Maryland Congressional District Memo

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Introduction

Following the 2020 Census, Marlyand has been apportioned 8 Congressional seats for elections held through 2030. We have been asked to use an automated redistricting algorithm to generate several ensembles– that is, large sets of valid Congressional redistricting plans– that observe various criteria.

Specifically, we have been asked to consider several parameters: municipal and county splits, the compactness of districts, and the question of whether of not to allow districts that span the Chesapeake Bay.

First, we have been asked to develop an ensemble of redistricting plans that ignore municipal boundaries but intentionally minimize county splits. We were able to generate a large number of plans that only split between 3 and 7 counties. We ask several questions about these plans. What is the range of compactness scores exhibited by these county-split-minimizing plans? What is the most compact plan among these? What is the range of municipality splits exhibited by these plans? What is the plan that exhibits the smallest number of municipal splits? Does there appear to be a trade-off between compactness and municipal splits?

We conduct this set of county-split-minimizing exercises twice– each time under two very different conditions. First, we generate ensembles in which districts are allowed to span the Chesapeake Bay. Second, we generate ensembles, with 10,000 plans each, in which the entire East Shore is forced to remain whole.

Next, we switch from an approach that minimizes county splits to one that minimizes municipal splits. We generate 10,000 redistricting plans that attempt to minimize municipal splits, which keeps municipality splits between 3 and 20.[1] For these plans also, we consider ensembles with and without constraints regarding the East Shore.

[1] This is inflated due to non-contiguous municipalities.

Our main goals are 1) to provide the Commission with an understanding of possibilities and trade-offs associated with the development of a Maryland Congressional plan, and 2) to provide some sample maps with compact districts that minimize jurisdictional splits.

Preview of Results

Due to Maryland's shape and its political geography, at the scale of Congressional districts, we do not find evidence of large trade-offs on the dimensions we were asked to consider.

There is no trade-off between split minimization and compactness. On the contrary, the plans with the fewest splits are also the most compact. Likewise, as one might anticipate, there is no trade-off between efforts to minimize county spits and efforts to minimize municipal splits. It is straightforward to achieve very few splits of either. However, we emphasize that our conclusions might be different when we focus on state legislative districts. It is also easy to draw plans with very few splits whether one allows districts to cross the Chesapeake Bay or not.

Data

For population counts, we use the adjusted Maryland Census data. This data takes Census counts and reassigns individuals counted in correctional institutions within the state. Individuals from within the state are reassigned to their last known address. Individuals from out of state are removed from the count. This results in a lower total population count than the official Census count to comply with Maryland state law.

To build districts, we use the Census voting tabulation districts (VTDs) as the basic geographic unit. VTDs are created as part of the Redistricting Data Program. VTDs are analogous to state precinct shapes and are made of Census blocks, which allow for accurate population counts of those who reside within a VTD.

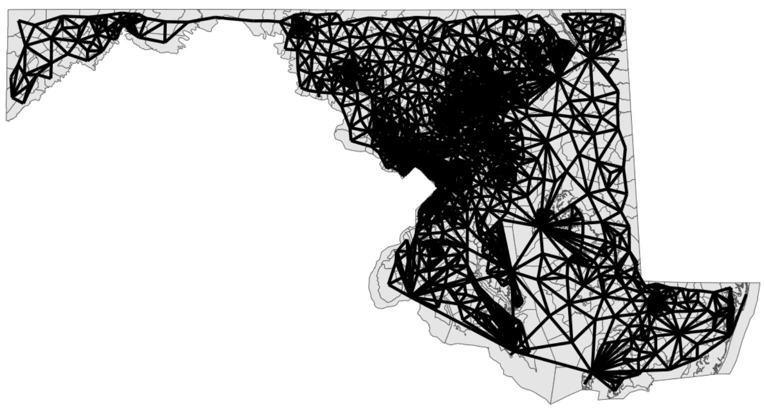
How do we Simulate Plans?

The number of valid, equal-population plans with districts that are contiguous and relatively compact is extremely large. Our goal is to draw a diverse representative sample from that distribution of potential redistricting plans. From that sample, we can learn some things about specific trade-offs associated with the task of dividing Maryland's geography into eight districts, and we can extract some plans that are especially attractive on various criteria for further study.

