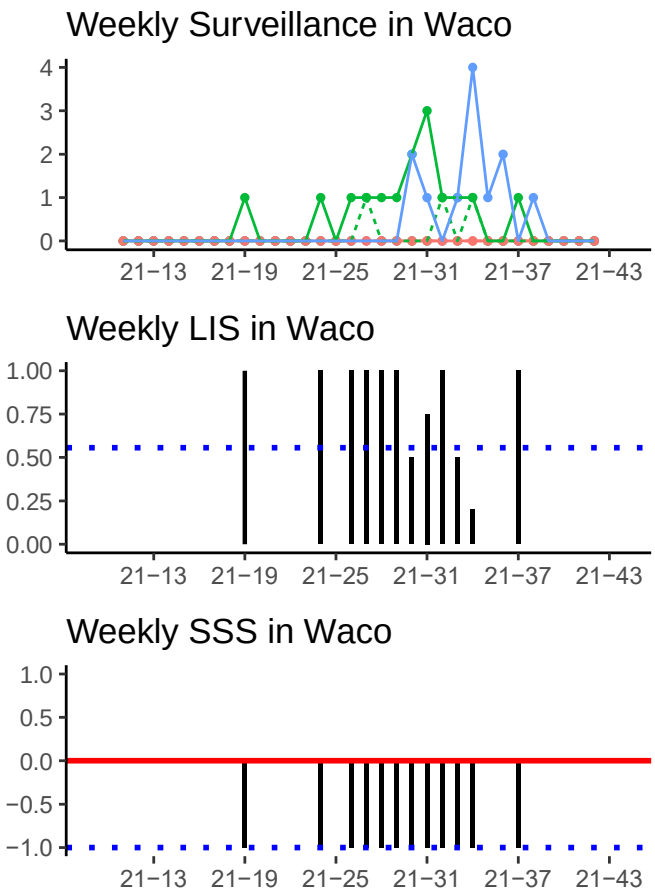
131



132

133 **Supplementary Figure 24. The epidemic trend in Victoria**

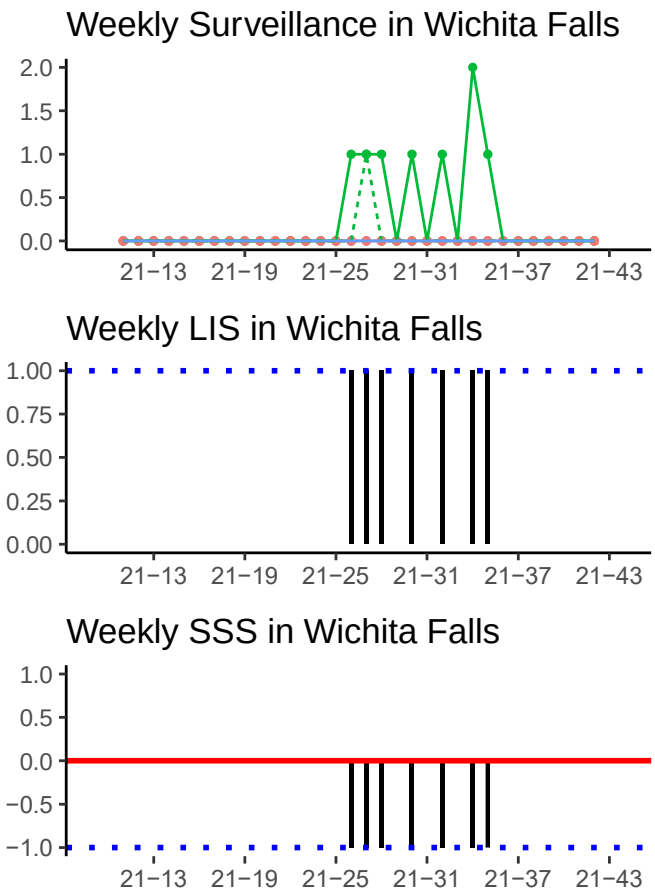
134



135

136 **Supplementary Figure 25. The epidemic trend in Waco**

137



Supplementary Figure 26. The epidemic trend in Wichita Falls

Supplementary Table 4. Centrality analysis of metropolitan areas in Texas

Metro areas	Betweenness	Closeness	Degree
Dallas-Fort Worth	79.417	0.042	24
Houston	59.000	0.038	22
San Antonio	51.417	0.037	21
Austin	12.800	0.029	13
McAllen	3.200	0.026	9
Midland	1.200	0.024	7
Bryan-College Station	1.000	0.024	6
Odessa	0.667	0.023	5
Corpus Christi	0.600	0.024	7
San Angelo	0.500	0.023	5
Brownsville	0.500	0.024	6
Lubbock	0.250	0.023	5
Abilene	0.250	0.023	5
Waco	0.200	0.023	4
Texarkana	0.000	0.022	3
Wichita Falls	0.000	0.022	3
Victoria	0.000	0.022	4
Tyler	0.000	0.022	4
Sherman	0.000	0.022	3
El Paso	0.000	0.023	4
Killeen	0.000	0.022	4
Amarillo	0.000	0.022	4
Laredo	0.000	0.022	4
Beaumont-Port Arthur	0.000	0.022	3
