Analysis of Common Water Quality Parameters and Analytical Methods Using the RESTORE Council's Monitoring and Assessment Program (CMAP) Inventory

Prepared by:
Consolidated Safety Services, Inc.

Authors:
Jacob Howell, Sarah Hile, Christiana Kumar, PhD, Bethany Pertain, Asmita Shukla, PhD, and Christopher F.G. Jeffrey, PhD

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For more information on the Gulf Coast Ecosystem Restoration Council, please visit:
https://restorethegulf.gov/

For more information on the RESTORE Council's Monitoring and Assessment Program (CMAP), please visit:
https://coastalscience.noaa.gov/project/restore-council-monitoring-and-assessment-program-building-a-comprehensive-monitoring-network/

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Or direct questions and comments to:

Jacob Howell
jhowell@css-inc.com

1. Introduction

The Gulf Coast Ecosystem Restoration Council (RESTORE Council) Monitoring and Assessment Program (CMAP) established a Gulf of America-wide (hereafter referred to as 'Gulf'), comprehensive, and georeferenced inventory of water quality, habitat monitoring, and mapping programs (hereafter referred to as 'Inventory') which was completed in 2019 (NOAA and USGS, 2019a). That project, administered by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS), was designed to support the Council's commitment to make science-based decisions, evaluate restoration effectiveness (incorporate lessons learned into management as needed), and meet its reporting obligations by improving the discoverability and accessibility of existing monitoring data. The Inventory was subsequently updated in 2021 (Howell et al., 2021) and expanded to include living marine resource monitoring programs in 2024 (NOAA, 2024). In addition to the Inventory, the first phase of CMAP produced a catalog of baseline assessments, evaluated monitoring program elements and methodologies, and conducted a gap assessment examining informational, temporal, and spatial monitoring gaps. All of these products are accessible online (https://coastalscience.noaa.gov/project/restore-council-monitoring-and-assessment-program-building-a-comprehensive-monitoring-network/; NOAA and USGS, 2019a; 2019b; 2020a; 2020b; 2021).

As evidenced by the CMAP project, there is a wide diversity of monitoring efforts being conducted throughout the Gulf, often with program-specific intricacies that can complicate synthesizing or comparing the data generated. The Gulf of America Alliance (hereafter referred to as 'Alliance') has been working to establish a Gulf-wide monitoring network with the goal of making water quality data from across the Gulf more accessible and comparable. As part of this effort, the Alliance commissioned a pilot study after the first phase of the CMAP project aimed at demonstrating the application of the Inventory and other CMAP products to inform water quality and habitat assessment projects. The pilot study focused on three water quality parameters (total nitrogen, total phosphorus, and chlorophyll) and included an in-depth examination of monitoring data and methodologies discoverable via the Inventory at both a Gulf-wide and watershed scale (Howell et al., 2022).

The core goal of the current study was to build upon the pilot study originally completed in 2021 by assisting in the creation of a Gulf Monitoring Network Forum and conducting an in-depth analysis of the analytical methods utilized by monitoring programs across the Gulf to generate water quality data. Instead of just three focal parameters, however, analytical methods were examined for each of the 38 water quality parameters included in the CMAP Inventory.

2. Approach

Gulf Monitoring Network Forum

Before any monitoring programs or analytical methods were examined, it was crucial for this project to establish a Gulf Monitoring Network Forum consisting of Alliance stakeholders and Priority Issue Team members, monitoring program points of contact, and water quality experts from across the Gulf. The purpose of this Forum was to guide the project team, identify monitoring needs/goals, provide feedback on the data collection process, and to be a starting point for the creation of a larger Gulf Monitoring Network. The initial group of Forum members were first identified from those who had previously participated in the Community of Practice developed during the first phase of the CMAP project as well as others thought to be interested in joining. This group met for the first time at the Gulf of Mexico Conference on February 19, 2024 to discuss the proposed plan for the project, initial guidance on the approach, and the identification of additional people to reach out to to join the Forum.

After the kick-off meeting at the Gulf of Mexico Conference, additional Forum webinars were held every other month to discuss project progress, solicit feedback, and pose any questions that had come up during data collection to the group. Throughout these meetings and as awareness of the project increased, additional members of the Forum were added. In total, four Gulf Network Forum webinars were held, along with additional presentations to the Alliance's Data and Monitoring Priority Issue Team mid-year meeting, the Alliance's Seagrass Working Group, and the Pensacola and Perdido Bays Estuary Program Technical Committee. The Monitoring Network Forum members were also given the opportunity to review draft versions of the final products of this project during a month-long review period. Final presentations were given at the Alliance's All Hands meeting in May 2025 focused solely on the results of the project and planning future work.

Analytical Method Examination

During the first phase of the CMAP project, monitoring protocol documents detailing the collection and/or analytical methods programs used to generate data were collected into an internal library. These documents were collected either from monitoring program points of contact or via program websites. Using custom scripts, these monitoring protocol documents were searched for keywords related to the 38 water quality parameters (Table 1) and passages of text were extracted to allow for more efficient identification of analytical methods used by each monitoring program. The CMAP Inventory denotes which of the water quality parameters each program monitors, and attempts were made to identify and compile which analytical methods were used for each of the relevant parameters into an analytical method catalog spreadsheet (Appendix A). In cases where the protocol documents were unable to be searched by the scripts or the scripts did not yield useful results, manual searches of the documents were conducted. For any monitoring programs that did not already have collected protocol documents, attempts were made to locate and examine such documents in order to identify analytical methods. Similarly, when protocol documents contained analytical methods for some, but not all, of a monitoring program's water quality parameters, attempts were made to locate alternate sources of information. In cases where an analytical method for a particular parameter was unable to be identified, "no method" was input into the catalog for the focal monitoring program.

Table 1. Water quality parameters included in the CMAP Inventory

Water Quality Parameters		
• Total nitrogen • Nitrate • Nitrite • Nitrite + Nitrate • Ammonia • Ammonia + organic nitrogen • Total phosphorus • Soluble phosphorus • Phosphate • Orthophosphate • Silicate	• Cyanobacteria • Algal toxins • *Escherichia coli* • *Enterococcus* • Total coliforms • Fecal coliforms • *Giardia* • *Cryptosporidium* • *Vibrio* • Suspended sediment concentration • Total suspended solids	• Conductance (salinity) • Water temperature • Dissolved oxygen • Turbidity • pH • Currents • Water level • Light attenuation • Organic carbon • Polycyclic aromatic hydrocarbons • Phytoplankton • Chlorophyll

Once all analytical methods were identified and cataloged, crosswalk tables were created for each water quality parameter (Appendix B). The fields contained within the crosswalk tables are defined in Table 2. Each analytical method identified in the catalog was listed in the crosswalk table for the appropriate parameter. In order to populate the crosswalk table fields, the original analytical method documentation was examined (for example, the text of U.S. Environmental Protection Agency (US EPA) Method 353.2 was reviewed for nitrate). Some monitoring program protocol documents only identified the types of instrumentation used to generate data (e.g., YSI probes for many field parameters). In these cases, the instrumentation identified from the protocol documents was included in the "General Analytical Method (Instrumentation)" field. Attempts were also made to identify specific analytical methods that these instruments adhere to (e.g. EPA Method 360.1 for YSI 6 series sondes measuring dissolved oxygen) via the product manuals or other documentation associated with the instruments. If found, this analytical method information was added to the "Analytical Method" field.

Table 2. Fields and definitions included in the method crosswalk tables in Appendix B.

Field Name	**Definition**
PID	List of unique identifiers from the CMAP Inventory denoting which monitoring programs utilize the analytical method
Analytical Method	The name of the method by which the sample is being analyzed
Number of CMAP Programs	The total number of monitoring programs utilizing the analytical method
General Analytical Method (Instrumentation)	A general summary of the analytical method or noted instrumentation used
Collection Method	The method by which the sample being measured is collected
Field or Lab Method	Field indicating if the analytical method is field or laboratory based

Units	The units in which the program reports data for this parameter
Applicable Concentration Range	The range of concentrations over which analytes can be measured with typical use of the method (NEMI, 2022)
Detection Limit	Field noting the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016a)
Sample Fraction (Filtration status)	Field indicating if the sample was filtered prior to analysis or not
Chemical Form	The chemical form of the parameter measured by the analytical method
Notes	Field containing notes related to the analytical method that do not correspond to the other fields in the crosswalk
URL	Field containing URLs to the original analytical documentation

After the crosswalk tables were populated, the information was used to draft a data dictionary document aimed at providing general information about each water quality parameter and the common analytical methods utilized across the Gulf (Appendix C). The glossary originally published with the first phase of the CMAP project (NOAA and USGS, 2019a) was built upon for this data dictionary. The most commonly identified analytical methods, units, applicable concentration limits, and the number of programs noted as using the method were added to each parameter's definition.

In addition to the data dictionary, the information compiled into the analytical method catalog and crosswalk tables were used to generate spatial representations of how many monitoring programs measure each water quality parameter, how many monitoring programs utilize each identified analytical method, where each analytical method is used across the Gulf, and where monitoring data is most accessible (Appendix D). The spatial footprints of monitoring programs produced during the first phase of the CMAP project was linked to the analytical method and data accessibility information and, following the framework outlined in NOAA and USGS (2020b), a 500 km^2 hexagon grid was chosen as the spatial unit of analysis for aggregation and visualization of the data. Stock polygons representing the parts of each of the Gulf states contained within the CMAP area of interest were used to denote which states each hexagon from the grid intersected so that state method counts could be obtained.

3. Summary of Results

Analytical Method Catalog

Every analytical method identified for all the parameters monitored by each water quality monitoring program were compiled into the analytical method catalog spreadsheet. On average, the 359 water quality monitoring programs from the CMAP Inventory measured nine parameters with a range of one to 26 parameters. Two of the water quality parameters, *Giardia* and *Cryptosporidium*, were not measured by any of the monitoring programs in the Inventory. Across the water quality parameters, an average of 21 unique analytical methods were identified (Figure 1) with dissolved oxygen having the most (67 analytical methods) and suspended sediment concentration having the fewest (three analytical methods). In some instances, the only information available for a given parameter was the instrumentation used. For example, only instrumentation was found for light attenuation rather than official analytical methodology. Conversely, the ammonia + organic nitrogen parameter had official analytical methodology identified 100% of the time. Most parameters with reported methodology had instances where official analytical methods were not reported. This presents a large methodology datagap. Additionally, the diversity of analytical methods utilized across the Gulf highlights the challenge of determining how comparable each method is to one another as well as the importance of continuing to build out the Monitoring Network Forum so that the expertise of its members can be leveraged.

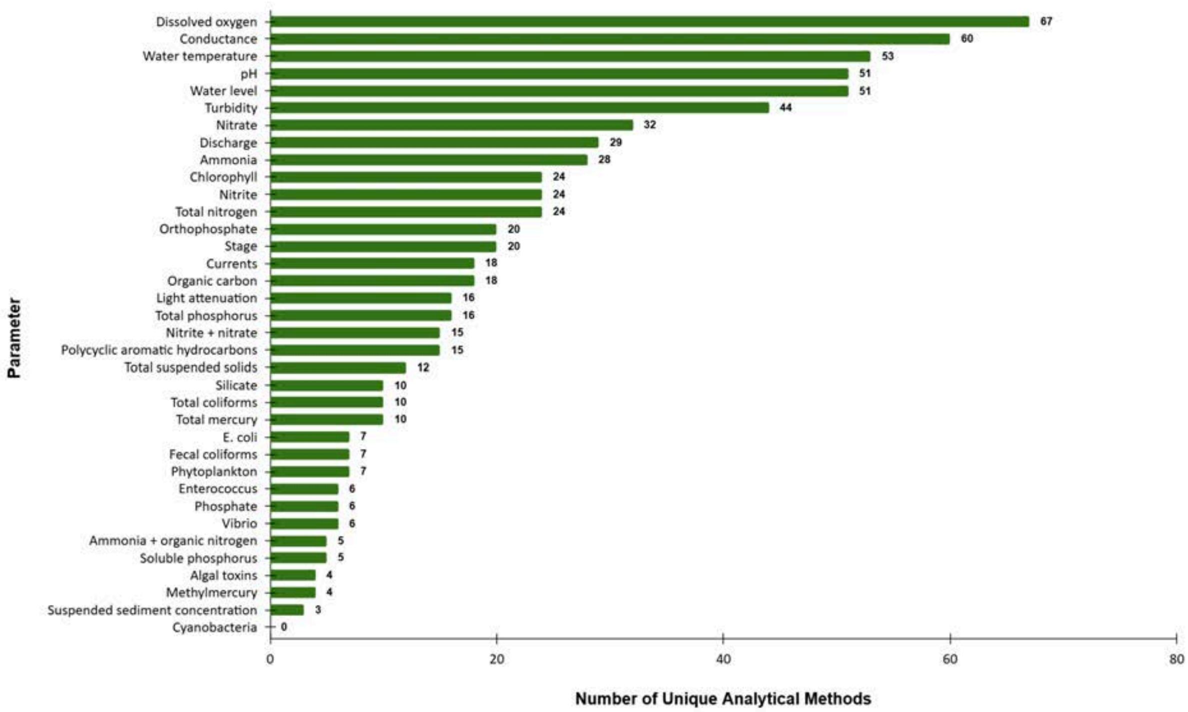

Figure 1. The number of unique analytical methods identified for each water quality parameter

When methodology information was unavailable for a particular monitoring program, a classification of “no method” was assigned. This designation comprised a large number of programs within most of the parameters (e.g., 81 of the 156 programs measuring chlorophyll). On average, a method could not be identified 62% of the time for a given parameter. This percentage ranged from 43% for the dissolved oxygen and total mercury parameters to 100% for the cyanobacteria parameter (Figure 2). The large numbers of monitoring programs for which no analytical methods were able to be identified are indicative of data and accessibility hurdles across the Gulf where such information is difficult or impossible to find online. If analytical methods cannot be identified via accessible websites, documentation, or linked to the data produced by monitoring programs, it can diminish its usefulness for secondary purposes as well as make it difficult to leverage data already generated to maximize the effectiveness of limited monitoring resources.

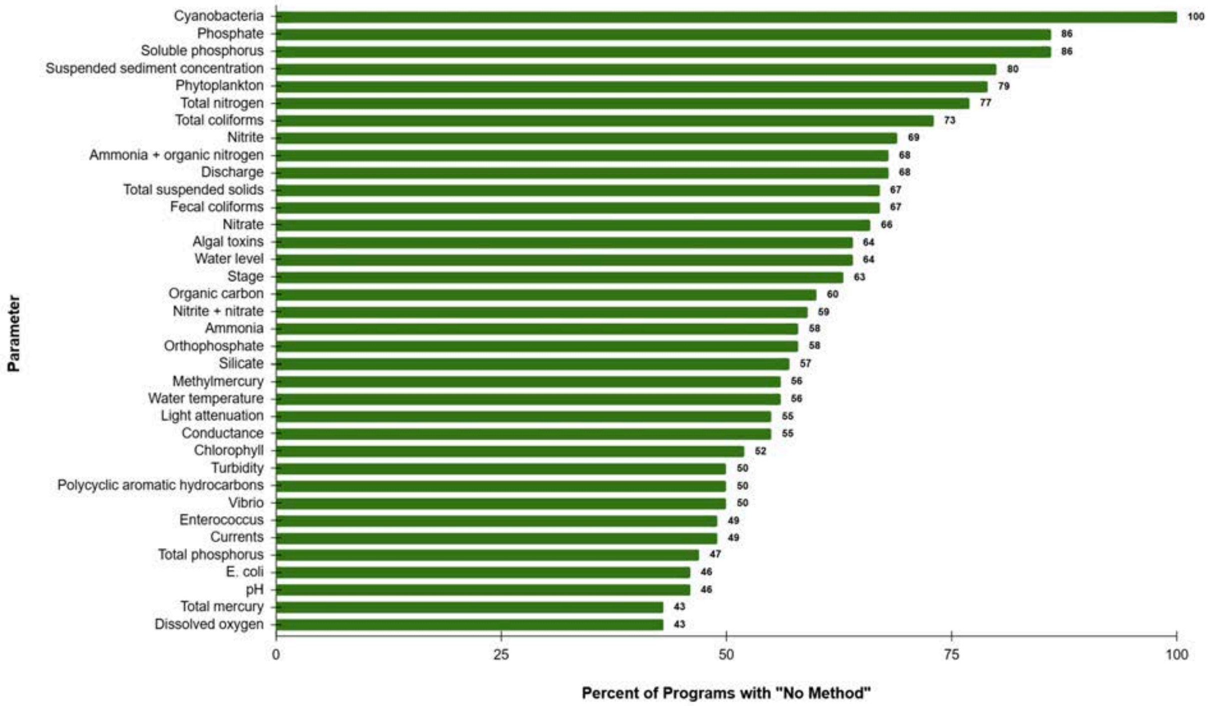

Figure 2. Percentage of monitoring programs measuring each water quality parameter that did not have a method identified and received the “no method” designation

Analytical Method Crosswalks

The analytical method crosswalks allow the identified methods for each water quality parameter to be compared to one another and acts as a starting point for the Monitoring Network Forum to discuss method comparability. Like the analytical method catalog, however, there are informational gaps highlighted by the creation of these crosswalks. For example, there are some analytical methods identified from a monitoring program’s protocol documentation that could not be found online for further examination. In some cases, this lack of information may have resulted from potential typographical errors in the monitoring protocol documentation or metadata (e.g., Standard Method 1200-M identified for chlorophyll). In others, this informational gap may have resulted from difficulties locating the full text of a method or methods being restricted behind paywalls.

Additionally, monitoring program protocol documents or metadata often only note that a particular parameter is measured by a particular instrument (e.g., unspecified sensor) or generalized method (e.g., chromatography). This makes reproduction of the method challenging. Many, but not all, of these more generalized methods were found among the field-based parameters such as stage or pH. An average of 47% of methods identified instrument methodology only and not official analytical methodology. Parameters with highest percentages of instrument methodology rather than specific analytical methodology included algal toxins (100%), light attenuation (100%), stage (95%), currents (94%), water temperature (92%), and water level (90%; Figure 3). Ammonia + organic nitrogen was the only parameter that did not have a general/instrumentation method included in its crosswalk.

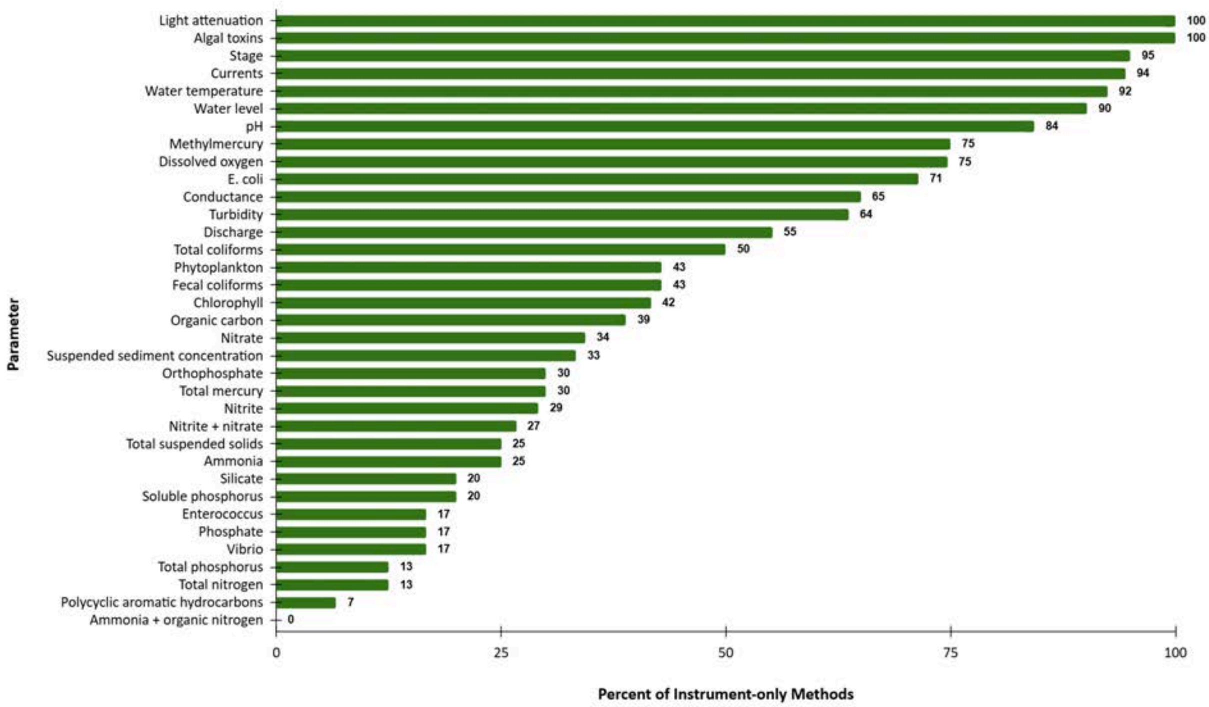

Figure 3. Percent of methods with instrument information but a lack of an official analytical method.