We want to make sure to sample a distribution of plans that have equal population, and where the districts are relatively compact. Moreover, we would like to introduce additional constraints related to county and municipal boundaries. Each of these tasks is handled very well by the Sequential Monte Carlo Algorithm introduced by

[McCartan and Imai, 2020].

At the heart of our analysis is what is called an "adjacency graph," depicted below. For each VTD in Maryland, we ascertain the full set of other VTDs with which it shares at least some part of its border, and therefore might be joined in the construction of a district.



The key task in making a redistricting plan is to make splits in the adjacency graph. The algorithm samples redistricting plans by sequentially implementing a splitting procedure. The algorithm begins by partitioning the adjacency graph into two. One of the chunks is the first of what will eventually be 8 districts, and the remainder is the rest of the graph. Next, this splitting procedure is repeated on the remaining chunk, forming the second district, and so on, until all 8 districts are created.

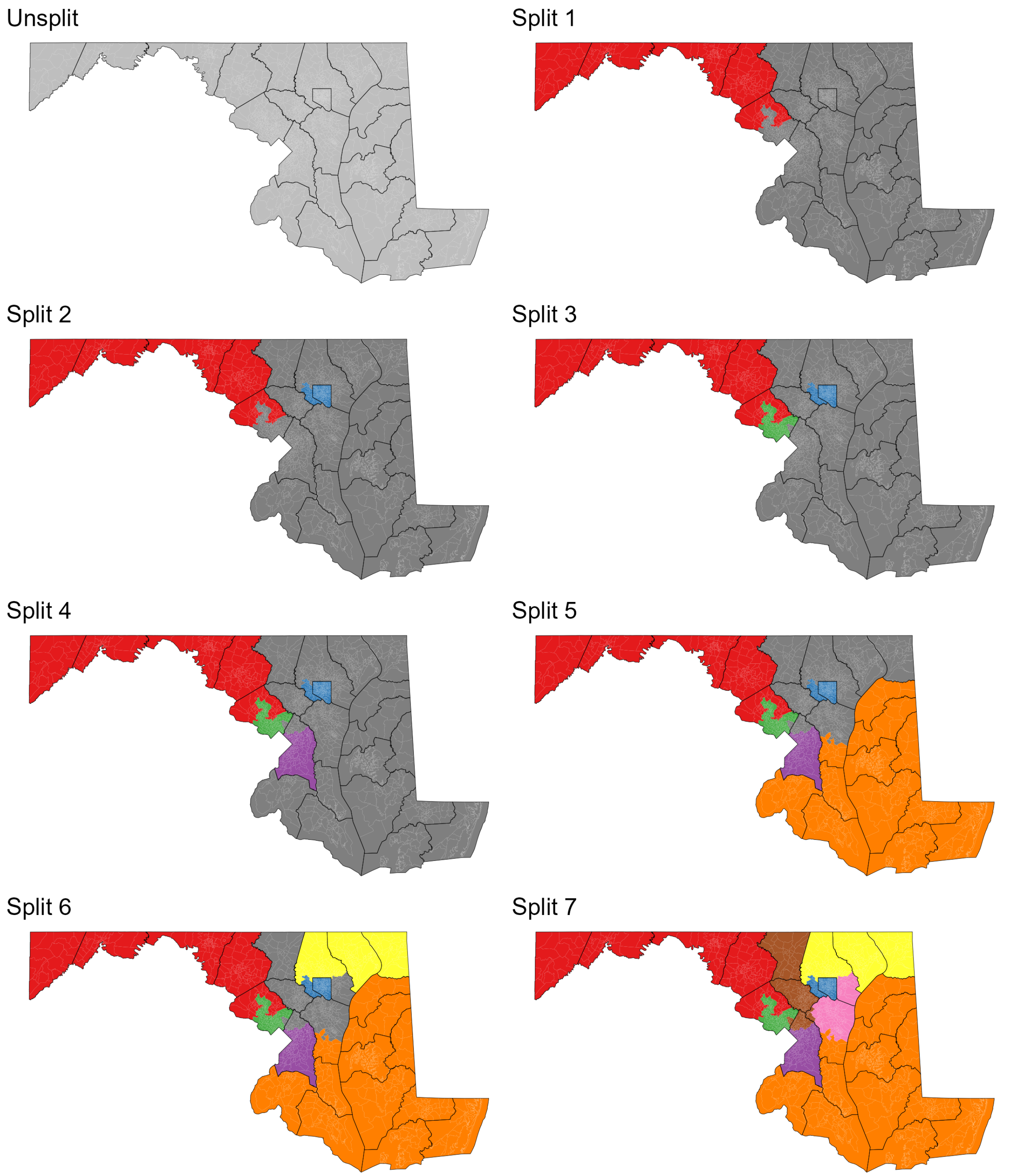
At each iteration, the algorithm samples many candidate partitions which meet the population constraint, and then resamples a certain number of these partitions, but doing so in a way that is guided by a set of weights.[2] We build in a preference for sampling relatively compact districts by favoring plans that make fewer cuts in the adjacency graph. Intuitively, a plan that makes a larger number of cuts in the adjacency graph will have long internal boundaries, driving up the average district perimeter. In contrast, plans that make the smallest possible number of cuts will have relatively short internal boundaries, and produce relatively compact districts. If it would be of interest to the commission, we can experiment in the future with this parameter, but in this report, we present plans with a preference for compact districts. Additionally, we build a preference for fewer county or municipal splits directly into the sampling algorithm, such that splits