Longview	0.000	0.022	3

Supplementary Table 5. Source Sink Score and Local Import Score

Metro areas	RUCC	SSS	LIS
Dallas-Fort Worth	1	0.092	0.163
Houston	1	0.063	0.176
San Antonio	1	0.000	0.214
Austin	1	-0.444	0.343
Lubbock	2	-0.556	0.500
McAllen	2	-0.581	0.370
Odessa	3	-0.600	0.471
Victoria	3	-0.714	0.600
Sherman	3	-0.750	0.500
Bryan-College Station	2	-0.750	0.519
Amarillo	2	-0.778	0.276
Brownsville	2	-0.800	0.574
Corpus Christi	2	-0.814	0.639
Longview	3	-0.833	0.647
Beaumont-Port Arthur	2	-0.862	0.563
Midland	3	-0.875	1.000
El Paso	2	-0.882	0.696
Killeen	2	-0.920	0.600
Wichita Falls	3	-1.000	1.000
Waco	2	-1.000	0.556
Tyler	3	-1.000	0.615
Texarkana	3	-1.000	1.000
San Angelo	3	-1.000	1.000
Laredo	2	-1.000	0.538
Abilene	3	-1.000	0.857
rural	4-8	-0.717	0.558

Sensitivity Analysis

Supplementary Table 6 provides a detailed summary of the sensitivity analysis across all 10 replicates, which assess the robustness of the Source Sink Score and Local Import Score estimates.