None of the crosswalk tables were fully populated due to the aforementioned data and information gaps, but they are a convenient resource that users can reference in order to see the most commonly utilized methods from across the Gulf. In general, applicable concentration ranges, detection limits, and sample fractions were the most difficult pieces of information to find for the analytical methods in the crosswalk tables. For example, detection limit information was found for 36% of ammonia methods. These types of information may also vary between laboratories which may require additional investigation.

Additionally, the same issues of nomenclature and chemical form noted in the pilot study (Howell et al., 2022) were encountered during this effort. Six of the methods used by monitoring programs to generate total nitrogen data, including the most common method, are not specifically noted as total nitrogen methods but instead are labeled as TKN, ammonia, or nitrite + nitrate methods. This could be due to total nitrogen often being a calculated value resulting from other measured values such as TKN and inorganic nitrogen. One example of this is two monitoring programs using a combination of EPA method 351.1 and EPA method 300.0 or EPA method 353.2.

Data Dictionary

The data dictionary is meant to be an initial resource for the Alliance and Monitoring Network Forum to develop nomenclature, chemical forms, and common analytical methods that are clear,consistent, and equivalent amongst water quality data collectors, providers, and users in the Gulf. The data dictionary includes general definitions for each parameter identified within CMAP which, where applicable, include notes about common nomenclature issues like those observed for total nitrogen and total Kjeldahl nitrogen. In addition, brief descriptions of each parameter, the most common methods, units of measure, concentration ranges, and the number of programs utilizing the methods are included. This allows the user easy access to technical information pertaining to the most commonly used methods. The crosswalk can then be referenced for further detail on methodology.

Spatial Data

Parameter-Specific Maps

Geospatial layers were generated to assess the extent of water quality monitoring by various programs along with the number of unique analytical methods identified for each water quality parameter. Additional layers were created to show the spatial extent of each identified analytical method across the Gulf. In this section, nitrate will be used as an example parameter to showcase how this data can be represented through mapping. Maps for the remaining water quality parameters can be found in Appendix D.

The first set of maps visualize how many monitoring programs measure or monitor a particular parameter within each of the hexagons in the grid. In Figure 4, for example, the largest number of monitoring programs that measure nitrate occurs in south Florida. Fewer numbers of monitoring programs measure this parameter on Louisiana’s and Mississippi’s coasts and the Big Bend region of Florida. Areas where hexagons do not exist are areas where nitrate none of the monitoring programs in the Inventory monitor the nitrate and could, thus, represent monitoring or data gaps. Using these types of maps showing where parameters of interest are already being monitored in tandem with the Inventory to determine which monitoring programs operate in an area of interest can be helpful project planning and data mining tools.

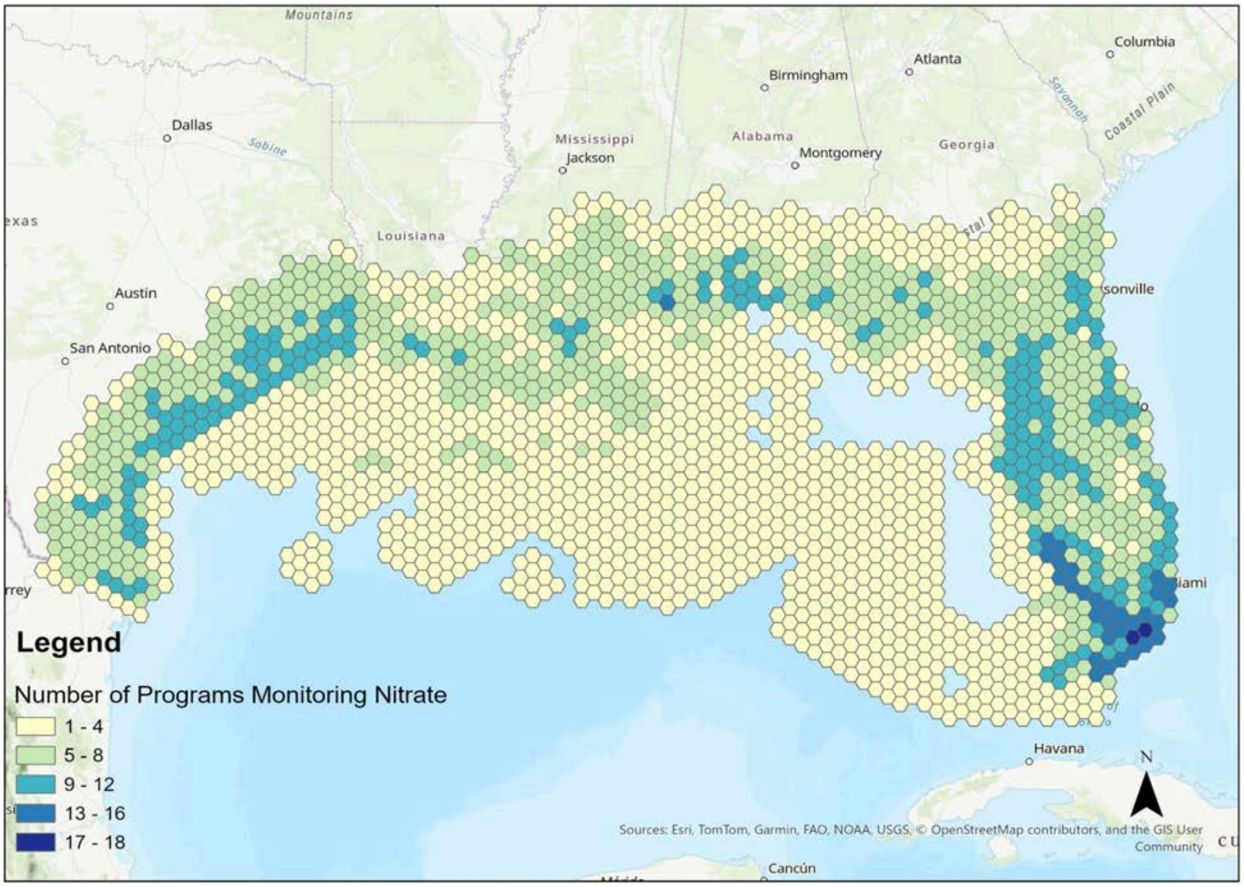

Figure 4. Map visualizing the number of monitoring programs that measure nitrate across the Gulf

The second set of maps are similar to those detailed previously but instead visualize the number of unique analytical methods utilized within each hexagon. Figure 5, displays the number of analytical methods identified to measure nitrate and underscores the wider diversity of analytical methods for Florida and Texas than the other Gulf states. Additionally, for nitrate, spatial distribution of program number generally coincides with the count of unique analytical methods (Figure 4). Areas with greater diversity of analytical methods could indicate that the data produced from these areas may need extra care to ensure that it is comparable.

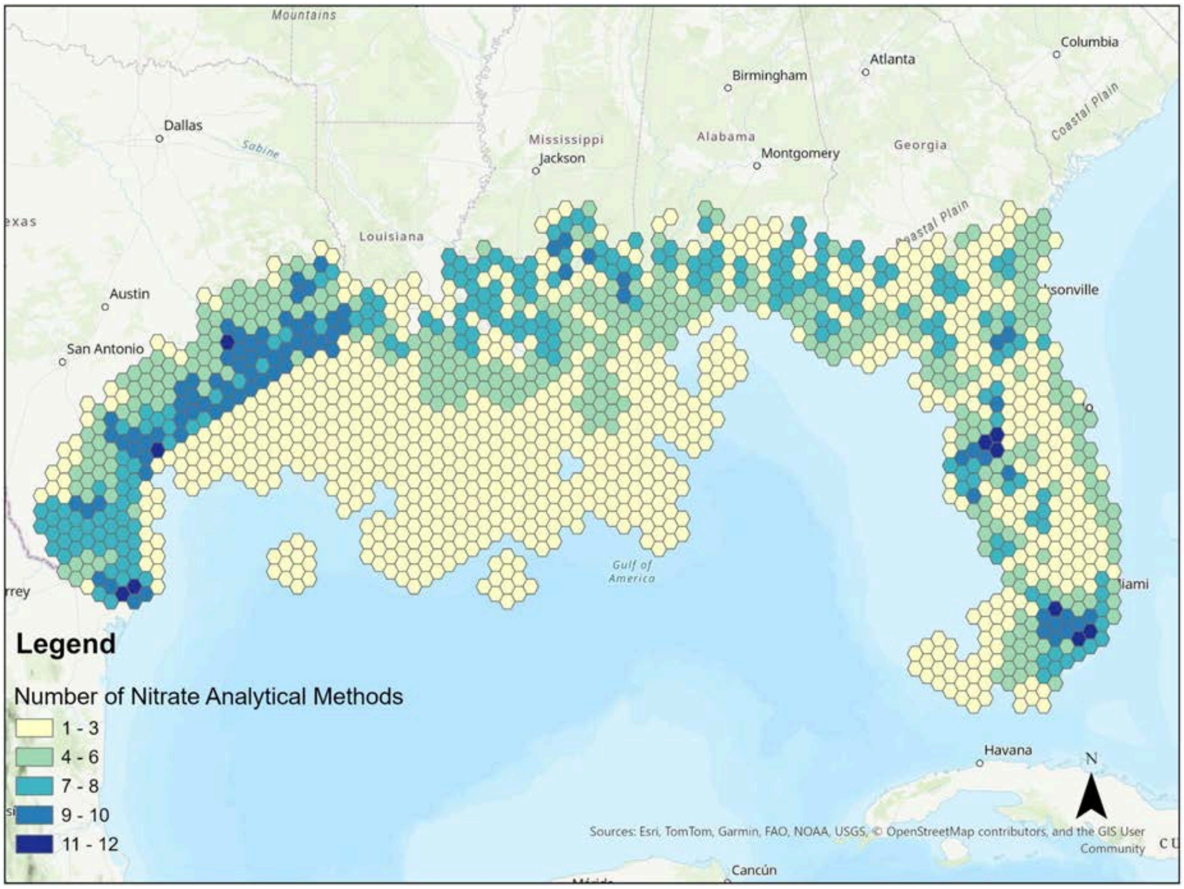

Figure 5. Map visualizing the number of analytical methods used to measure nitrate across the Gulf

The last group of maps visualize the extent across the Gulf where each analytical method for a particular parameter is used. Due to the extensive spatial area covered and the large number of analytical methods identified for each water quality parameter and associated overlaps, the layers displaying the spatial extent of each method are difficult to display on a single map. In most cases, the extents overlap and obscure one another, thus these maps are best viewed within a GIS environment such as ArcGIS Pro where the symbologies of each method can be turned on and off. These spatial extent maps could be helpful, when used in conjunction with the method crosswalk tables, in determining the most appropriate method to employ for new monitoring efforts in a particular area.

Figure 6 shows all of the identified analytical methods used to measure nitrate and where they are used across the Gulf while Figure 7 shows the most commonly identified method: EPA method 353.2. Unsurprisingly, EPA method 353.2 is widely used across the Gulf, though the extent is patchier in Louisiana, Mississippi, and Alabama than Texas and Florida. This distribution can be attributed to a single nationwide monitoring program from the Inventory (the National Rivers and Streams Assessment) accounting for all of the grid cells where EPA method 353.2 is used in Louisiana, Mississippi, and Alabama whereas multiple monitoring programs in Texas and Florida use this analytical method.

Figure 6. Map visualizing the spatial extents of all the identified analytical methods used to measure nitrate across the Gulf.

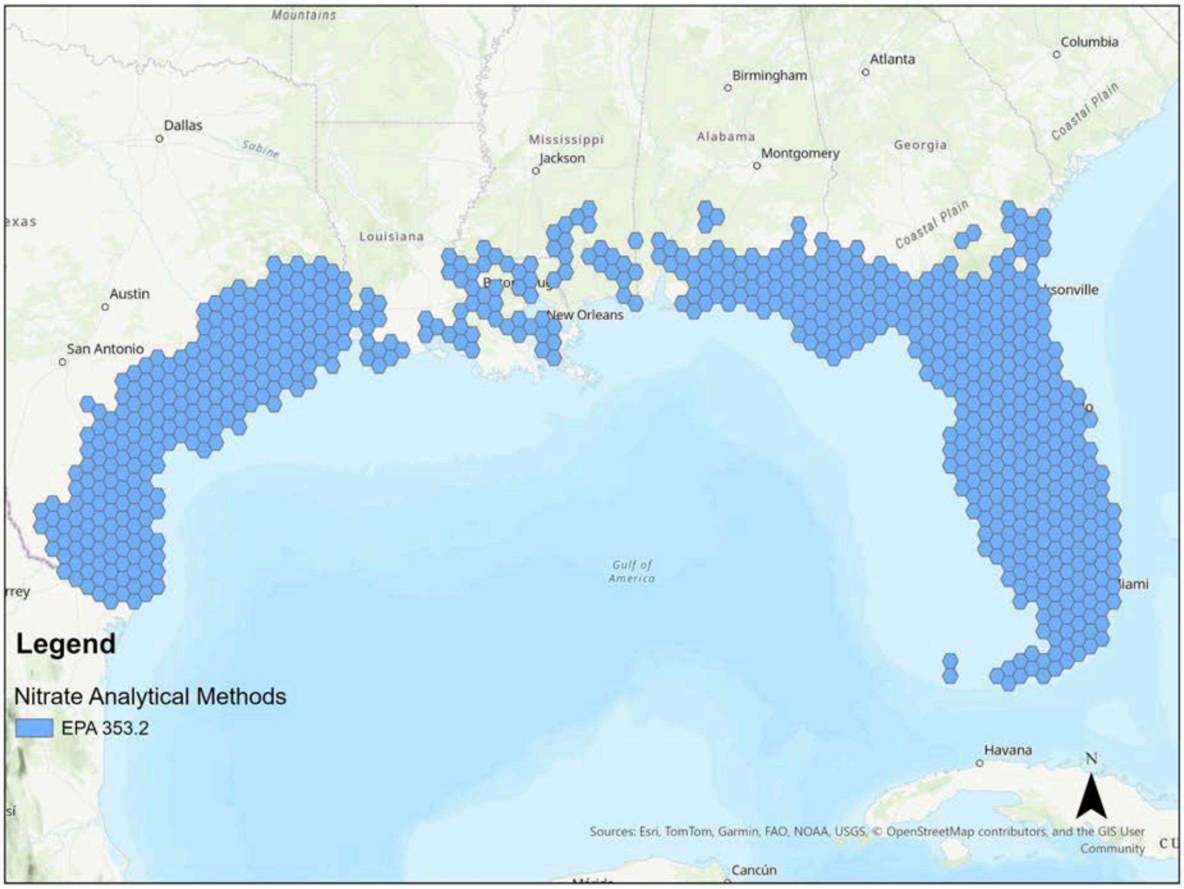

Figure 7. Map showing the spatial extent of where EPA method 353.2, the most commonly identified analytical method used to measure nitrate, is used across the Gulf.

Additionally, metrics such as those detailed above can be derived for each of the Gulf states or any other area of interest within the Gulf by selecting only the hexagons within that area. Each of the geospatial layers contain fields indicating if a particular hexagon falls within each of the Gulf states or not. For example, Figure 8 shows the geographic extent within just Alabama for each of the analytical methods used to measure nitrate. From this map, it is also possible to note that some of the identified analytical methods are not utilized within Alabama such as ion chromatography.

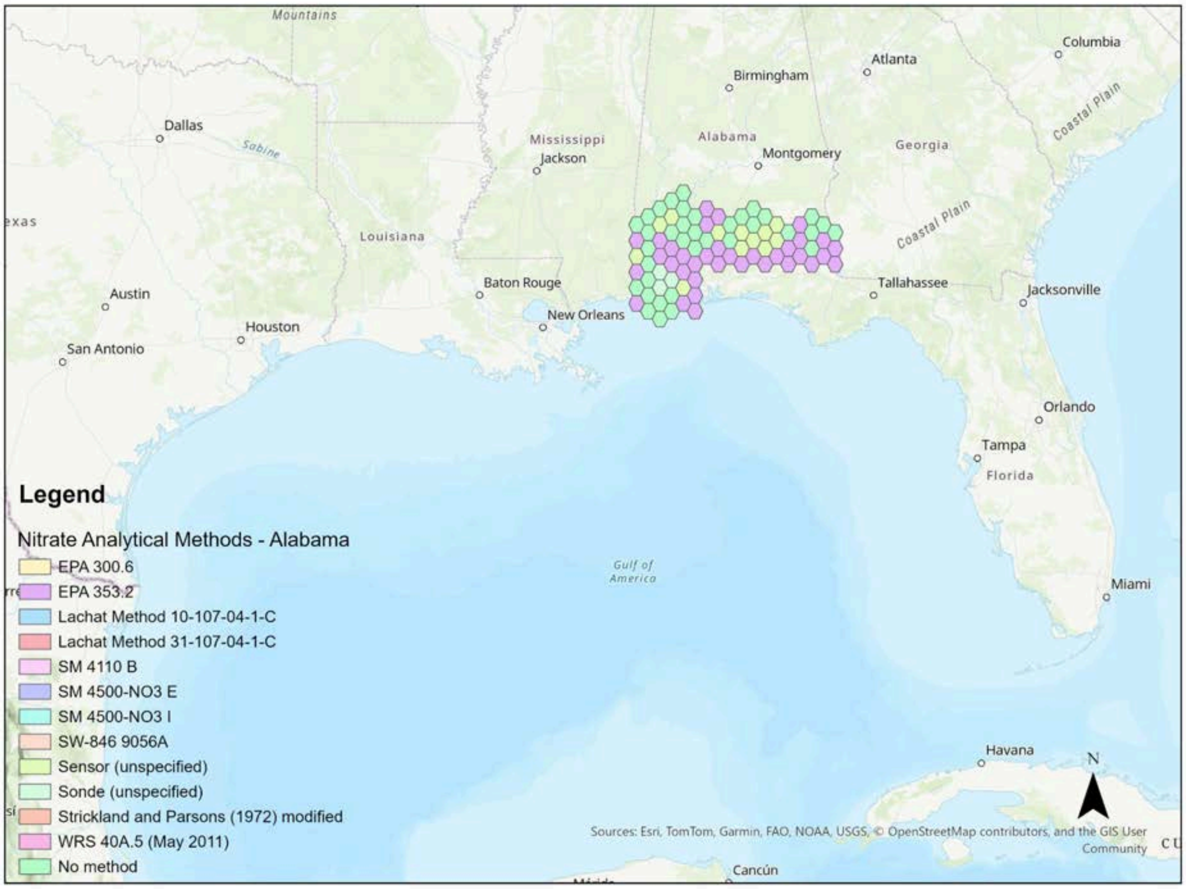

Figure 8. Map showing the spatial extent within Alabama of each analytical method used to measure nitrate that was identified from the state.

Besides the nitrate examples above, examples of additional trends found through visual analysis of the maps generated for the other water quality parameters (Appendix D) include:

1. Algal toxins: Higher numbers of monitoring programs along the coastlines of Florida, Louisiana, and Texas.
2. Ammonia: Monitoring methodology was reported for offshore areas in the central Gulf but not the eastern or parts of the western Gulf.
3. Ammonia + organic nitrogen: Alabama and Florida had the largest number of monitoring programs.
4. Chlorophyll: The largest number of monitoring programs and analytical methods were found in southwest Florida.
5. Conductance: The highest number of monitoring programs and analytical methods were found along the entire Gulf coastline.
6. Currents: The highest numbers of monitoring programs were primarily found on the Louisiana and Texas coasts.
7. Cyanobacteria: No analytical methods were identified for this parameter.
8. Discharge: Florida had the most diversity in analytical methods.