[2] These weights help ensure that the final set of simulated plans are representative of the set of feasible plans.

along county or municipal lines are favored over other types of splits.

For drawing Congressional districts, a single iteration of the algorithm splits a map seven times, creating 8 contiguous districts. The following figure illustrates the process for drawing a single plan.

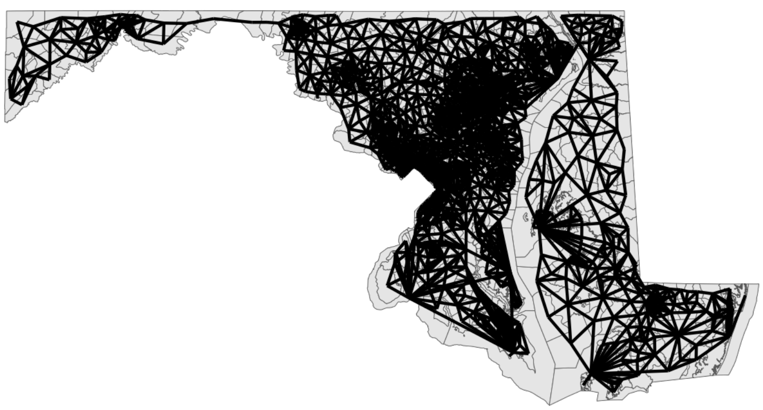
We simply repeat this procedure thousands of times, building in a preference either for minimizing municipal or county splits, and either allowing districts to cross the Chesapeake or not.


Unsplit
Split 1
Split 2
Split 3
Split 4
Split 5
Split 6
Split 7

Considering Adjacencies: Chesapeake Bay

Dealing with the Chesapeake Bay requires a careful decision: Can districts cross the Bay or not? We have been asked to sample a set of plans that allow for this, and another that prevents it. Note that in the adjacency graph displayed above, there are lines running across the Chesapeake, so that some VTDs on the East Shore are considered to be adjacent to a set of VTDs across the Chesapeake.

In order to prevent the algorithm from sampling plans that cross the Chesapeake, we simply alter the adjacency graph. In the graph below, the VTDs on opposite sides of the Chesapeake are no longer considered to be adjacent.



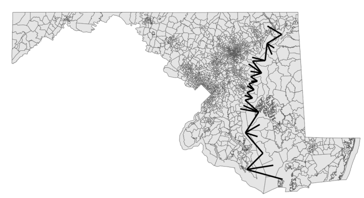


Figure 1: Edges removed from the adjacency graph to disconnect VTDs across Chesapeake Bay.

Trade Offs

It is possible to draw valid Maryland Congressional plans with very few county or municipal splits. In the ensembles that attempted to minimize county splits, the lowest number of splits was three. And among the plans with only three county splits, a number of plans emerged with only five municipal splits.

In the ensembles that attempted to minimize municipal splits, the lowest number of splits was also three. And among the plans with only three municipal splits, we were able to identify a number of plans with as few as five county splits.

