A large partnership systematically collected long-term water quality data from the Upper Mississippi River System, USA, for over 25 years. The river is thought to occur in multiple 'ecological states', which are recurring bundles of chemical and biological conditions. Identifying ecological states and the driving ecological variables that define the states would improve understanding of river status and help prioritize large restoration projects. We use new mathematical tools like topological data analysis (TDA) because of the complexity due to the large size (80,000+ sample sites) and high dimensionality of the data. We employed TDA Mapper, an algorithm that casts high dimensional data into lower dimensions, at a system scale (1200 km) and pool scale (80 km; La Grange Pool in Illinois) to determine ecological states and variables at different spatial scales. We found that the Upper Mississippi River System is dominated by three ecological states, which vary in turbidity and total suspended solids (measures of water clarity). La Grange, on the other hand, is dominated by a single ecological state and characterized by high turbidity and total suspended solids. Ultimately, topological data analysis can offer new insights into complex ecologies.