9. Dissolved oxygen: The largest number of monitoring programs were found along the Mississippi/Alabama coast and southwest Florida.
10. *E. coli*: Louisiana has the fewest number of monitoring programs.
11. *Enterococcus*: The largest number of monitoring programs were found along the Alabama coast and southwest Florida.
12. Fecal coliforms: The largest number of monitoring programs were found along the Alabama coast and southwest Florida.
13. Light Attenuation: Primarily measured along the coast.
14. Methylmercury: Largest number of analytical methods was identified at the southern tip of Florida with large areas throughout the Gulf without identified analytical methods.
15. Nitrite: South Florida reported the highest number of monitoring analytical methods.
16. Nitrite + Nitrate: Highest number of analytical methods were identified for the Texas coast and southern tip of Florida.
17. Organic Carbon: South Florida had the largest number of analytical methods.
18. Orthophosphate: The largest number of analytical methods were identified from Texas and south Florida.
19. pH: No analytical methods were identified in the eastern offshore area of the Gulf.
20. Phosphate: Few analytical methods were identified with large gaps in all the Gulf states.
21. Phytoplankton: Few analytical methods were identified throughout the Gulf, with most being identified from Texas and southwest Florida.
22. PAHs: The highest number of monitoring programs and analytical methods were found in Louisiana.
23. Silicate: There were higher numbers of monitoring programs measuring silicate off the coast of Louisiana and southeastern Florida.
24. Soluble phosphorus: Larger numbers of monitoring programs were found in Alabama and Florida.
25. Stage: Southwest Florida had the largest number of monitoring programs.
26. Suspended sediment concentration: Despite southwest Florida having a large number of monitoring programs measuring this parameter, no analytical methods were identified in that state.
27. Total coliforms: Larger numbers of analytical methods were identified in Alabama and Florida.
28. Total mercury: Fewer analytical methods were identified in Louisiana and the Big Bend region of Florida.
29. Total nitrogen: The largest number of analytical methods were identified from Florida.
30. Total phosphorus: Few analytical methods were identified for offshore areas.
31. Total suspended solids: The largest number of analytical methods were identified from southwest Florida.
32. Turbidity: There was a diverse number of analytical methods identified throughout all the Gulf states.
33. Vibrio: Only two monitoring programs (both from Texas) were identified that measure this parameter in the Inventory.

34. Water level: There was a diverse number of analytical methods identified throughout all the Gulf states.
35. Water temperature: The largest number of monitoring programs and analytical methods were found along the coast.

Accessibility Maps

Geospatial layers were also generated to visualize water quality data and metadata accessibility. These maps can be useful in identifying the most accessible monitoring programs. As shown in Figure 9, there are four regions (Texas/Louisiana border, Mobile Bay area, Tampa Bay area, and south Florida) where large numbers of monitoring programs have at least some accessible data (e.g., online or by request). The information used to generate these maps is contained in the Inventory at a program-scale rather than a parameter-scale, thus, a program may have accessible data or metadata for some but not all of the parameters they measure. The Inventory also includes links to data that is accessible online. Many of these monitoring programs also upload the data they generate to the Water Quality Data Portal or similar repositories.

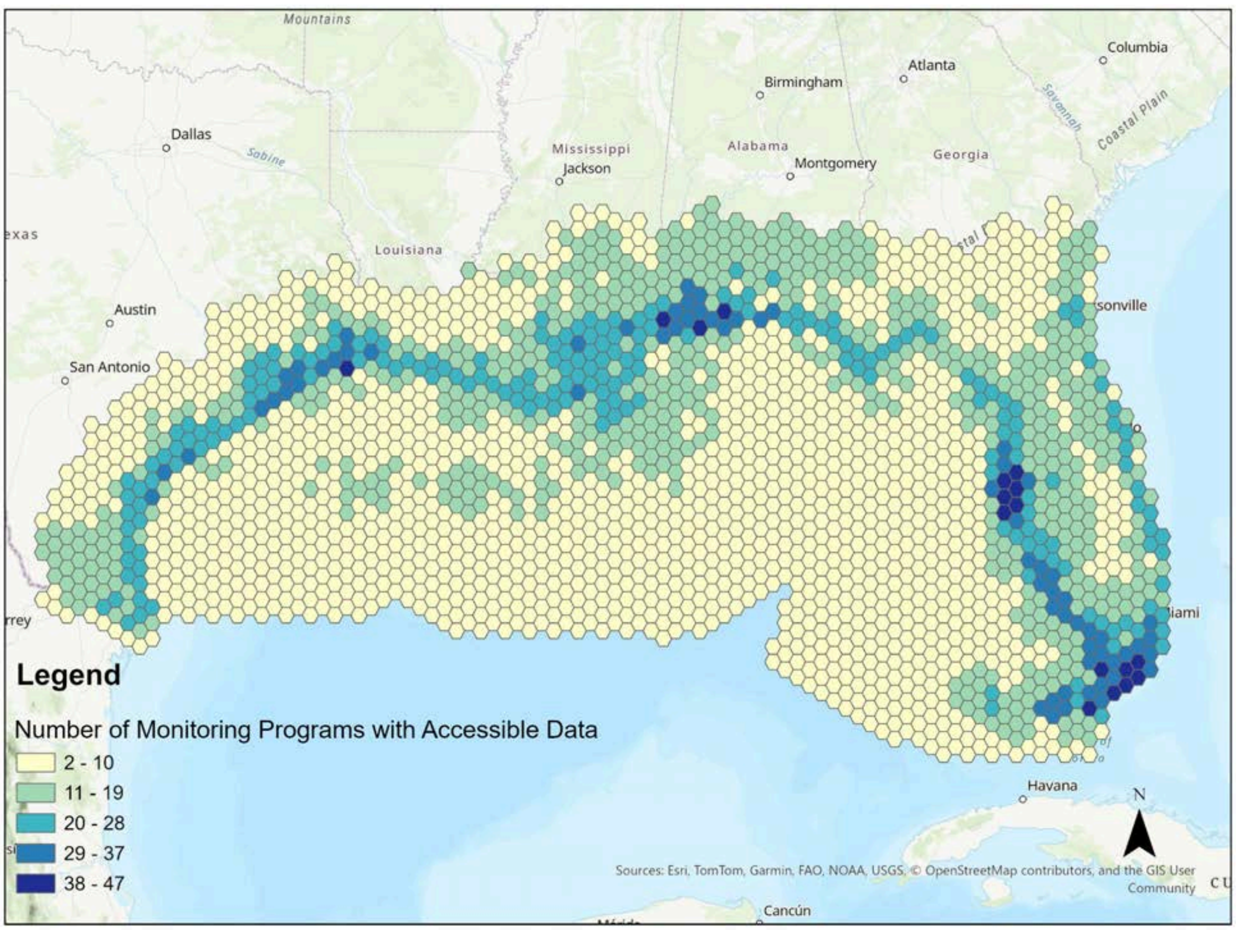

Figure 9. Map visualizing the number of monitoring programs with accessible data across the Gulf.

Interestingly, there are fewer monitoring programs with accessible metadata (Figure 10) compared to accessible data in the regions noted above for Figure 9. Metadata accessibility is less common for monitoring programs in the Inventory, highlighting an important gap for the Gulf since metadata is a crucial tool for understanding the scientific data generated by monitoring programs. Without metadata, it is often difficult to determine collection procedures and data quality.

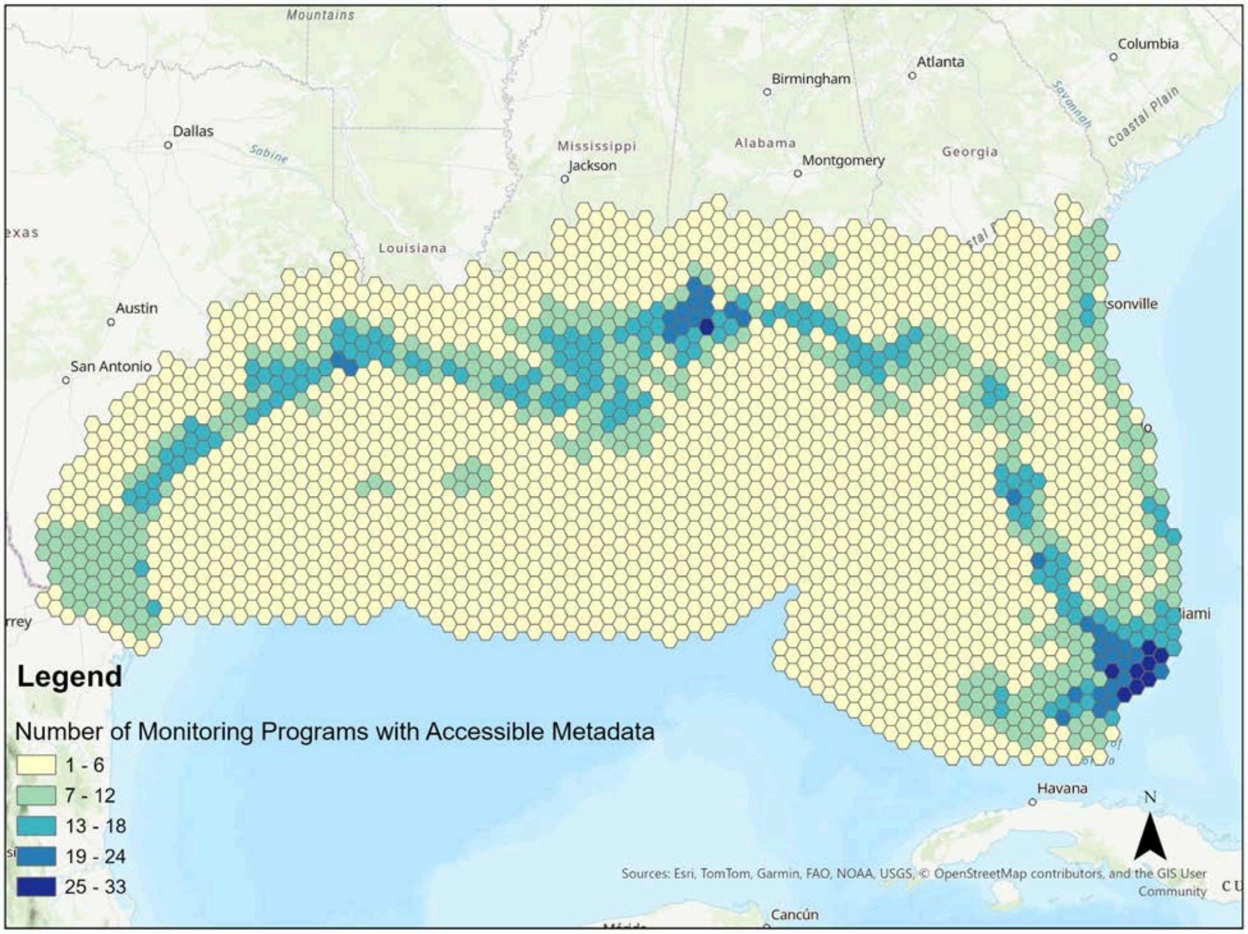

Figure 10. Map visualizing the number of monitoring programs with accessible metadata.

4. Discussion/Future Work

Overall, the products developed during this project show that one of the largest gaps in knowledge and primary hurdles toward increasing data comparability is the analytical method details. The exercise to compile analytical methods suggested that the said information is not easily accessible on public platforms. Across the Inventory and all the water quality parameters, an analytical method was unable to be identified almost 50% of the time. Even when information related to analytical methods was found, it was often generalized or incomplete, as evidenced by the crosswalk tables.

As previously mentioned during the pilot study (Howell et al., 2022), several limitations constrain the use of the CMAP Inventory and its derived products. Primarily, the information contained in the Inventory is static and only as accurate as the last update to the programmatic metadata information. There are also monitoring programs or efforts that may not be captured in the Inventory either due to them not meeting the criteria for inclusion or by virtue of not being aware of them at the time. In order to alleviate some of the limitations this could cause, the Monitoring Network Forum members were sent a list of all the water quality monitoring programs in the Inventory and asked to identify any programs or efforts that were not included. The feedback received from the Monitoring Network Forum did not suggest additional monitoring programs that should be included, but future improvements of these products should be based on solicited input from the Monitoring Network Forum members to ensure that new or previously overlooked programs not included in the Inventory can be included in the water quality comparability discussion.

Additionally, the library of monitoring protocol documents was generated during the first phase of the CMAP project. While there has not been a targeted effort to update the monitoring protocol document library, attempts were made during the creation of the analytical method catalog to locate additional or more recent documents and information when possible. Future work that seeks to build upon these products could expand the protocol document library by reaching out to the monitoring program points of contact listed in the Inventory. Points of contact could also be helpful in obtaining additional information to further complete the analytical method catalog and crosswalks. Due to time constraints and the level of effort required to reach out to over 300 points of contact, this could not be accomplished during this stage of the project.

Even with the aforementioned limitations, the CMAP Inventory and the products created during this project are all helpful resources for water quality monitoring practitioners and data users across the Gulf. The analytical method catalog, crosswalk tables, data dictionary, and spatial data presented here are also primed to be built upon as the Alliance continues working to increase data comparability and accessibility. When the draft products were presented at the Gulf of America Alliance All-Hands Meeting in May 2025, the Monitoring Network Forum members and other attendees discussed how these products could be used and expanded moving forward. The final versions of all the products will be available via the Gulf of America Alliance, and the spatial data will be linked to the Gulf Online Mapping Open Data Portal (GOMOD; https://gmod-portal-gomalliance.hub.arcgis.com/). This will allow easy access to the resources for both the Monitoring Network Forum as well as the general public.

The Inventory also contains information related to which monitoring programs have online accessible data, many of which already upload their data to the Water Quality Data Portal. GOMOD currently links and provides access to data contained in the Water Quality Data Portal. This information is useful for identifying monitoring programs the Monitoring Network Forum could work with in the future to help increase data accessibility across the Gulf by either making inaccessible data available online, adding online accessible data to the Water Quality Data Portal, or linking data services to GOMOD.

The analytical method catalog provides information on monitoring programs, the parameters measured, and methodology identified. The crosswalk tables allow users to access information pertaining to each identified method for every water quality parameter. This information can also be used to quickly assess some metrics of comparability such as detection limits. This can aid the user in identifying an appropriate methodology for specific project needs. The data dictionary pulls together aspects of the analytical method catalog and crosswalks to help ensure users are on the same page when it comes to water quality parameters. It is also a shortcut to determining the most commonly used methods per parameter. Lastly, the spatial layers allow the user to visually identify trends and/or geographic datagaps using a mapping interface. In addition to trends and datagaps, the user can also determine if their method of choice is commonly used in the geographic area of interest or if they will be addressing an identified datagap.

These products were developed as a bedrock upon which to increase comparability across the Gulf. They will allow users to see which analytical methods are most commonly identified for the water quality parameters across the Gulf. They can also, using the spatial data, subset this information to determine, for example, the most common analytical method to measure dissolved oxygen in Louisiana. Method crosswalks could then be examined to compare different analytical methods to one another to ensure that the user chooses the right method for their work. Moving forward, however, there are many things discussed with the Monitoring Network Forum at the All-Hands Meeting that could be done to make these products even more effective.

For example, a web user interface could be developed that would allow users to query the crosswalk tables. The crosswalk tables could be expanded to include information related to which analytical methods are required for regulatory purposes, length of monitoring efforts, or costs associated with the different methods which would allow for more informed decision making. Similar products could also be developed for water quality sampling methods to have a more complete picture of the water quality monitoring landscape of the Gulf. Additionally, the same process described for this project could be done for other monitoring types such as habitat or living marine resource monitoring.

Regardless of how these products are built upon, it will be crucial to continue to engage with and expand the Gulf Monitoring Network Forum. The Forum members are the subject matter experts who will be able to provide guidance on which methods are actually comparable to one another. It will also be important to raise awareness of these products and how they can be accessed and used moving forward.

References

Howell, J., Burkart, H., Hile, S. D., and Clark, R. (2021). Maintenance and updates of the RESTORE Council's Monitoring and Assessment Program Inventory of Water Quality and Habitat Monitoring and Mapping Programs [White Paper]. NOAA NOS National Centers for Coastal Ocean Science.

Howell, J., Burkart, H., Hile, S. D., and Clark, R. (2022). Practical application of conducting a gap analysis using the RESTORE Council's Monitoring and Assessment Program (CMAP) inventory: A case study [White Paper]. NOAA NOS National Centers for Coastal Ocean Science.

NOAA. (2024). Coastal Observations, Monitoring, and Assessment Resource Inventory (COMARI) Framework: An Expansion of the RESTORE Council Monitoring and Assessment Program Inventory—Incorporating Living Marine Resources Monitoring Programs for the Gulf of Mexico. NOAA National Ocean Service, National Centers for Coastal Ocean Science. NOAA Technical Memorandum NOS NCCOS 348. https://doi.org/10.25923/1hw2-dk69

NOAA and USGS. (2019a). Council Monitoring and Assessment Program (CMAP): Inventory of Existing Habitat and Water Quality Monitoring, and Mapping Metadata for Gulf of Mexico Programs. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 262. Silver Spring, MD. 155 pp. doi: 10.25923/gwpx-ff30

NOAA and USGS. (2019b). Council Monitoring and Assessment Program (CMAP): Compilation of Existing habitat and Water Quality, and Mapping Assessments for Gulf of Mexico Programs. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 269. Silver Spring, MD. 50 pp. doi: 10.25923/bpj6-z187

NOAA and USGS. (2020a). Council Monitoring and Assessment Program (CMAP): Common Monitoring Program Attributes and Methodologies for the Gulf of Mexico Region. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 285. Silver Spring, MD. doi: 10.25923/vxay-xz10

NOAA and USGS. (2020b). Council Monitoring and Assessment Program (CMAP): A Framework for Using the Monitoring Program Inventory to Conduct Gap Assessments for the Gulf of Mexico Region. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 284. Silver Spring, MD. 55 pp. doi: 10.25923/mrdd-h727

NOAA and USGS (2021). RESTORE Council Monitoring and Assessment Program (CMAP): Supporting Information (NCEI Accession 0224419). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/hnwn-rt12. Accessed 07/08/2025.

Water Quality Portal. (2021). Washington (DC): National Water Quality Monitoring Council, United States Geological Survey (USGS), Environmental Protection Agency (EPA). https://doi.org/10.5066/P9QRKUVJ.

Appendices

Appendix A - Analytical method catalog

See attached spreadsheet

Appendix B - Analytical method crosswalks

See attached spreadsheet

Appendix C - Gulf Monitoring Network Forum: Water Quality Parameter Data Dictionary

Water quality data is often generated from a wide range of monitoring efforts using program-specific methodologies. The methodologies utilized may not be easily accessible which can make using, synthesizing, or comparing water quality data across regions more difficult. The products developed for the RESTORE Council Monitoring and Assessment Program (CMAP; described in NOAA and USGS, 2019 and NOAA and USGS, 2020) can be used as resources to increase comparability and accessibility of water quality data. This data dictionary is based on the original water quality parameter glossary developed for CMAP and is intended to provide groundwork for the Alliance's Monitoring Network Forum to build upon. In many cases, monitoring programs only identified field instruments as the methods by which data is generated. Where possible, the analytical methods to which these field instruments adhere to are included below.