In some settings, when municipalities or counties have odd shapes and districts are relatively small relative to the size of these administrative units, a requirement to minimize jurisdiction-splitting can lead to odd-shaped, non-compact districts. This is not the case here.

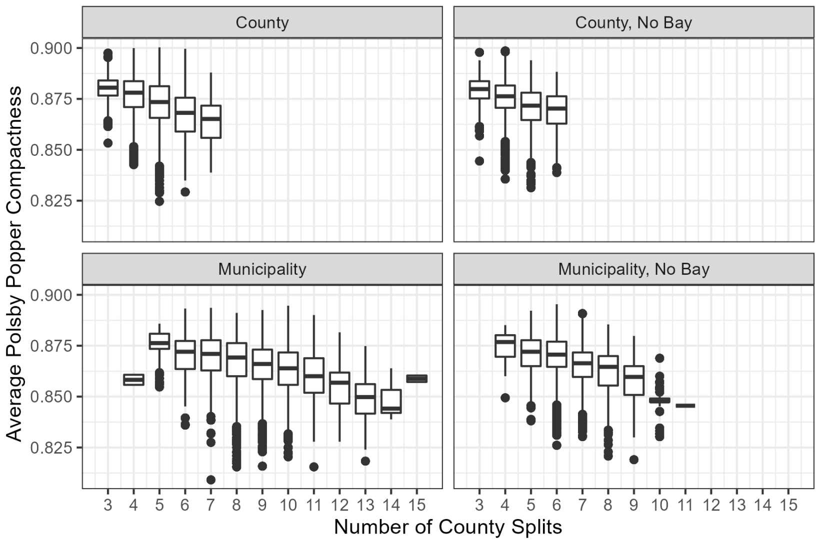
In the graph below, on the horizontal axis is the number of county splits, and on the vertical axis is the average Polsby-Popper score– a compactness measure for which higher numbers are associated with higher levels of compactness.

Polsby Popper scores are measured district by district, as

$$\frac{4\pi A}{P^2}$$

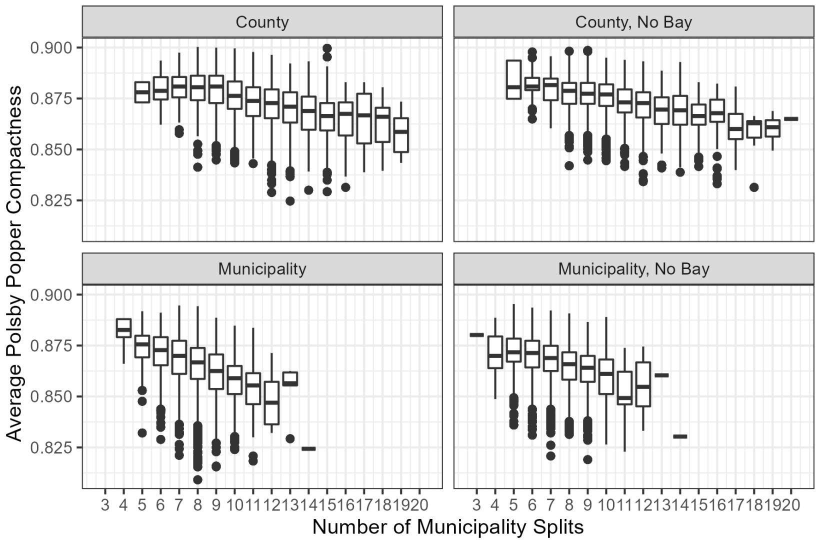
where A is the area of a district and P is the perimeter of a district.

Each of the four graphs corresponds to our four ensembles: the one on the upper left minimizes county splits without any constraints regarding the Chesapeake, and the graph on the upper right does so without allowing districts to cross the Bay. The lower graphs are for the ensembles that minimize municipal splits, again with and without constraints regarding the Chesapeake.