Supplementary Table 6. Sensitivity analysis

	Houston	Dallas-Fort Worth	San Antonio	Austin	McAllen	Odessa	rural	Corpus Christi	Amarillo	Longview	Lubbock	Beaumont-Port Arthur	Brownsville	Bryan-College Station	Midland	Killeen	Waco	Sherman	San Angelo	Wichita Falls	Tyler	Texarkana	Laredo	El Paso	Victoria	Abilene
SSS																										
REP_0	0.190	0.084	-0.325	-0.458	-0.375	-0.500	-0.624	-0.610	-0.846	-0.818	-0.889	-0.867	-0.813	-0.917	-1.000	-0.933	-0.750	-1.000	-1.000	-1.000	-0.733	-0.667	-1.000	-1.000	-1.000	-0.750
REP_1	0.092	0.073	-0.071	-0.390	-0.464	-0.800	-0.621	-0.636	-0.400	-0.875	-0.556	-0.800	-0.615	-0.923	-0.500	-0.871	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
REP_2	0.118	0.150	-0.100	-0.449	-0.440	-0.200	-0.727	-0.800	-0.455	-1.000	-1.000	-0.765	-0.935	-0.800	-1.000	-0.852	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-0.833	-1.000	-1.000	-1.000
REP_3	0.087	0.115	-0.081	-0.516	-0.333	-0.667	-0.619	-0.581	-0.778	-0.714	-1.000	-0.813	-0.742	-0.800	-1.000	-1.000	-0.895	-0.778	-1.000	-1.000	-1.000	-1.000	-1.000	-0.909	-1.000	-1.000
REP_4	0.158	0.049	-0.015	-0.513	-0.659	-0.500	-0.735	-0.750	-0.143	-0.571	-0.750	-0.935	-0.926	-0.818	-0.867	-0.778	-0.818	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
REP_5	0.077	0.127	-0.135	-0.351	-0.302	-0.500	-0.673	-0.739	-0.833	-0.818	-0.545	-0.867	-1.000	-0.481	-0.846	-0.947	-0.909	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
REP_6	0.063	0.092	0.000	-0.444	-0.581	-0.600	-0.717	-0.814	-0.778	-0.833	-0.556	-0.862	-0.800	-0.750	-0.875	-0.920	-1.000	-0.750	-1.000	-1.000	-1.000	-1.000	-1.000	-0.882	-0.714	-1.000
REP_7	0.146	0.083	-0.198	-0.466	-0.583	-0.500	-0.617	-0.733	-0.714	-0.692	-0.905	-0.771	-0.667	-0.909	-0.571	-0.933	-0.778	-0.818	-0.333	-1.000	-1.000	-1.000	-0.857	-1.000	-1.000	-1.000
REP_8	0.127	0.108	0.054	-0.440	-0.882	-1.000	-0.573	-0.551	-0.800	-0.714	-1.000	-0.784	-0.813	-0.909	-1.000	-0.867	-0.810	-1.000	-1.000	-0.778	-0.714	-1.000	-1.000	-1.000	-1.000	-1.000
REP_9	0.174	0.152	-0.208	-0.583	-0.633	-0.333	-0.554	-0.321	-0.833	-0.692	-0.739	-0.688	-0.889	-0.895	-1.000	-0.733	-1.000	-0.778	-1.000	-0.600	-1.000	-1.000	-1.000	-0.917	-1.000	-1.000
LIS																										
REP_0	0.153	0.157	0.275	0.385	0.367	0.529	0.515	0.440	0.444	0.588	0.810	0.528	0.644	0.719	0.750	0.592	0.600	0.667	0.800	0.889	0.591	0.625	0.769	0.846	0.625	1.000
REP_1	0.165	0.160	0.220	0.353	0.466	0.600	0.538	0.450	0.200	0.833	0.636	0.443	0.583	0.714	0.545	0.690	0.739	1.000	1.000	0.909	0.636	0.571	0.722	0.696	1.000	0.571
REP_2	0.171	0.153	0.214	0.353	0.375	0.500	0.518	0.529	0.276	0.938	0.826	0.566	0.732	0.563	0.929	0.735	0.846	0.800	1.000	1.000	0.625	1.000	0.647	0.950	0.889	0.700
REP_3	0.178	0.157	0.213	0.370	0.350	0.588	0.549	0.386	0.235	0.706	0.724	0.518	0.628	0.486	0.909	0.718	0.621	0.615	0.667	0.889	0.652	0.571	0.833	0.875	0.571	1.000
REP_4	0.156	0.169	0.205	0.401	0.405	0.750	0.545	0.500	0.286	0.550	0.560	0.625	0.650	0.645	0.667	0.727	0.645	0.583	1.000	1.000	0.619	0.750	0.818	0.870	0.714	0.889
REP_5	0.171	0.154	0.238	0.356	0.326	0.462	0.549	0.460	0.524	0.526	0.630	0.459	0.600	0.606	0.923	0.902	0.700	0.889	1.000	0.833	0.619	1.000	0.615	0.778	1.000	0.750
REP_6	0.176	0.163	0.214	0.343	0.370	0.471	0.558	0.639	0.276	0.647	0.500	0.563	0.574	0.519	1.000	0.600	0.556	0.500	1.000	1.000	0.615	1.000	0.538	0.696	0.600	0.857
REP_7	0.173	0.155	0.245	0.386	0.481	0.529	0.543	0.582	0.429	0.550	0.769	0.564	0.595	0.656	0.611	0.707	0.640	0.769	0.400	0.909	0.600	1.000	0.619	0.714	0.800	0.667
REP_8	0.156	0.151	0.183	0.359	0.571	0.909	0.445	0.481	0.391	0.632	0.789	0.569	0.644	0.724	0.833	0.737	0.792	0.733	1.000	0.727	0.600	0.800	0.688	0.759	0.833	0.750
REP_9	0.152	0.142	0.245	0.397	0.494	0.471	0.519	0.455	0.314	0.647	0.690	0.529	0.654	0.545	0.929	0.650	0.875	0.727	0.500	0.400	0.667	1.000	0.692	0.793	0.800	0.800

154