Algal toxins: A toxin produced by aquatic microorganisms mainly microalgae, dinoflagellates, and cyanobacteria. Algal toxins can be produced in large quantities during algal bloom events and can pose a serious environmental threat. Within the original CMAP application, the algal toxins parameter includes brevetoxins, microcystins, and domoic acid. Two analytical methods to measure algal toxins were identified. The most common was:

- **Enzyme linked immunosorbent assay (ELISA)**
  - Three different ELISA kits were identified: Abraxis Microcystins-ADDA test kit, Abraxis Cylindrospermopsin test kit, and Microtiter Plate ELISA for Microcystin
  - Units: µg/L
  - Concentration range: 0.01 - 5.00 µg/L
  - Number of programs: 4

Ammonia: A common form of nitrogen (NH_3) that exists in aquatic environments that can cause toxic effects on aquatic life. Ammonia is naturally produced through decomposition of organic matter, nitrogen fixation, as waste products from organisms, and other processes. This parameter can be reported as either NH_3 or NH_4^+mass (mg/L) or as nitrogen mass per unit volume (mg N/l). This parameter includes data generated from both filtered and unfiltered samples. For more information, see https://www.epa.gov/wqc/aquatic-life-criteria-ammonia. A total of 28 analytical methods to measure ammonia were identified. The two most were:

- **EPA 350.1**
  - Units: mg-N/L
  - Concentration range: 0.01 - 2.0 mg-N/L
  - Number of programs: 25
- **SM 4500-NH3 G**
  - Units: mg/L
  - Concentration ranges: 0.02 - 2.0 mg/L
  - Number of programs: 8

Ammonia + organic nitrogen: The total concentration of ammonia and organic nitrogen. In water chemistry, this summation is often used to express the amount of unoxidized nitrogen. This sum (NH_3-N + NH_4^+-N + Organic nitrogen as N), when expressed as nitrogen mass per unit volume, is often referred to as the total Kjeldahl nitrogen (TKN). This parameter includes data expressed as either compound mass or as nitrogen mass per unit volume, and includes the fractional results, dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Five analytical methods to measure ammonia + organic nitrogen in the Gulf of Mexico were identified. The most common was:

- **EPA 351.2**
  - Units: mg/L
  - Concentration range: 0.1 - 20 mg/L
  - Number of programs: 19

Chlorophyll: A green pigment that allows plants and algae to photosynthesize and can be used as a measure of the amount of algae or phytoplankton growing or the trophic condition of a waterbody. Within CMAP, the chlorophyll parameter includes all types of chlorophyll (i.e., A, B, C, etc.). Since phytoplankton produce chlorophyll and contain chlorophyll within their cells, phytoplankton and chlorophyll are very closely related terms, differing often only by methodology. Chlorophyll data, analyzed by various methods, are generally expressed as a mass of chlorophyll per unit volume, where phytoplankton data may be expressed by total biomass, biovolume, cell count, or diversity. Twenty-four analytical methods to measure chlorophyll were identified. The three most common were:

- **EPA 445.0**
  - Units: µg chl a/L
  - Concentration range: ≤ 250 µg chl a/L
  - Number of programs: 29
- **SM 10200 H**
  - Units: µg/L; mg/m^3
  - Concentration range: Not found
  - Number of programs: 27
- **EPA 446.0**
  - Units: mg chl a/L
  - Concentration range: ≤ 27 mg chl a/L
  - Number of programs: 15

Conductance: Conductance is the measure of the ability of water to pass an electrical current. In addition to being the basis of most salinity and total dissolved solids calculations, conductivity is an early indicator of change in a water system. Most bodies of water maintain a fairly constant conductivity that can be used as a baseline of comparison to future measurements. Within CMAP, salinity is included in the detailed parameter of conductance. A total of 60 analytical and/or field methods to measure conductance were identified. The three most common were:

- **YSI 6 series multiprobe**

    - Conforming to EPA 120.1, SM 2510B-1997, and ASTM Method D1125-95(99) (A)
    - Units: mS/cm; ppt
    - Concentration range: 0 - 100 mS/cm; 0 - 70 ppt
    - Number of programs: 28
- **YSI multiprobe (unspecified)**
    - Conforming to EPA 120.1, SM 2510B-1997, and ASTM Method D1125-95(99) (A)
    - Units: Not found
    - Concentration range: Not found
    - Number of programs: 20
- **Florida Department of Environmental Protection (FDEP) SOP FT 1200**
    - Conforming to EPA 120.1
    - Units: µmhos/cm
    - Concentration range: Not found
    - Number of programs: 13

Cryptosporidium: A parasite present in fecal material with pathogenic effects in humans. No programs within the CMAP Inventory were identified as measuring this parameter.

Currents: The rate of movement in the water. A total of 18 analytical methods to measure currents were identified. The most common were:

- **RDI model 300S Sentinel Acoustic Doppler Current Profiler (ADCP)**
    - Units: m/s
    - Concentration range: ±0.5 of measured velocity
    - Number of programs: 4
- **Aanderaa Doppler Current Sensor Acoustic Doppler Sampler**
    - Units: cm/s
    - Concentration range: 0 - 300 cm/s
    - Number of programs: 3

Cyanobacteria: A phylum of bacteria that obtain energy through photosynthesis, and are the only photosynthetic prokaryotes able to produce oxygen. Previously called "blue-green algae," they have since been renamed 'cyanobacteria' in order to avoid the term "algae", which in modern usage is restricted to eukaryotes. These bacteria can form dense mats and produce cyanotoxins, such as microcystin and domoic acid, that can be health hazards to humans and wildlife during harmful algal blooms. Cyanobacteria data, analyzed by various methods, are generally expressed as a mass cyanobacteria per unit volume, where phytoplankton data may be expressed by total biomass, biovolume, cell count, or diversity. No analytical methods to measure cyanobacteria were identified from the CMAP database.

Discharge: Rate of fluid flow passing a given point at a given moment in time. A total of 29 analytical and/or field methods to measure discharge were identified. The most common was:

- **SonTek FlowTracker Acoustic Doppler Velocimeter (ADV)**
    - Units: ft^3/sec; mgd
    - Concentration range: NA
    - Number of programs: 6

Dissolved oxygen: The amount of gaseous oxygen dissolved in water. Dissolved oxygen may be expressed as a concentration or as a percent saturation. Low dissolved oxygen is related to an excess of nutrients which can lead to excessive growth of vegetation. A total of 67 analytical and/or field methods to measure dissolved oxygen were identified. The two most common were:

- **YSI 6 series multiprobe**
    - Conforming to EPA 360.1
    - Units: mg/L; % saturation
    - Concentration range: 0 - 50 mg/L; 0 - 500% air saturation
    - Number of programs: 27
- **YSI multiprobe (unspecified)**
    - Units: mg/L
    - Concentration range: Not found
    - Number of programs: 22

Enterococcus: A large bacterial genus present in human and animal feces and used as an indicator of fecal pollution of water bodies. *Enterococcus* are highly tolerant to wide ranges of temperature, pH and salinity. Six analytical methods to measure *Enterococcus* were identified. The two most common were:

- **SM 9230 D**
    - Units: MPN/100 mL; Presence/Absence
    - Concentration range: 1 - 2419 MPN/100 mL (97-well Quanti-Tray/2000); 1 - 200 MPN/100 mL (51-well Quanti-Tray)
    - Number of programs: 15
- **EPA 1600**
    - Units: CFU/100 mL
    - Concentration range: Not found
    - Number of programs: 12

Escherichia coli: A large and diverse group of bacteria found in the environment, foods, and intestines/feces of people and animals and used as an indicator of fecal pollution of water bodies. Seven analytical methods to measure *E. coli* were identified. The two most common were:

- **SM 9223-B**
    - Units: MPN/100 mL; Presence/Absence
    - Concentration range: 1 - 2419 MPN/100 mL (97-well Quanti-Tray/2000); 1 - 200 MPN/100 mL (51-well Quanti-Tray)
    - Number of programs: 16

- **Coliscan Easygel**
  - Units: #/100 mL
  - Concentration range: Not found
  - Number of programs: 3

Fecal coliforms: A subset of total coliforms, fecal coliforms are distinguished by their tolerance for warmer temperatures. The fecal coliform group includes *Escherichia coli*. The fecal coliform parameter is used as a broad indicator of environmental contamination by human or animal waste. Seven analytical methods to measure fecal coliforms were identified. The two most common were:

- **SM 9222 D**
  - Units: CFU/mL; #/100 mL
  - Concentration range: 20 - 60 CFU/100 mL
  - Number of programs: 12
- **Alabama Department of Environmental Management (ADEM) SOP 5603 (rev 8)**
  - Units: MPN/mL; CFU/mL
  - Concentration range: 1 - 2419 MPN/100 mL (97-well Quanti-Tray/2000)
  - Number of programs: 5

Giardia: A protozoan parasite present in human and animal wastes that has pathogenic effects in both children and adults. No programs within the CMAP Inventory were identified as measuring this parameter.

Light attenuation: Light attenuation refers to the evaluation of the penetration of ambient sunlight below the water surface. A total of 16 analytical and/or field methods to measure light attenuation were identified. The two most common were:

- **Secchi disk**
  - Units: m
  - Concentration range: NA
  - Number of programs: 21
- **LI-COR light meter (unspecified)**
  - Units: Not found
  - Concentration range: NA
  - Number of programs: 19

Methylmercury: An organic form of mercury that acts as a bioaccumulative environmental toxicant. Methylmercury accumulates in fish tissue which is transferred to humans upon consumption. Four analytical methods to measure methylmercury were identified. The most common was:

- **EPA 1630**
  - Units: ng/L
  - Concentration range: 0.02 - 5 ng/L

- Number of programs: 2

Nitrate: Nitrogen in its fully oxidized form (NO_3), which is readily assimilated by plants and algae through photosynthetic processes. Excess nitrate in water can cause health problems in infants and contribute to eutrophication in water bodies. This parameter is reported as either nitrate mass per unit volume or as nitrogen mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Thirty-two analytical methods to measure nitrate were identified. The two most common were:

- **EPA 353.2**
    - Units: mg/L
    - Concentration range: 0.05 - 10 mg/L
    - Number of programs: 10
- **EPA 300**
    - Units: mg/L
    - Concentration range: 0.42 - 14 mg/L
    - Number of programs: 5

Nitrite: Nitrogen in an intermediate form of oxidation (NO_2). Nitrite is further oxidized to nitrate through biological oxidation (nitrification). This parameter includes data expressed as either nitrite mass per unit volume or as nitrogen mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Twenty-four analytical methods to measure nitrite were identified. Some of the monitoring programs identified nitrate analytical methods that could be modified to allow for measurement of nitrite. The two most common were:

- **EPA 353.2**
    - Units: mg/L
    - Concentration range: 0.05 - 10 mg/L
    - Number of programs: 13
- **EPA 300.0**
    - Units: mg/L
    - Concentration range: 0.36 - 12 mg/L
    - Number of programs: 5

Nitrite + nitrate: A measure of the combined concentrations of nitrite and nitrate. In water chemistry, this summation is often used to express the amount of inorganic nitrogen available for biological uptake. This parameter includes data expressed as either ion mass per unit volume or as nitrogen mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Fifteen analytical methods to measure nitrite + nitrate were identified. The most common was:

- **EPA 353.2**
    - Units: mg-N/L

    - Concentration range: 0.05 - 10 mg-N/L
    - Number of programs: 27

Organic carbon: The amount of carbon contained in organic compounds in water. The organic carbon parameter includes total organic carbon and dissolved organic carbon. Eighteen analytical methods to measure organic carbon were identified. The two most common were:

- **SM 5310 C**
    - Units: mg/L; µg/L
    - Concentration range: 0.1 - 4000 mg/L
    - Number of programs: 9
- **SM 5310 B**
    - Units: mg-C/L
    - Concentration range: Not found
    - Number of programs: 6

Orthophosphate: A term used to describe the phosphate molecule alone without any associated chemical species (PO_4^{3-}). Orthophosphate is readily consumable by the biological community and is usually the limiting factor of biological growth. This parameter includes data expressed as either PO_4^{3-} mass per unit volume or as phosphorus mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Twenty analytical methods to measure orthophosphate were identified. The two most common were:

- **EPA 365.1**
    - Units: mg-P/L
    - Concentration range: 0.01 - 1.0 mg-P/L
    - Number of programs: 22
- **SM 4500-P E**
    - Units: mg-P/L
    - Concentration range: 0.01 - 6.0 mg-P/L
    - Number of programs: 6

pH: The negative logarithm of the hydrogen ion concentration of a solution that is used as a measure of the acidity or alkalinity of a liquid. Fifty-one analytical and/or field methods to measure pH were identified. The three most common were:

- **YSI 6 series multiprobe**
    - Units: pH units
    - Concentration range: 0 - 14
    - Number of programs: 17
- **pH meter (unspecified)**
    - Units: Not found
    - Concentration range: Not found

- Number of programs: 16

- **YSI meter/datasonde (unspecified)**
  - Units: Not found
  - Concentration range: Not found
  - Number of programs: 10

Phosphate: A phosphorus-containing anion that is often a limiting nutrient in environments (especially freshwater environments) and is widely used in fertilizers and detergents. This parameter includes data expressed as either ion mass per unit volume or as phosphorus mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Six analytical methods to measure phosphate were identified. The most common was:

- **EPA 365.1**
  - Units: mg-P/L
  - Concentration range: 0.01 - 1.0 mg-P/L
  - Number of programs: 3

Phytoplankton: The term phytoplankton encompasses all photoautotrophic microorganisms in aquatic food webs. Phytoplankton serve as the base of the aquatic food web, providing an essential ecological function for all aquatic life. Phytoplankton are a diverse group that incorporates eubacterial and archaebacterial prokaryotes and protistan eukaryotes. Note that phytoplankton and chlorophyll are very closely related terms. Chlorophyll results, analyzed by various methods, are generally expressed as a mass of chlorophyll per unit volume, where phytoplankton results may be expressed by total biomass, cell count, or diversity. Seven analytical methods to measure phytoplankton were identified. The two most common were:

- **$NNaH_{14}CO_3$ incorporation via incubation (Pennock and Sharp 1986)**
  - Units: µg/L
  - Concentration range: Not found
  - Number of programs: 2

Polycyclic aromatic hydrocarbons (PAHs): PAHs are a large family of compounds including anthracene, phenanthrene, tetracene, chrysene, and others that occur naturally in coal, crude oil, and gasoline. They are also often produced by incomplete combustion or processes that involve high pressure. Fifteen analytical methods to measure PAHs were identified. The most common was:

- **Gas chromatography/mass spectrometry (selected ion mode)**
  - Units: Not found
  - Concentration range: Not found
  - Number of programs: 2

Silicate: Silicate, or silicic acid (H_4SiO_4), is an important nutrient in the ocean and estuaries. Unlike other major nutrients such as phosphate, nitrate, or ammonium needed by almost all marine plankton, silicate is an essential chemical requirement for very specific biota, including diatoms, radiolaria, silicoflagellates, and siliceous sponges. These organisms extract dissolved silicate from open surface waters for the buildup of their particulate silica (SiO_2), or opaline, skeletal structures. This parameter includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Ten analytical methods to measure silicate were identified. The most common was:

- **4500-SiO2 D**
  - Units: mg/L
  - Concentration range: 0.04 - 2.0 mg/L
  - Number of programs: 3

Soluble phosphorus: Hydrated phosphate ions that are dissolved in water through weathering or in the production of fertilizers that plants can use. Soluble phosphorus is also called soluble reactive phosphorus. This parameter includes data expressed as either ion mass per unit volume or as phosphorus mass per unit volume. A total of 5 analytical methods to measure soluble phosphorus were identified. The two most common were:

- **Lachat Method 10-115-01**
  - Units: mg-P/L
  - Concentration range: 0.01 - 1 mg-P/L
  - Number of programs: 4
- **Lachat Method 10-115-01-A**
  - Units: mg-P/L
  - Concentration range: 0.1 - 2 mg-P/L; 1 - 20 mg-P/L
  - Number of programs: 4

Stage: The height of the water surface above an established datum plane. The commonly used datums are NAVD88 and NGVD29. A total of 20 analytical methods to measure stage were identified. The two most common were:

- **U.S. Geological Survey gage**
  - Units: ft
  - Concentration range: NA
  - Number of programs: 5
- **Electronic water level tape**
  - Units: ft
  - Concentration range: NA
  - Number of programs: 4

Suspended sediment concentration (SSC): A measure of how much sediment is suspended and transported in a body of water. Three analytical methods to measure suspended sediment concentration were identified. The most common were:

- **GF/C filtration/Weight (Strickland and Parsons, 1972)**
    - Units: mg/L
    - Concentration range: Not found
    - Number of programs: 2

Total coliforms: A large group of bacterium which generally originate in the intestines of warm-blooded animals. This group includes *Citrobacter*, *Enterobacter*, *Hafnia*, *Klebsiella* and *Escherichia*. The total coliform parameter is used as a broad indicator of environmental contamination by human or animal waste. Ten analytical methods to measure total coliforms were identified. The two most common were:

- **ADEM SOP 5603 Rev 8: Fecal Coliform by Defined Substrate Technology—Multiple Well Procedure**
    - Units: MPN/mL; CFU/mL
    - Concentration range: 1 - 2419 MPN/100 mL (97-well Quanti-Tray/2000)
    - Number of programs: 4
- **SM 9222 B**
    - Units: CFU/mL
    - Concentration range: 20 - 80 CFU/100 mL; Maximum: 200 CFU/100 mL
    - Number of programs: 3

Total mercury: A measure of the concentration of mercury compounds, organic and inorganic in an environment or the tissues of an organism. Ten analytical methods to measure total mercury were identified. The most common was:

- **EPA 1631 E**
    - Units: ng/L
    - Concentration range: 0.5 - 100 ng/L
    - Number of programs: 9

Total nitrogen: The sum of organic nitrogen, nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3), all expressed as N. Excess nitrogen in aquatic environments can result in eutrophication, algal blooms, and low levels of dissolved oxygen. This parameter includes data expressed as either compound mass per unit volume or as nitrogen mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), or suspended (unfiltered - filtered). Total nitrogen is an estimated parameter since all components are analyzed using different methods. Twenty-four analytical methods to measure total nitrogen were identified. Many of the analytical methods identified from monitoring program protocol documents are not specifically total nitrogen methods, and instead are methods used to measure the components that can be used to generate total nitrogen values (e.g., total Kjeldahl nitrogen, nitrate-nitrite, or ammonia). The most common was:

- **EPA 353.2**
    - Units: mg-N/L
    - Concentration range: 0.05 - 10 mg-N/L

- Number of programs: 6

Total phosphorus: A measure of the sum of all phosphorus compounds. This parameter includes data expressed as either compound mass per unit volume or as phosphorus mass per unit volume, and includes the fractional results: dissolved (filtered), total (unfiltered), and suspended (unfiltered - filtered). Sixteen analytical methods to measure total phosphorus were identified. The two most common were:

- **EPA 365.1**
  - Units: mg/L
  - Concentration range: 0.01 - 1 mg/L
  - Number of programs: 51
- **EPA 365.4**
  - Units: mg/L
  - Concentration range: 0.01 - 20 mg/L
  - Number of programs: 19

Total suspended solids (TSS): The dry weight of solids suspended in water that can be trapped by a filter. This can include silt, decaying plant/animal matter, sewage, industrial waste, etc. Twelve analytical methods to measure total suspended solids were identified. The most common was:

- **SM 2540 D**
  - Units: mg/L
  - Concentration range: Not found
  - Number of programs: 23

Turbidity: A measure of relative clarity of a liquid or how many particles are suspended in it. Often, turbidity is measured by illuminating the water with a light source of specific wavelength, the sensor measures the scatter of light, giving a measurement that is independent of ambient light. Due to the specificity of the instrument's light source and sensor, turbidity measurement from different models of turbidity sensors can vary significantly. Additional variation can be attributed to the use of different standards of calibration. To overcome this difficulty, many different unit designations have been created, each defined to a specific instrument type and method of calibration. Examples include Nephelometric Turbidity Unit (NTU), Formazin Nephelometric Unit (FNU) and many others. Measurements which share the same unit designation can be considered comparable, but are not readily comparable to other unit designations. For more information see, https://water.usgs.gov/edu/turbidity.html and https://or.water.usgs.gov/grapher/fnu.html. A total of 44 analytical methods to measure turbidity were identified. Many monitoring programs reported using secchi disks, secchi tubes, or turbidity columns to measure turbidity. In addition to these being field instruments, it could also be argued that they measure transparency rather than turbidity. The three most common were:

- **EPA 180.1**
  - Units: NTU
  - Concentration range: 0 - 40 NTU

- Number of programs: 21
- **SM 2130 B**
  - Units: NTU
  - Concentration range: 0 - >1000 NTU
  - Number of programs: 18
- **Secchi disk**
  - Units: m
  - Concentration range: Not found
  - Number of programs: 18

Vibrio: Bacterial genus found in warm coastal waters that can cause human illness when raw/undercooked shellfish is contaminated or if an open wound is exposed to brackish/salt water. Six analytical methods to measure *Vibrio* were identified:

- **Polymerase chain reaction (PCR)**
  - Units: Not found
  - Concentration range: Not found
  - Number of programs: 1
- **Most Probably Number (MPN) Technique**
  - Units: MPN/g
  - Concentration range: Not found
  - Number of programs: 1
- **MPN real-time PCR**
  - Units: log MPN/g
  - Concentration range: Not found
  - Number of programs: 1
- **Enzyme immunoassay (EIA)**
  - Units: #/EIA well
  - Concentration range: Not found
  - Number of programs: 1
- **SYBR Gree 1 QPCR-MPN**
  - Units: Not found
  - Concentration range: Not found
  - Number of programs: 1
- **Direct Plating Method**
  - Units: Not found
  - Concentration range: Not found
  - Number of programs: 1

Water level: The height reached by the water in a waterbody. Fifty-one analytical and/or field methods to measure water level were identified. The most common were:

- **YSI 600 LS**
    - Units: ft
    - Concentration range: NA
    - Number of programs: 4
- **Wading rod**
    - Units: ft
    - Concentration range: NA
    - Number of programs: 4
- **Sounding reel**
    - Units: ft
    - Concentration range: NA
    - Number of programs: 4
- **Sounding line and weights**
    - Units: Not found
    - Concentration range: NA
    - Number of programs: 4
- **Sonic sounder**
    - Units: ft
    - Concentration range: NA
    - Number of programs: 4
- **Handline**
    - Units: Not found
    - Concentration range: NA
    - Number of programs: 4

Water temperature: A measure of water temperature. Water temperature can include temperature measures taken at the surface and throughout the water column. Fifty-three analytical and/or field methods to measure water temperature were identified. The most common was:

- **YSI 6 series multiprobe**
    - Conforming to EPA 170.1
    - Units: °C; °F; °K
    - Concentration range: -5 - 50°C
    - Number of programs: 27

References

NOAA and USGS. 2019. Council Monitoring and Assessment Program (CMAP): Inventory of Existing Habitat and Water Quality Monitoring, and Mapping Metadata for Gulf of Mexico Programs. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 262. Silver Spring, MD. 155 pp. doi: 10.25923/gwpx-ff30

NOAA and USGS. 2020. Council Monitoring and Assessment Program (CMAP): Common Monitoring Program Attributes and Methodologies for the Gulf of Mexico Region. National Oceanic and Atmospheric Administration and U.S. Geological Survey. NOAA Technical Memorandum NOS NCCOS 285. Silver Spring, MD. doi: 10.25923/vxay-xz10

Appendix D - Spatial data

The figures in this appendix include maps showing the number of monitoring programs that monitor a particular parameter, the number of analytical methods used to measure a particular parameter, and the spatial extents of where each analytical method is used for every water quality parameter in the CMAP Inventory.