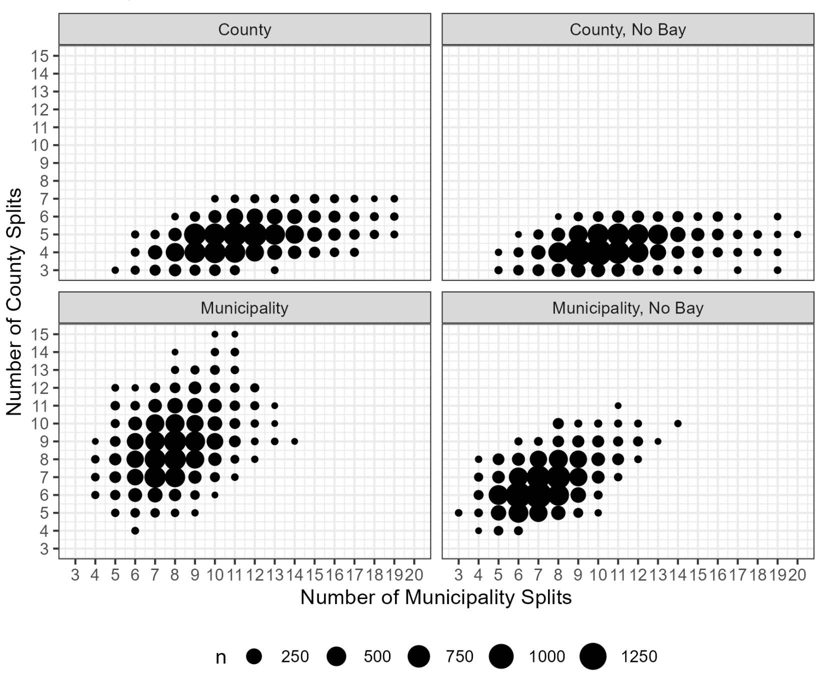


In these box plots, the horizontal line in the middle of each box is the median, and the outer edges of the box represent the range from the 25th to the 75th percentile. The individual dots represent some plans that are outliers relative to the rest of the distribution. The basic lesson is that no matter which set of simulations we look at, the most compact plans are those with the fewest county splits. In the world of U.S. redistricting, Polsby-Popper scores above .85 can be considered to be extremely compact. The algorithm identified a number of very compact plans with only three county splits.

Similarly, we can compare the relationship between municipality splits and compactness. The story is very similar. The algorithm is able to identify a relatively large number of very compact plans with only four municipal splits, and in the ensemble that prevents districts from crossing the Chesapeake, it finds one plan (displayed below) with only three.



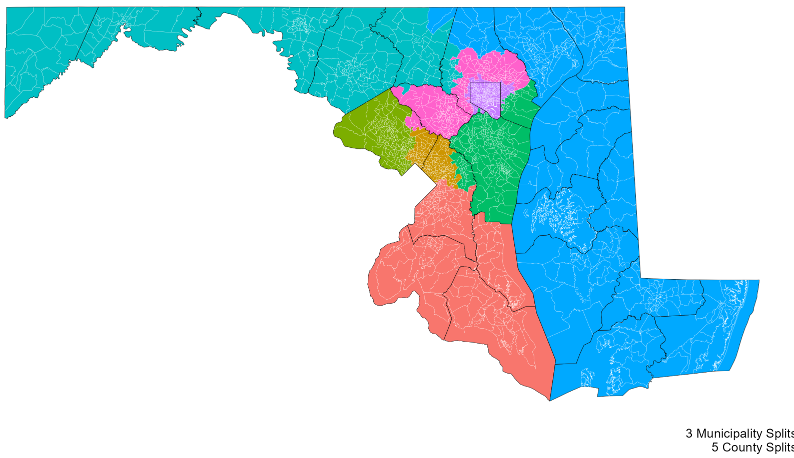
Next, we examine whether there is any trade-off between the minimization of county and municipal splits. Below, for each of our ensembles, we plot the relationship between the number of county splits and the number of municipal splits. The size of the data marker corresponds to the number of plans that emerged with a specific set of characteristics. There is a positive relationship, such that plans splitting relatively few counties also split relatively few municipalities, and there are many plans that split rather few of either.