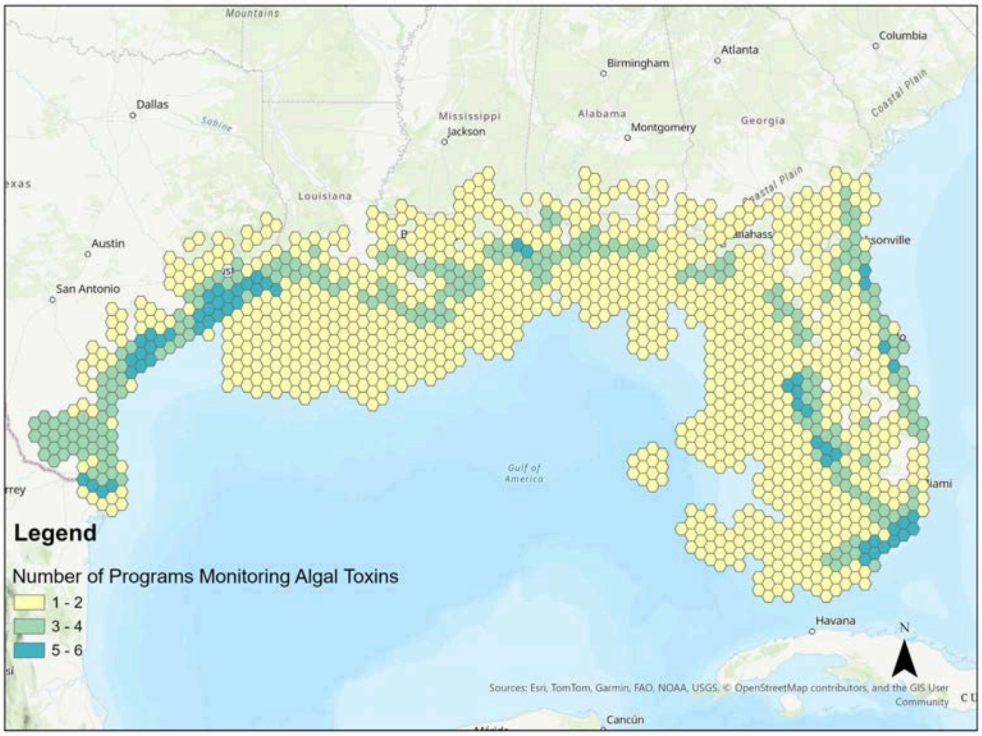

Figure D1. Map visualizing the number of monitoring programs monitoring algal toxins across the Gulf.

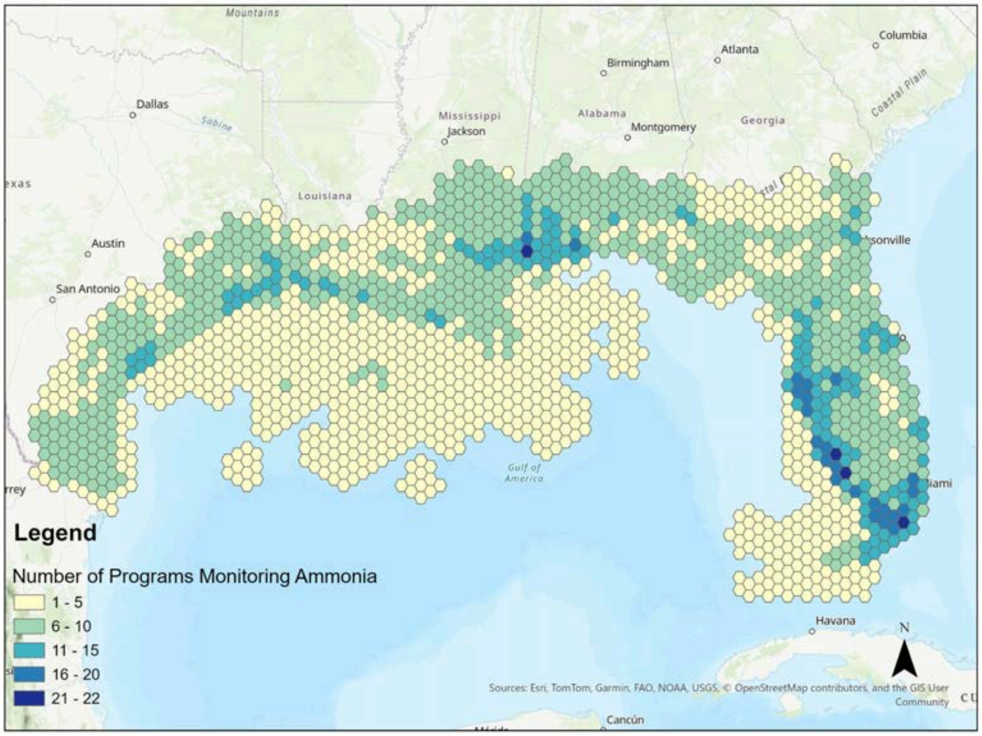

Figure D2. Map visualizing the number of monitoring programs monitoring ammonia across the Gulf.

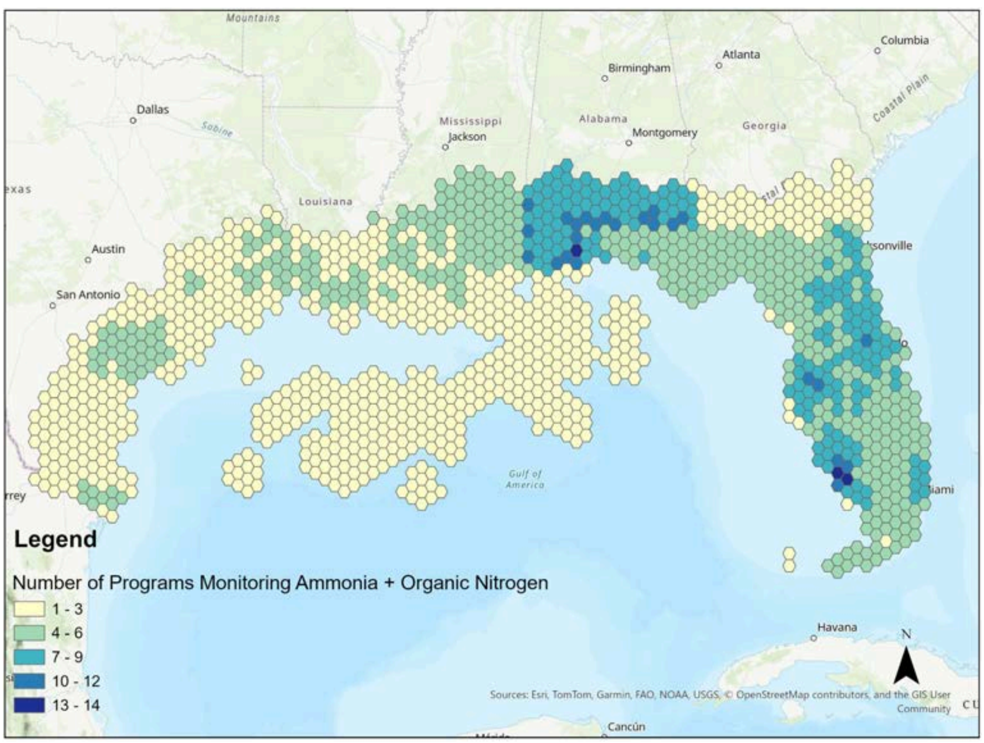

Figure D3. Map visualizing the number of monitoring programs monitoring ammonia + organic nitrogen across the Gulf.

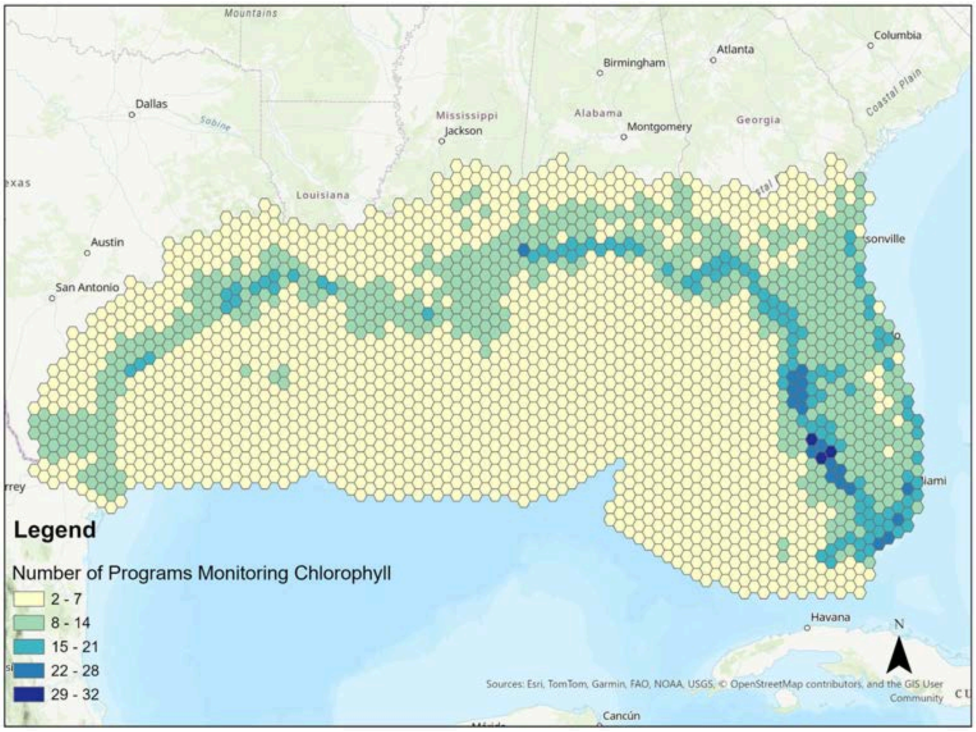

Figure D4. Map visualizing the number of monitoring programs monitoring chlorophyll across the Gulf.

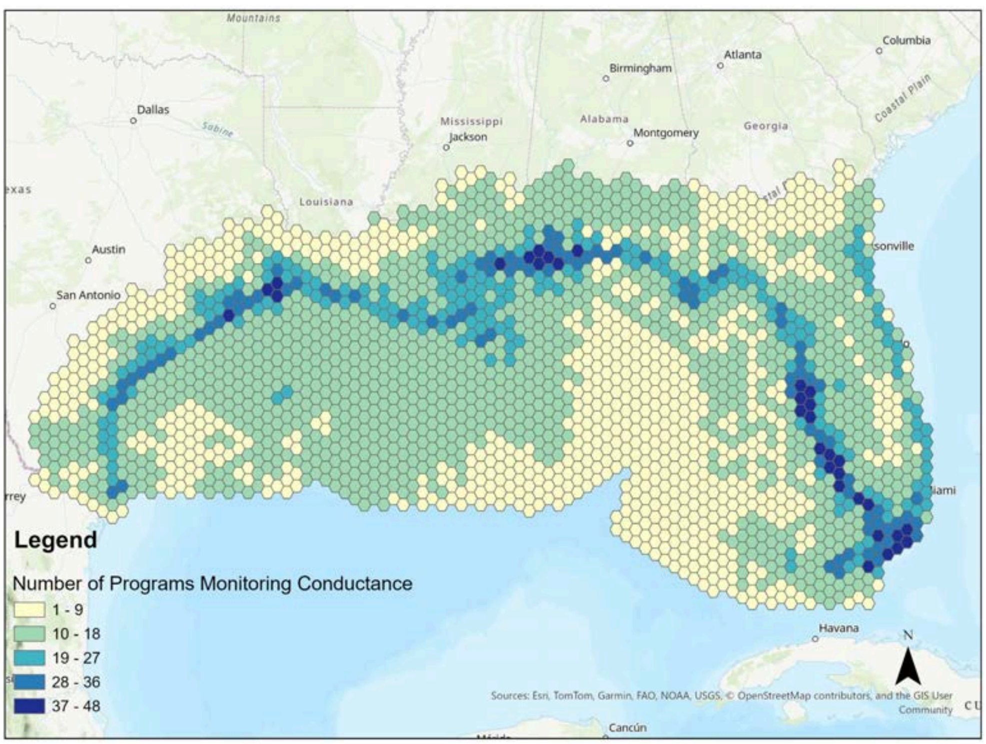

Figure D5. Map visualizing the number of monitoring programs monitoring conductance across the Gulf.

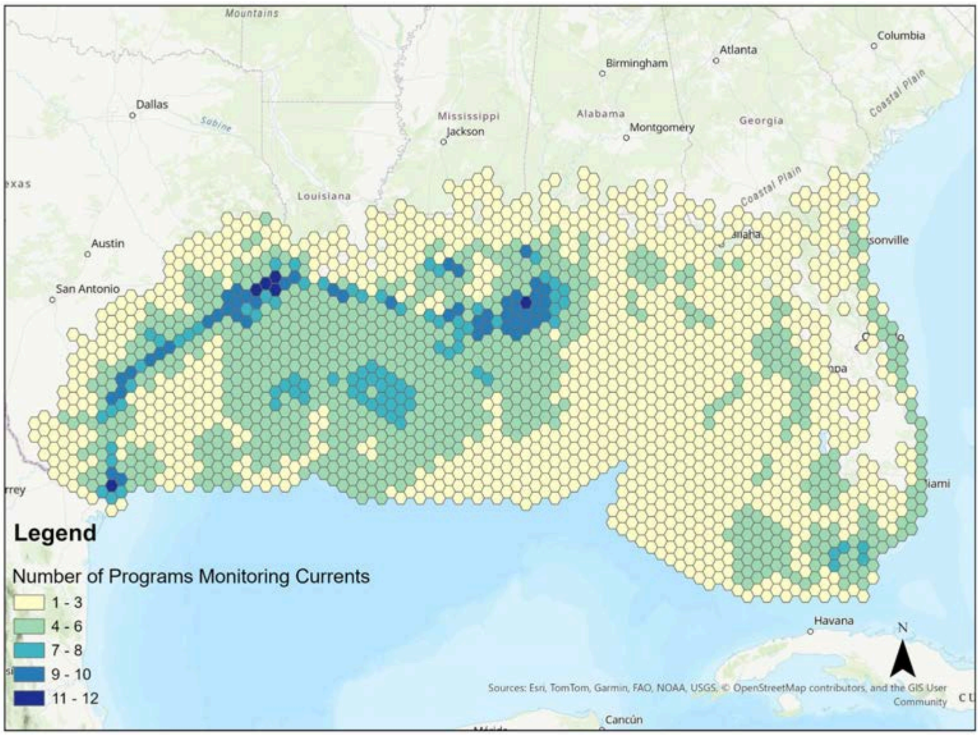

Figure D6. Map visualizing the number of monitoring programs monitoring currents across the Gulf.

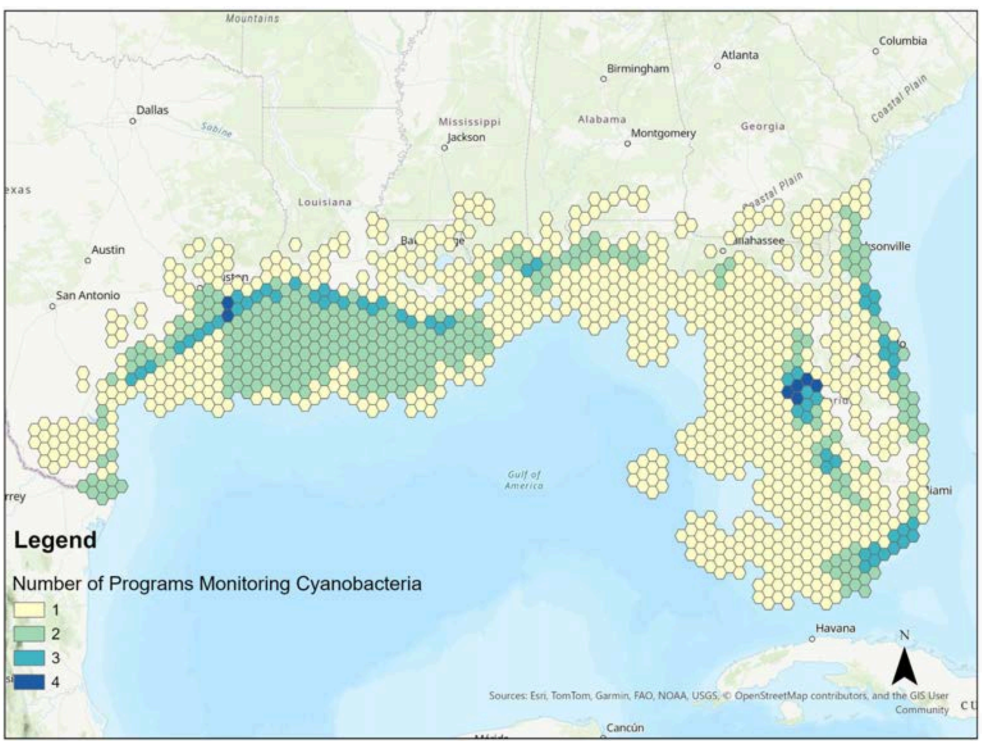

Figure D7. Map visualizing the number of monitoring programs monitoring cyanobacteria across the Gulf.

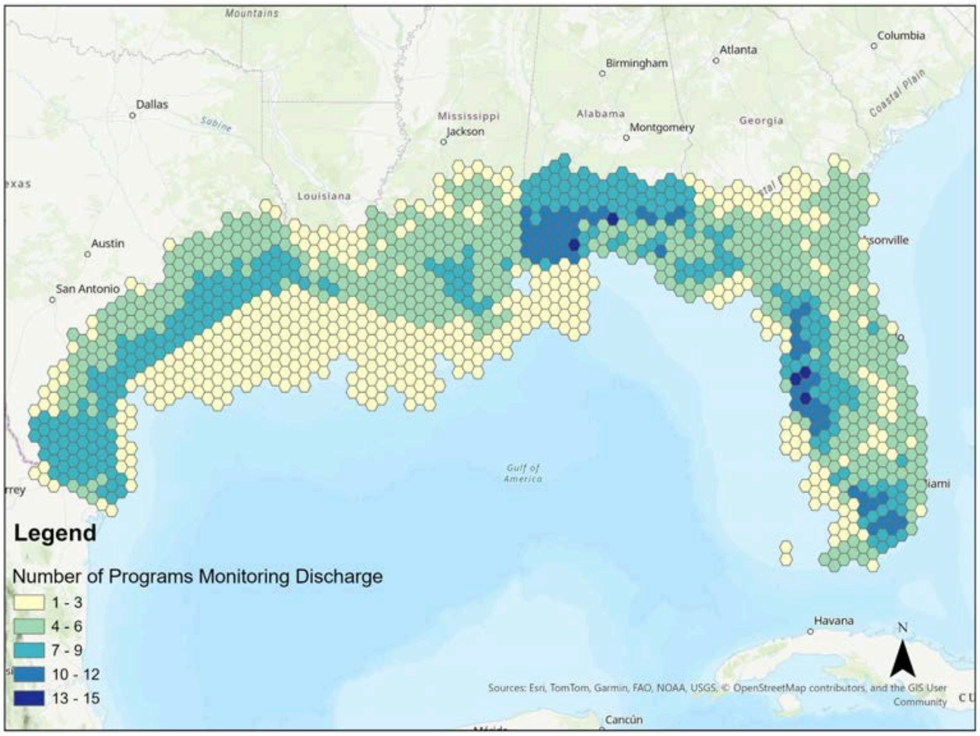

Figure D8. Map visualizing the number of monitoring programs monitoring discharge across the Gulf.

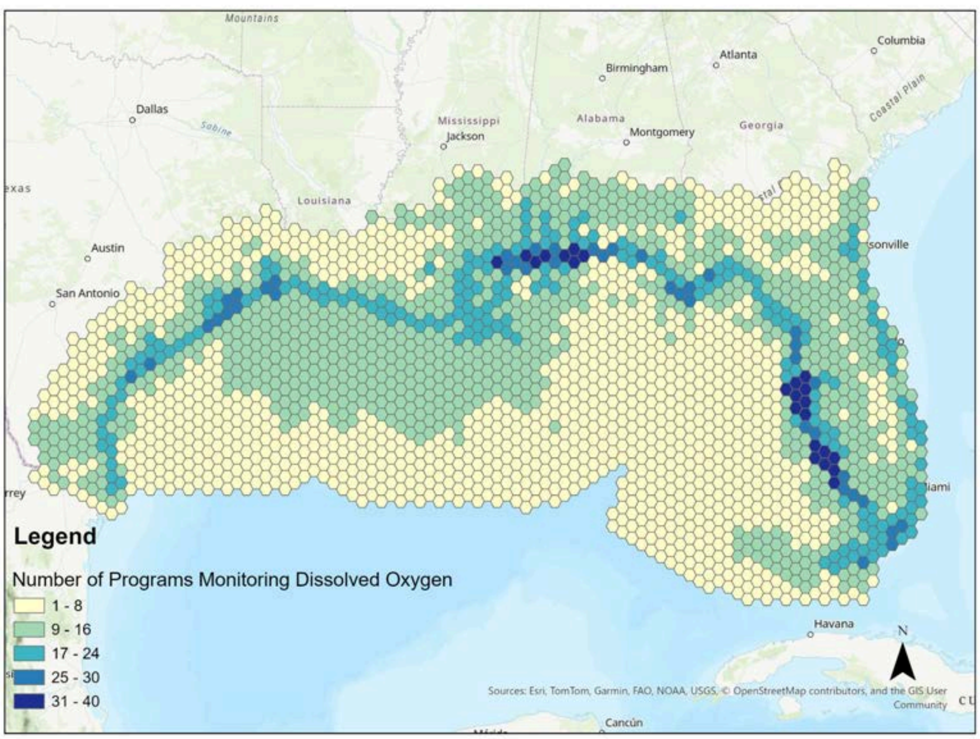

Figure D9. Map visualizing the number of monitoring programs monitoring dissolved oxygen across the Gulf.

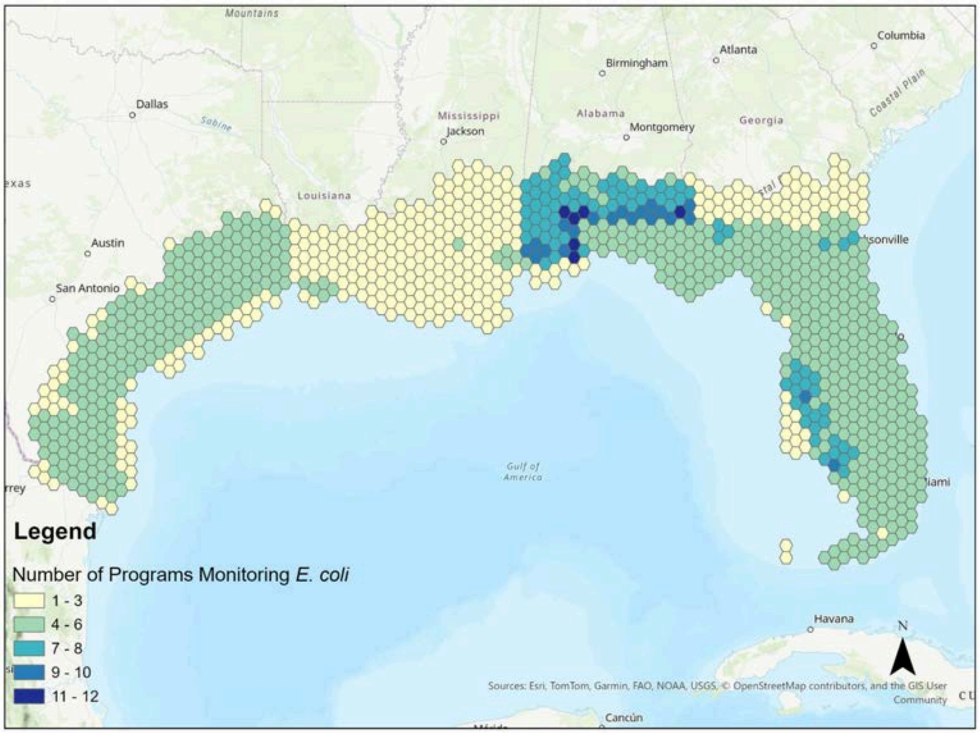

Figure D10. Map visualizing the number of monitoring programs monitoring *E. coli* across the Gulf.

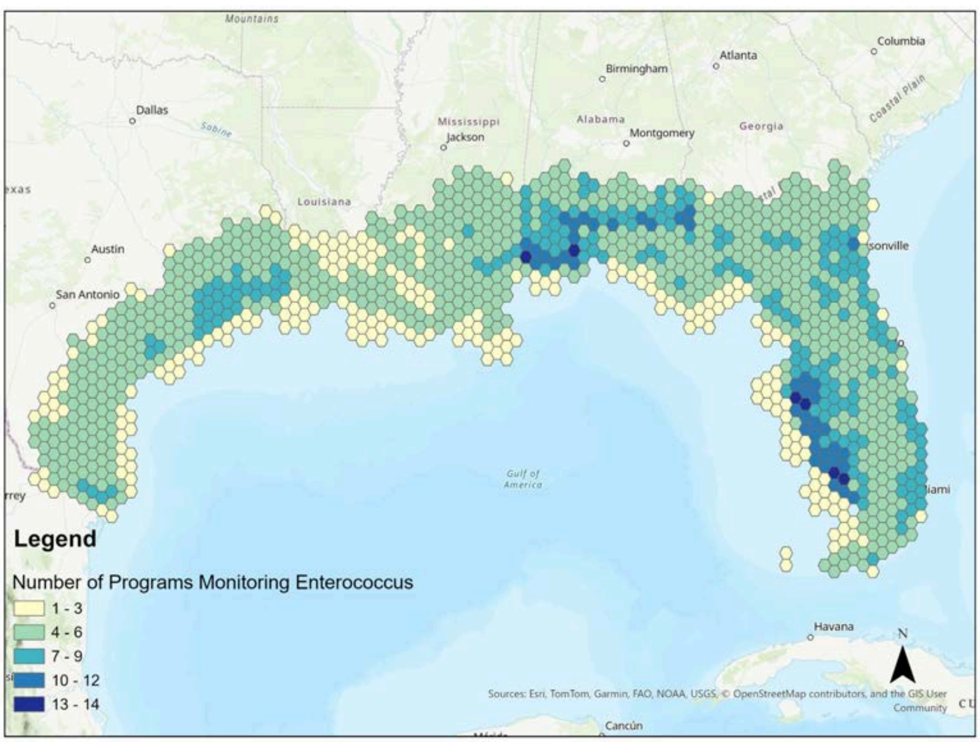

Figure D11. Map visualizing the number of monitoring programs monitoring *Enterococcus* across the Gulf.

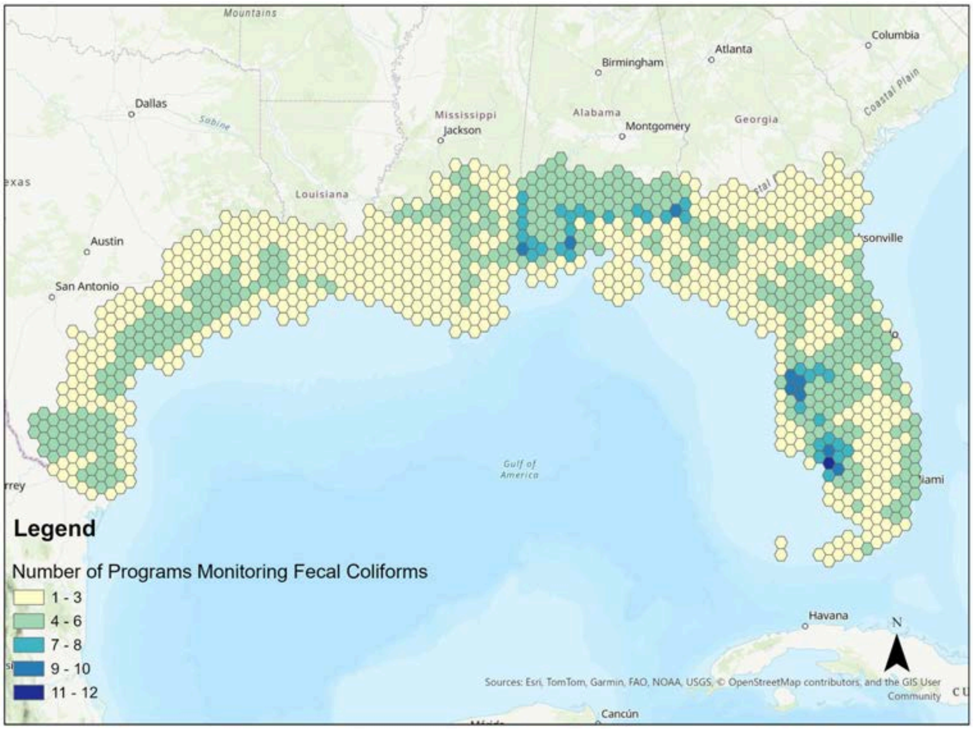

Figure D12. Map visualizing the number of monitoring programs monitoring fecal coliforms across the Gulf.

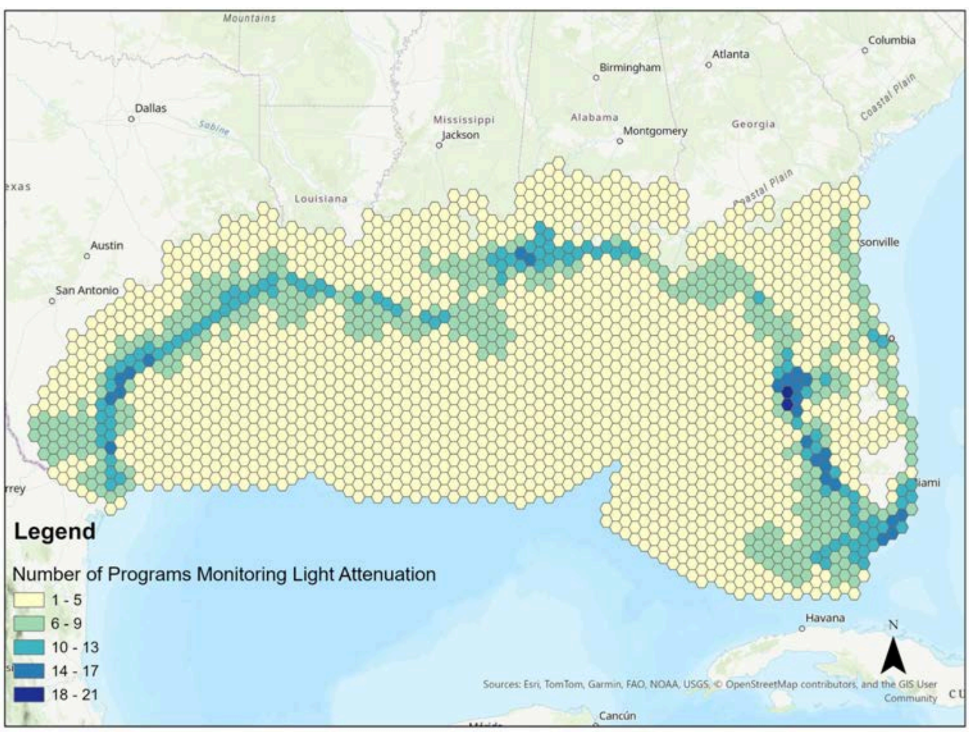

Figure D13. Map visualizing the number of monitoring programs monitoring light attenuation across the Gulf.

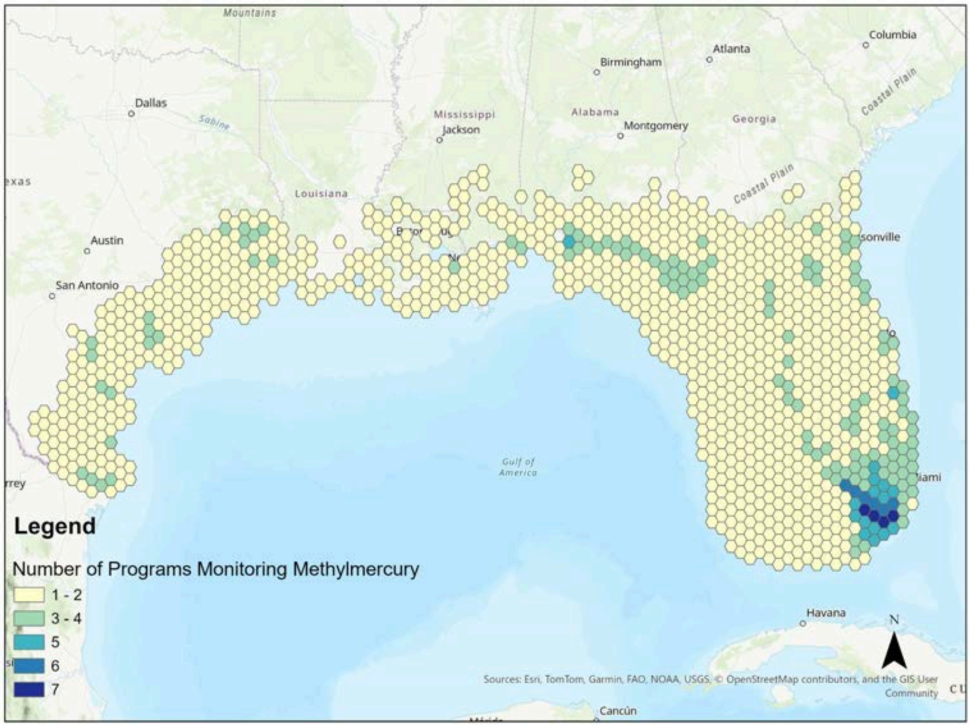

Figure D14. Map visualizing the number of monitoring programs monitoring methylmercury across the Gulf.

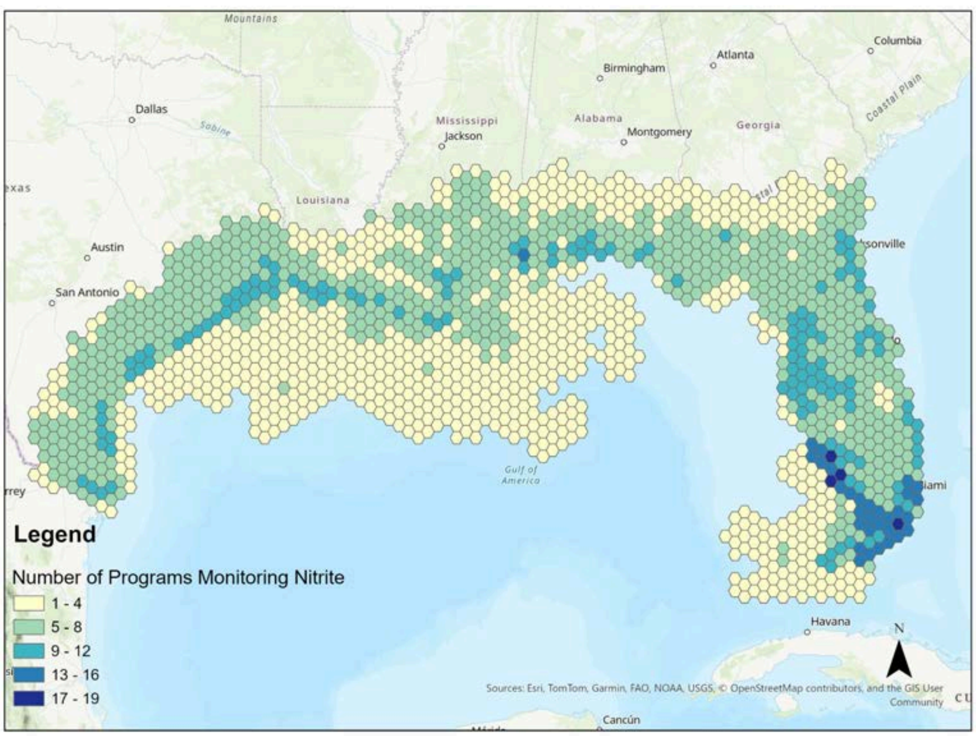

Figure D15. Map visualizing the number of monitoring programs monitoring nitrite across the Gulf.

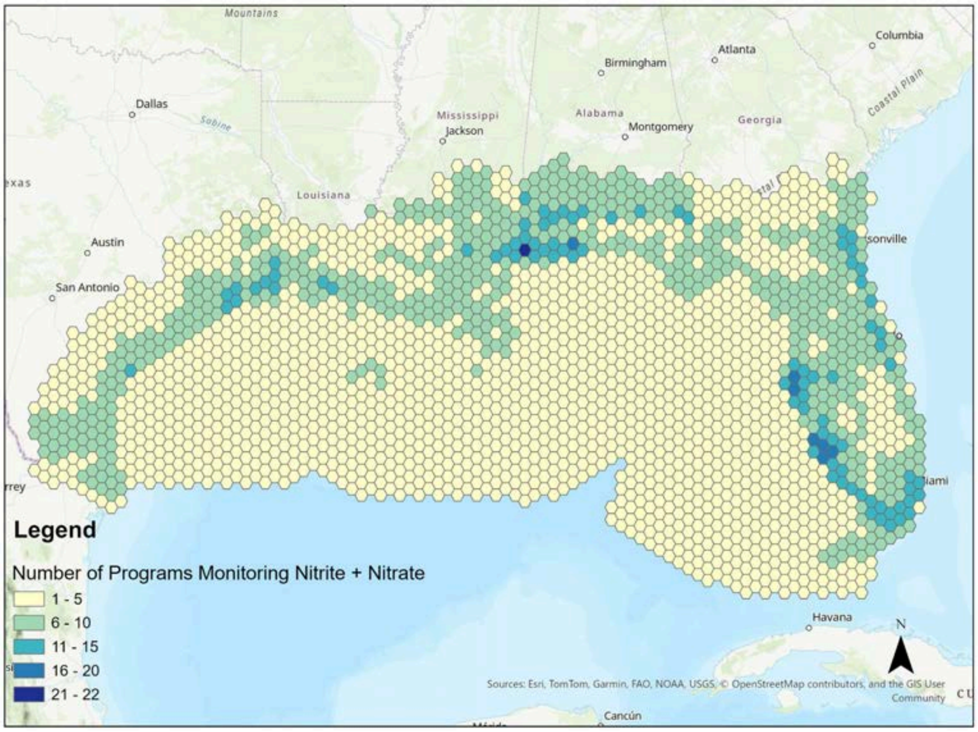

Figure D16. Map visualizing the number of monitoring programs monitoring nitrite + nitrate across the Gulf.

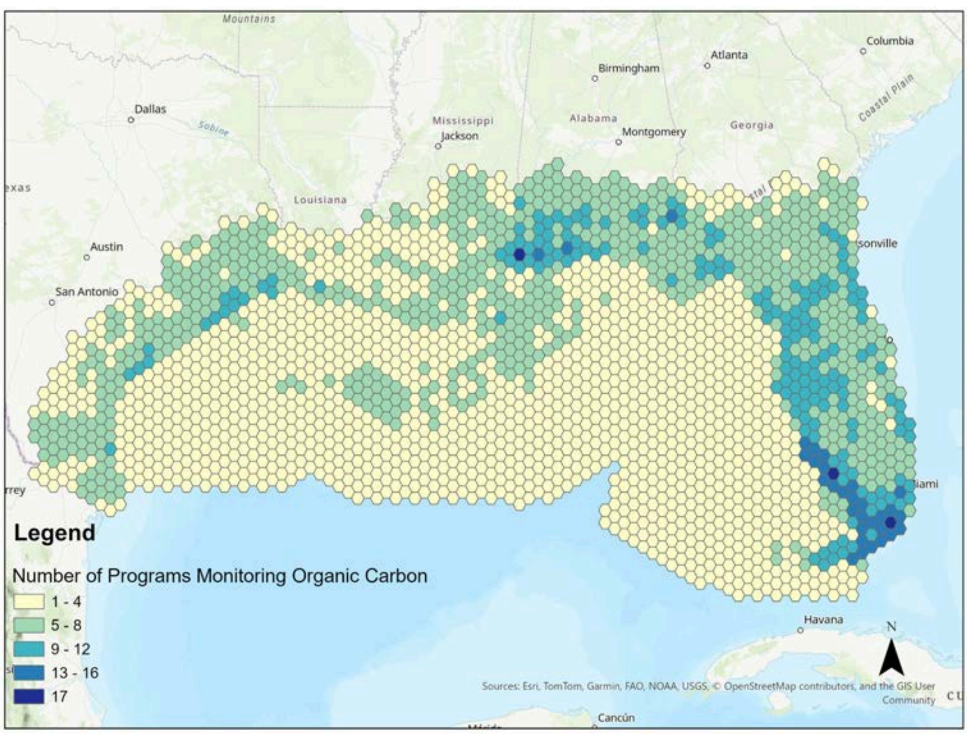

Figure D17. Map visualizing the number of monitoring programs monitoring organic carbon across the Gulf.