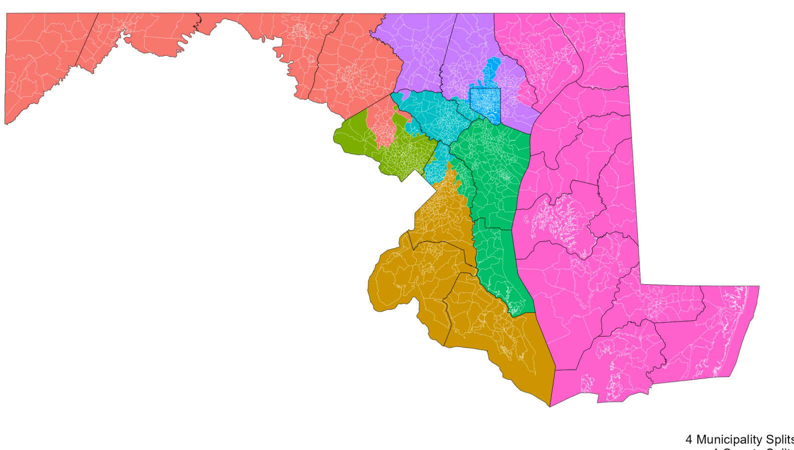
Selected Maps

Next, let us examine some of the maps sampled by the algorithm.

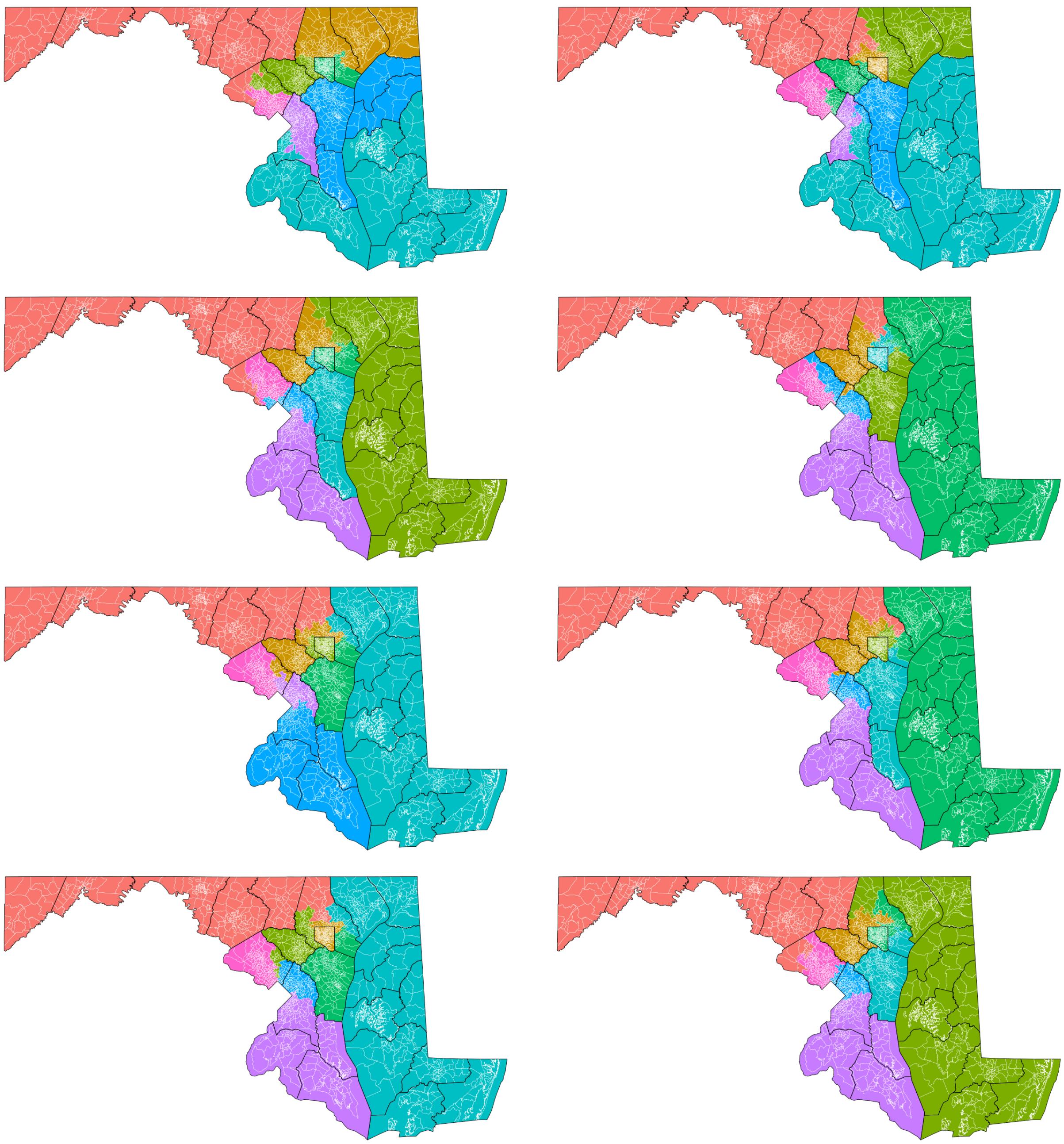
First, we select a map from our ensemble that minimizes municipal splits. There is a single map that only splits three municipalities. It emerged from our ensemble that avoided crossing the Chesapeake. This map only splits five counties.