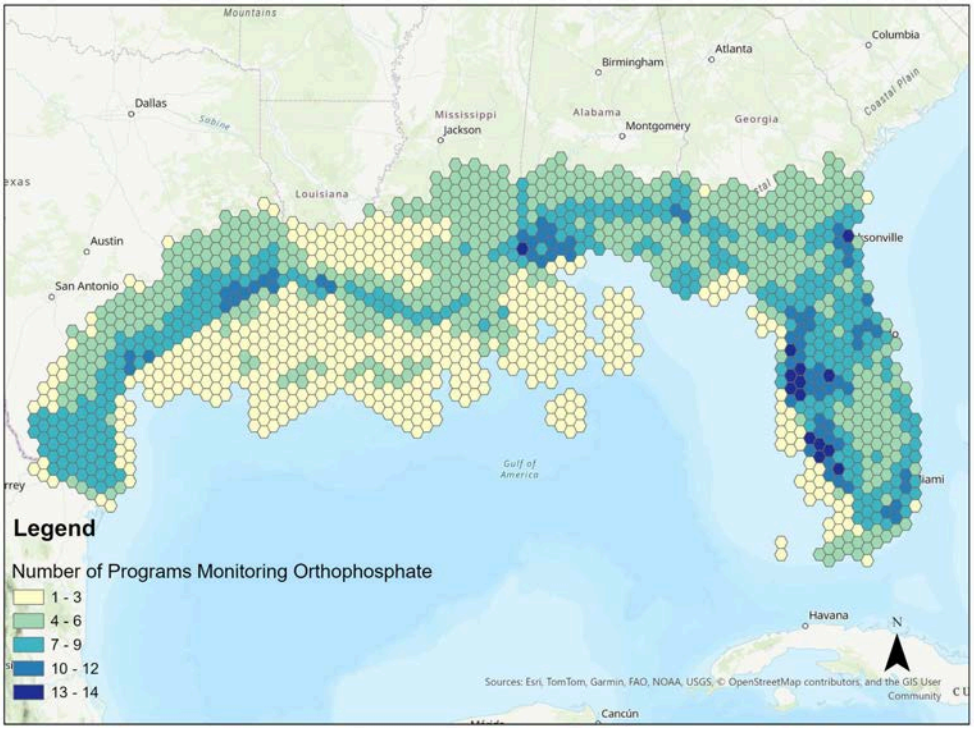

Figure D18. Map visualizing the number of monitoring programs monitoring orthophosphate across the Gulf.

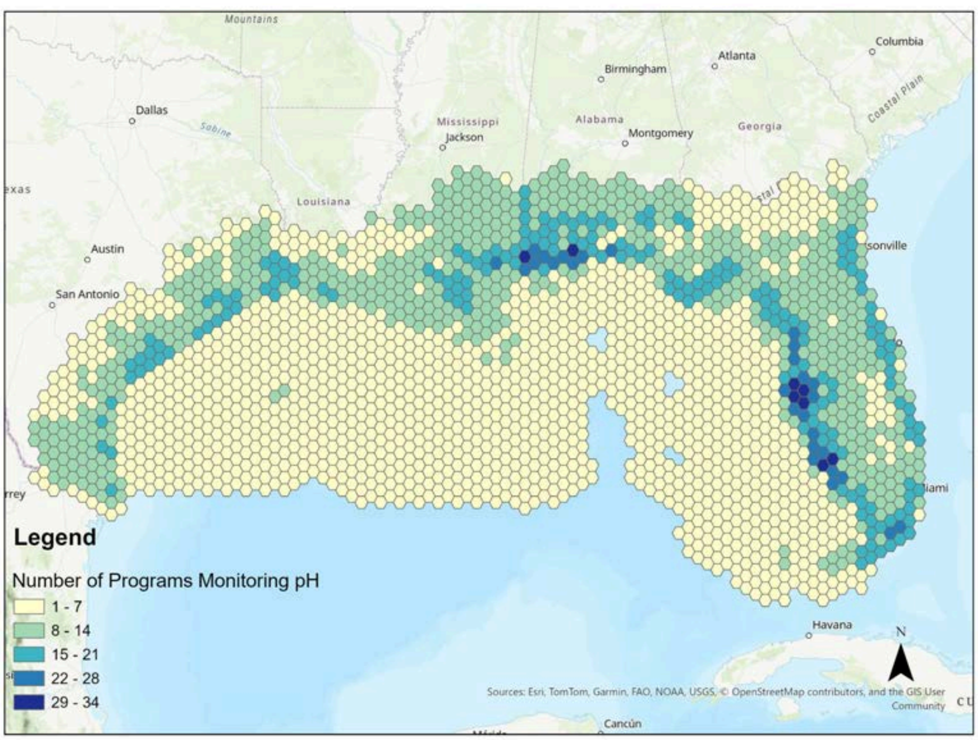

Figure D19. Map visualizing the number of monitoring programs monitoring pH across the Gulf.

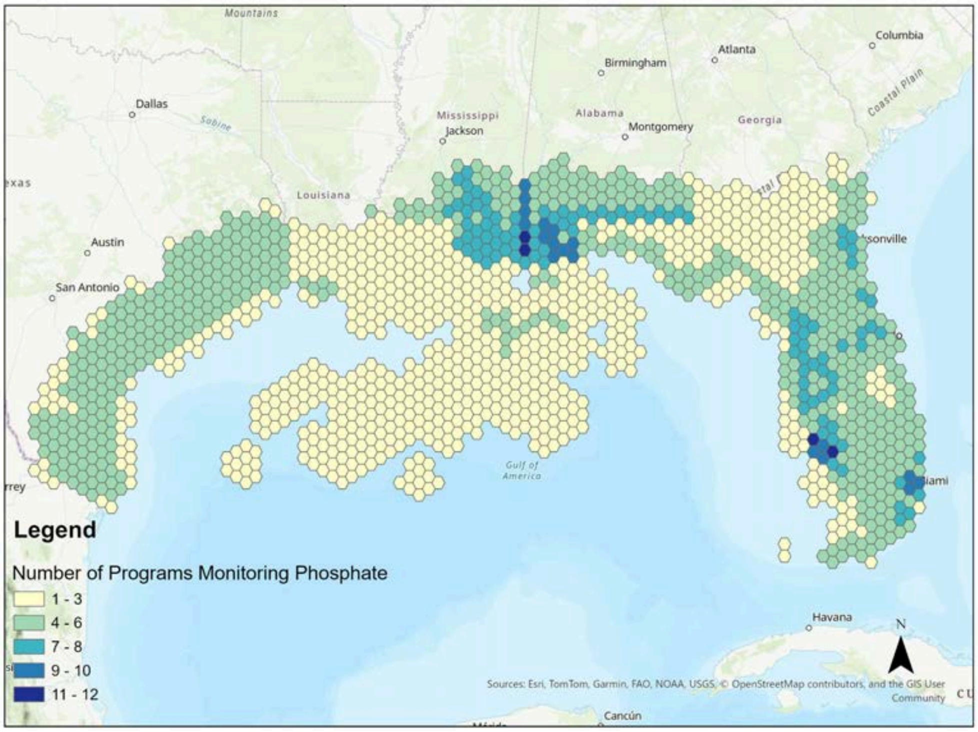

Figure D20. Map visualizing the number of monitoring programs monitoring phosphate across the Gulf.

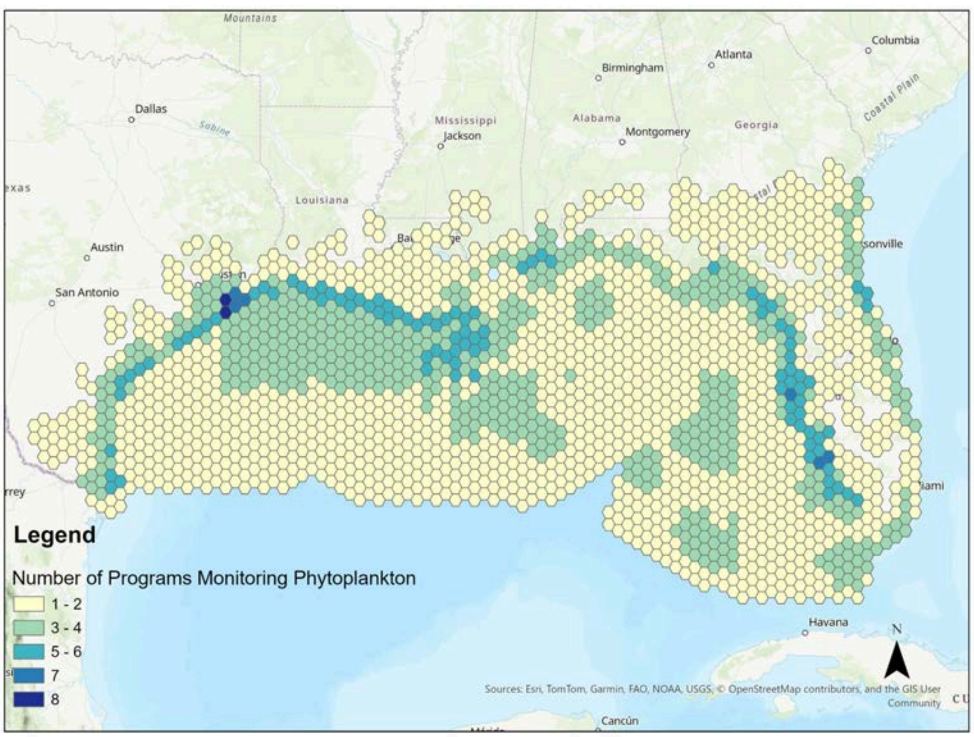

Figure D21. Map visualizing the number of monitoring programs monitoring phytoplankton across the Gulf.

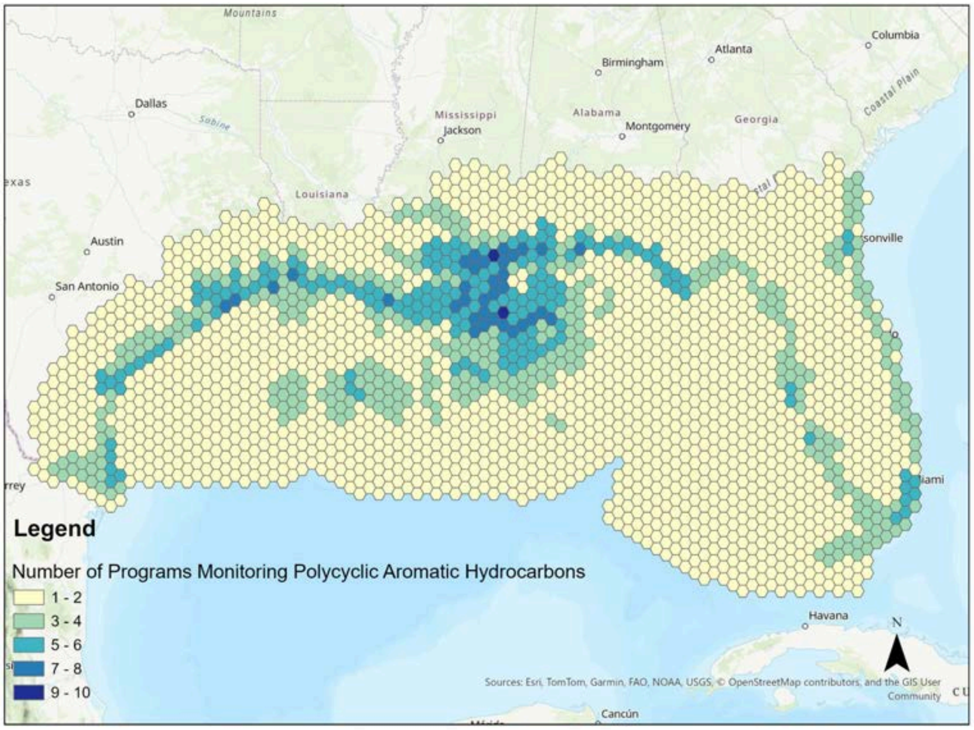

Figure D22. Map visualizing the number of monitoring programs monitoring polycyclic aromatic hydrocarbons across the Gulf.

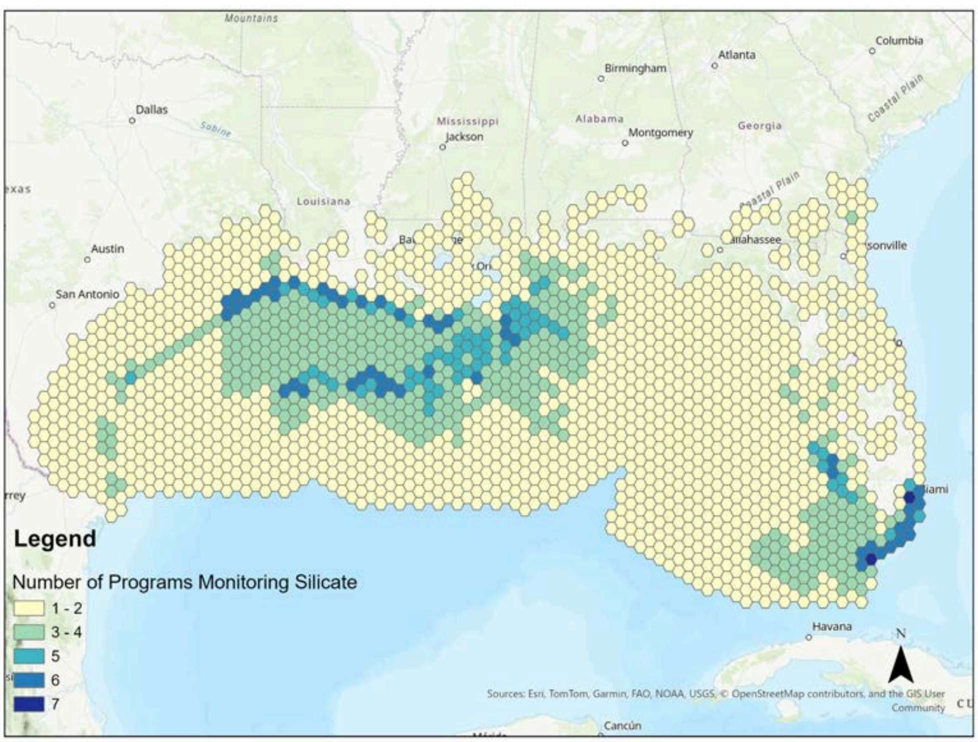

Figure D23. Map visualizing the number of monitoring programs monitoring silicate across the Gulf.

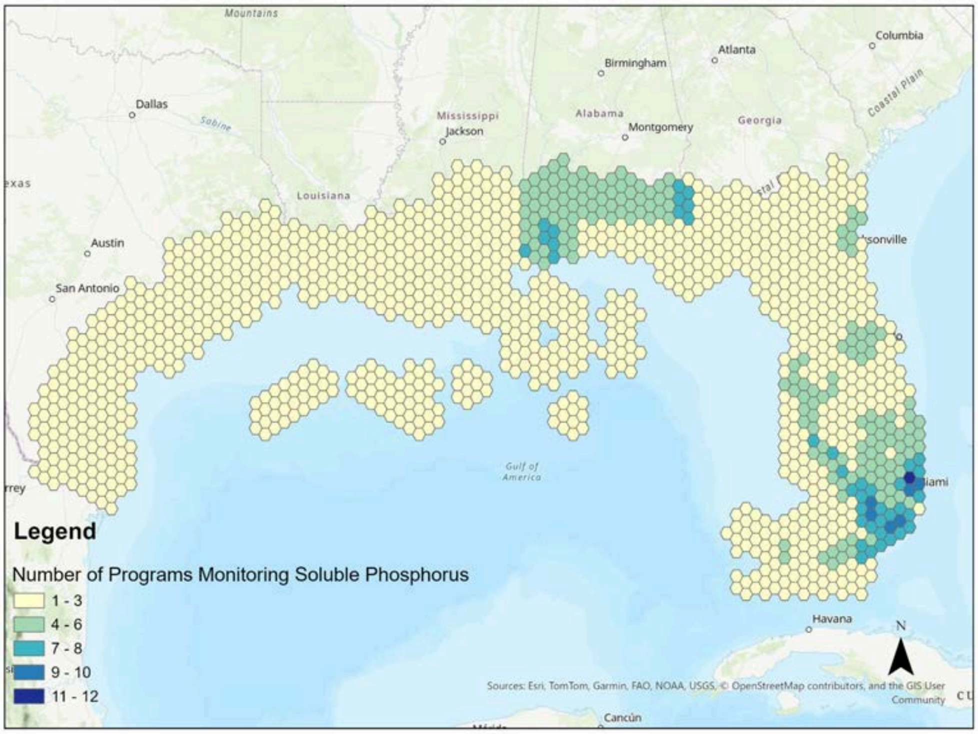

Figure D24. Map visualizing the number of monitoring programs monitoring soluble phosphorus across the Gulf.

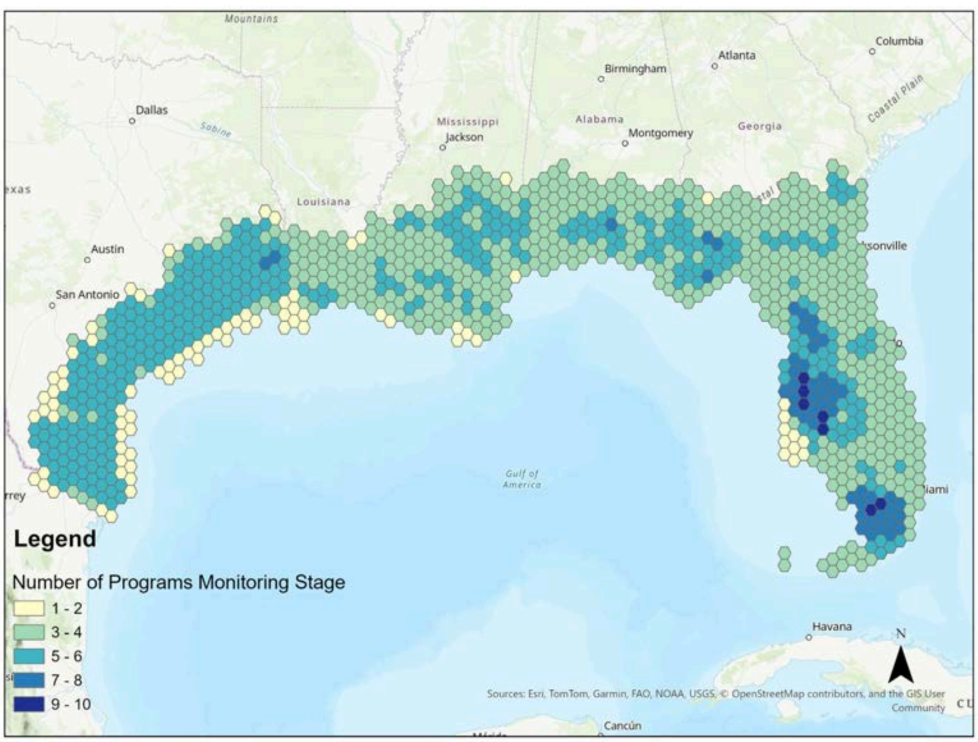

Figure D25. Map visualizing the number of monitoring programs monitoring stage across the Gulf.