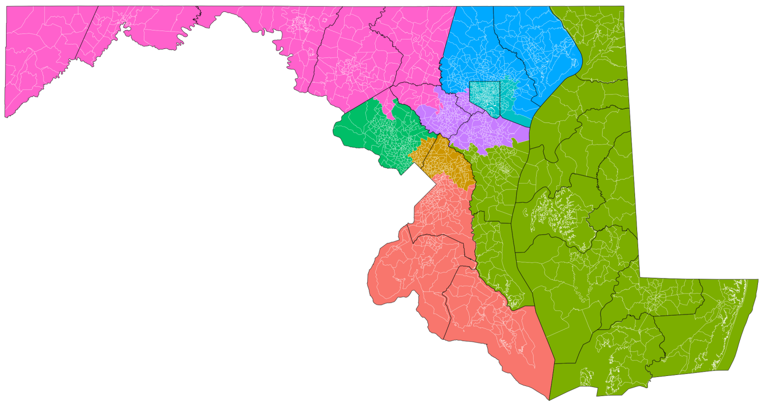
Next, let us examine the larger set of maps that split four municipalities, and from this set, limit our attention to those with the smallest number of county splits, which have 4 split counties. From this subset, there is only one sampled map.



Next, let us start with our ensemble that minimized county splits by producing only three. There are eight maps from this subset of the ensemble that have only five municipal splits. We include these in the following figure.

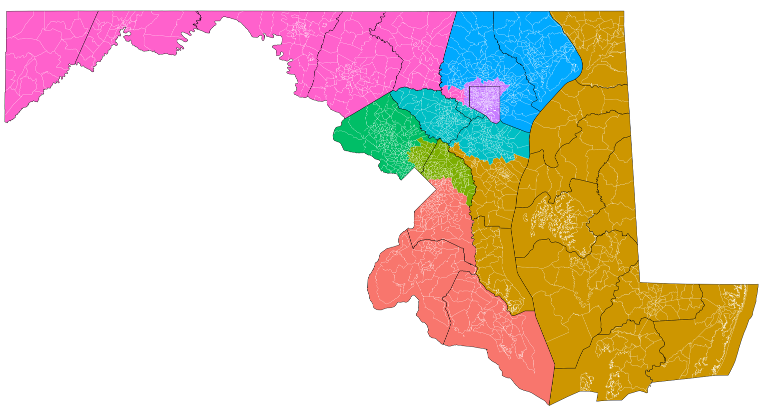


Finally, instead of starting with constraints driven by numbers of splits, let us simply extract from all of our ensembles the map with the highest average Polsby-Popper score. This map has 8 municipality splits and 5 county splits.



8 Municipality Splits
5 County Splits

Next, we include a demonstration map has a Polsby-Popper score that is only slightly lower, with 9 municipality splits and only 4 county splits.



9 Municipality Splits
4 County Splits

Future Work

We are happy to present additional maps from these ensembles, or to produce additional ensembles that would be of interest to the Commission. We also anticipate responding to specific ideas about how to conceptualize the requirements of the Voting Rights Act in Maryland, and to sampling maps for Maryland House and Senate districts.

References

Cory McCartan and Kosuke Imai. Sequential Monte Carlo for sampling balanced and compact redistricting plans. *arXiv preprint arXiv:2008.06131*, 2020.