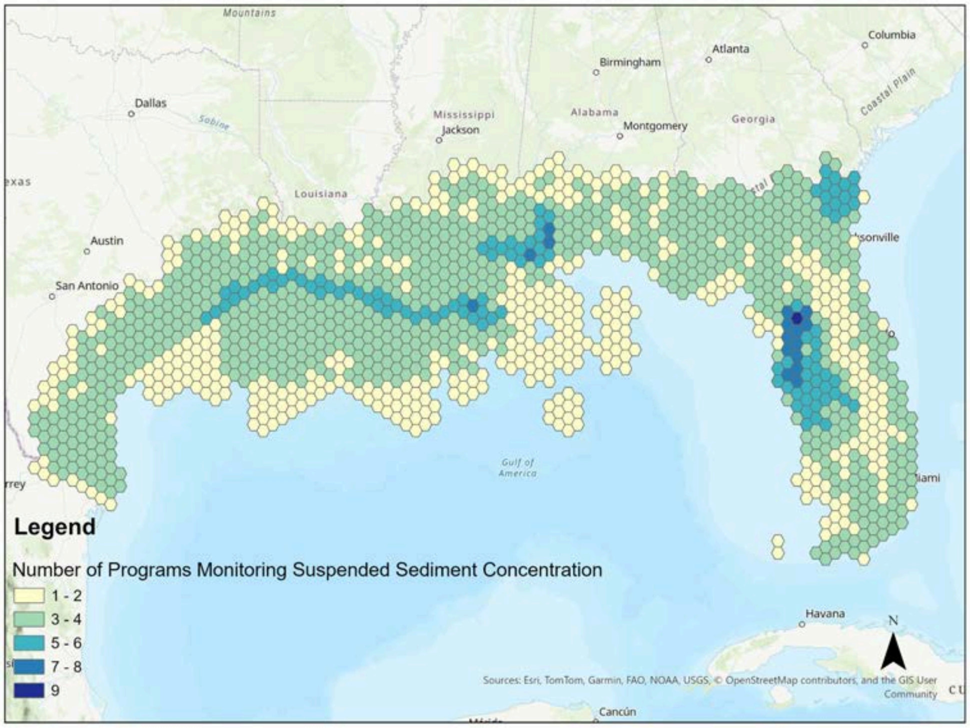

Figure D26. Map visualizing the number of monitoring programs monitoring suspended sediment concentration across the Gulf.

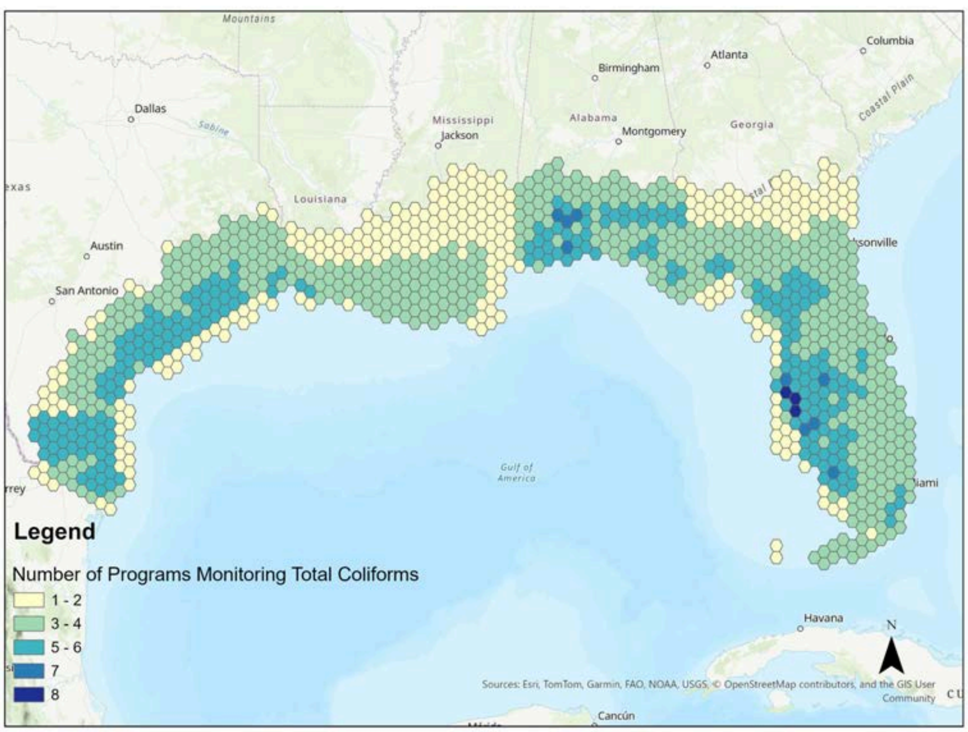

Figure D27. Map visualizing the number of monitoring programs monitoring total coliforms across the Gulf.

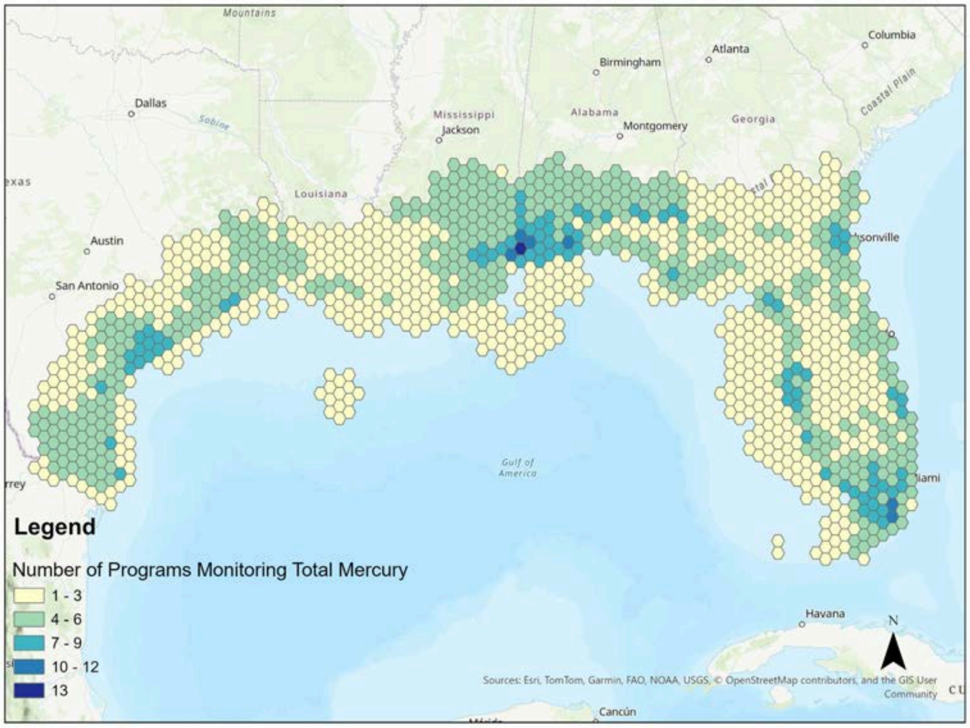

Figure D28. Map visualizing the number of monitoring programs monitoring total mercury across the Gulf.

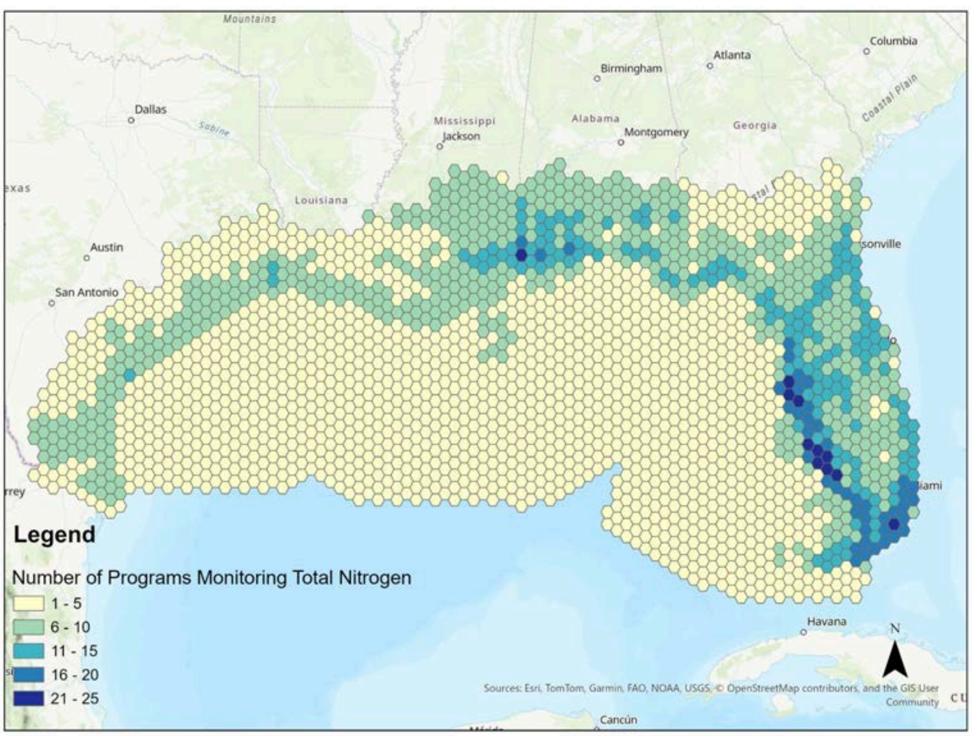

Figure D29. Map visualizing the number of monitoring programs monitoring total nitrogen across the Gulf.

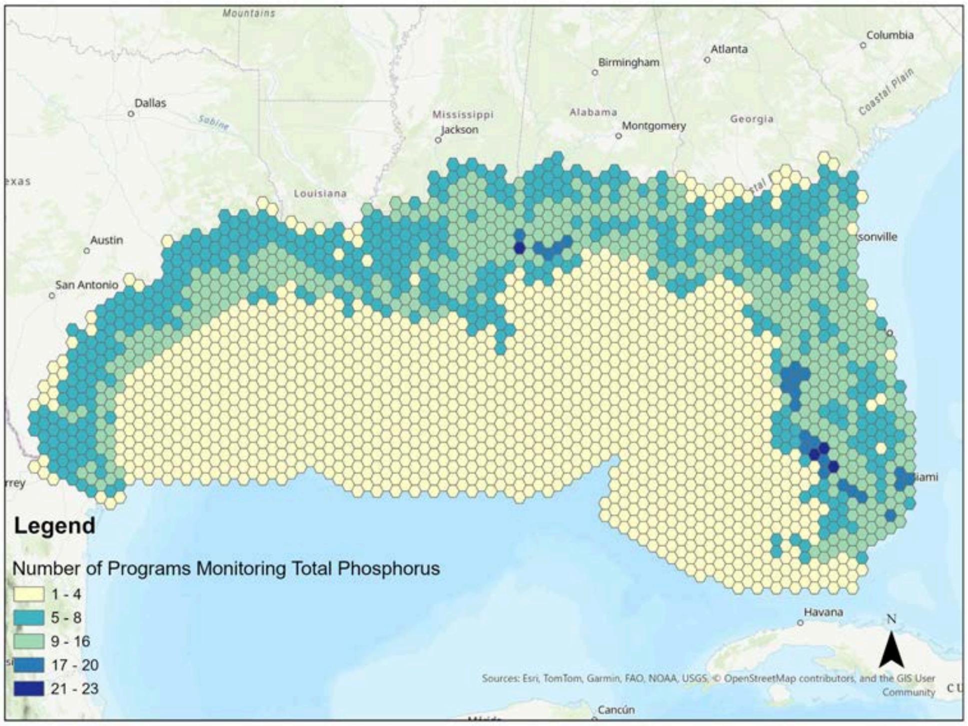

Figure D30. Map visualizing the number of monitoring programs monitoring total phosphorus across the Gulf.

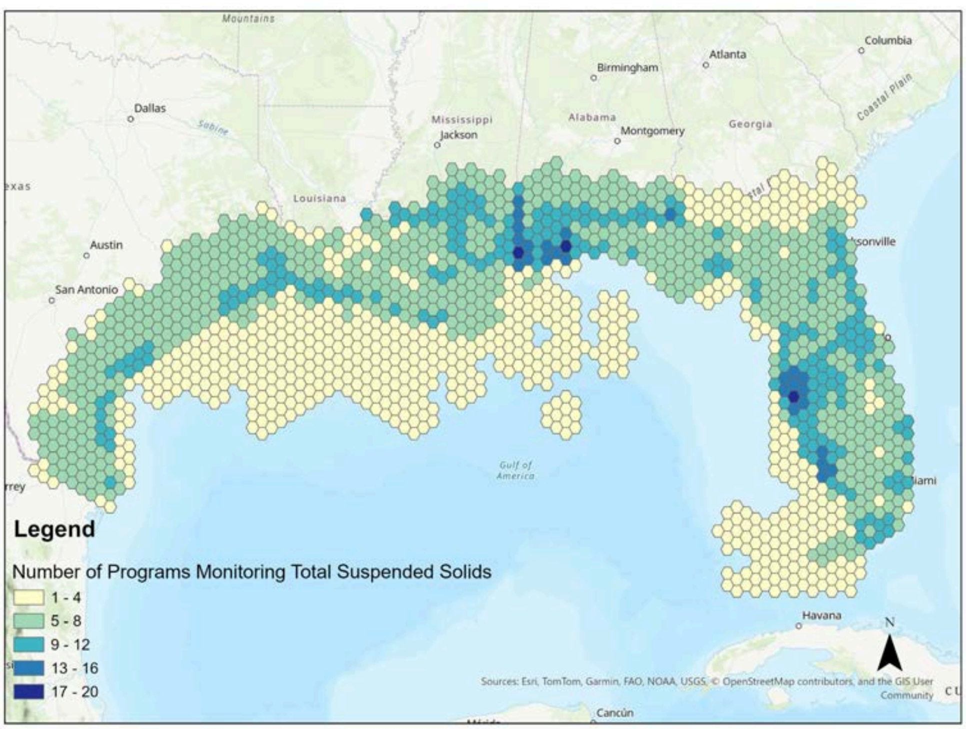

Figure D31. Map visualizing the number of monitoring programs monitoring total suspended solids across the Gulf.

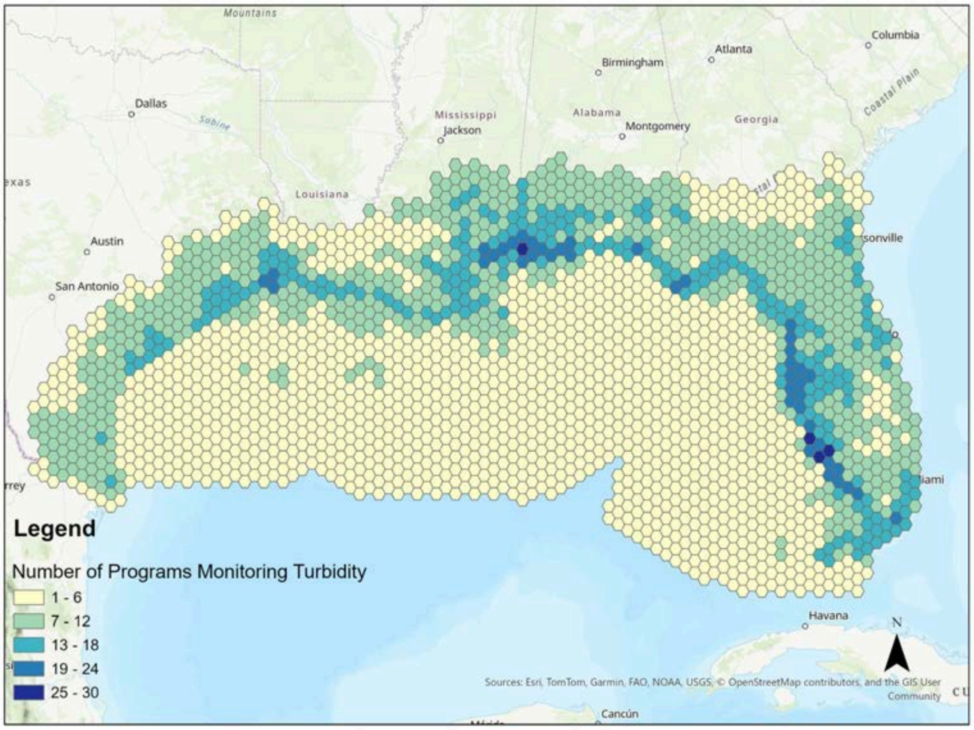

Figure D32. Map visualizing the number of monitoring programs monitoring turbidity across the Gulf.

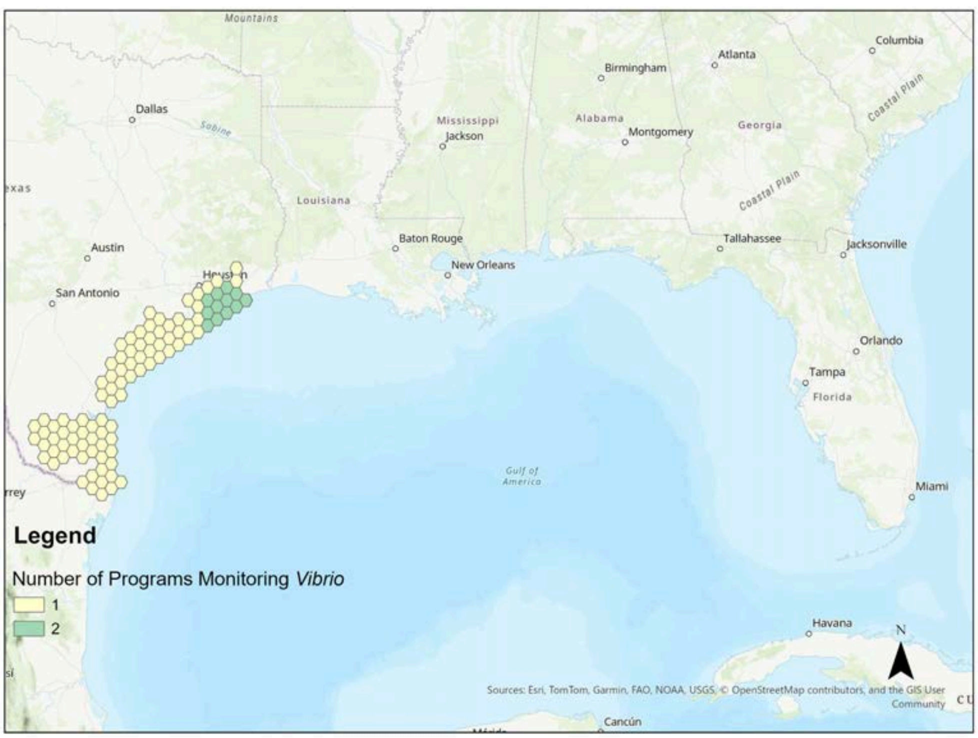

Figure D33. Map visualizing the number of monitoring programs monitoring *Vibrio* across the Gulf.

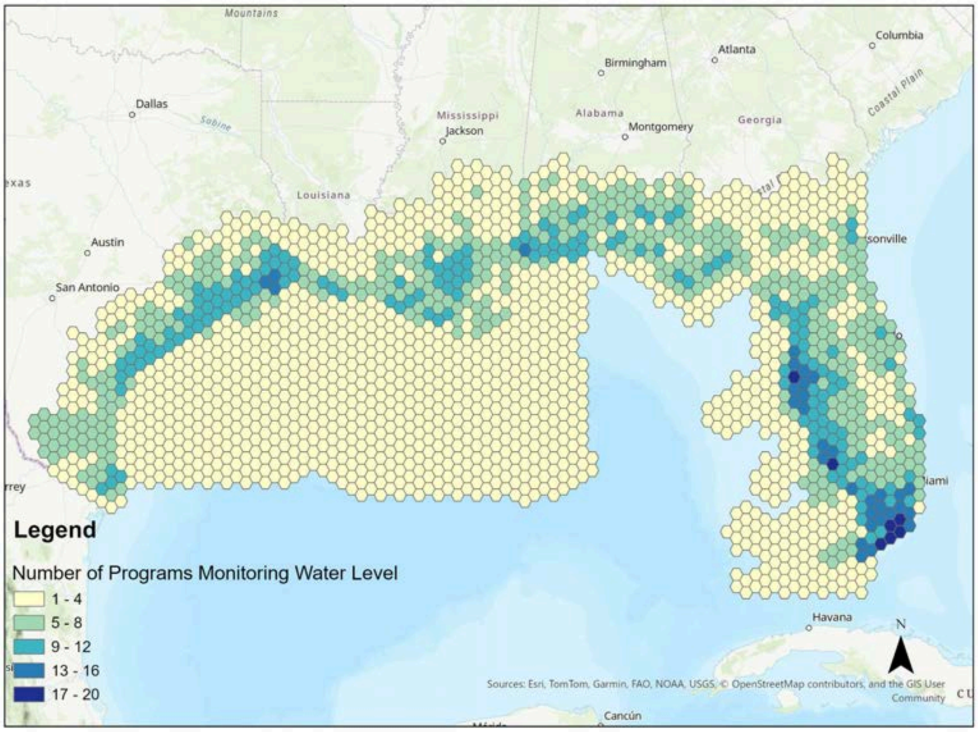

Figure D34. Map visualizing the number of monitoring programs monitoring water level across the Gulf.

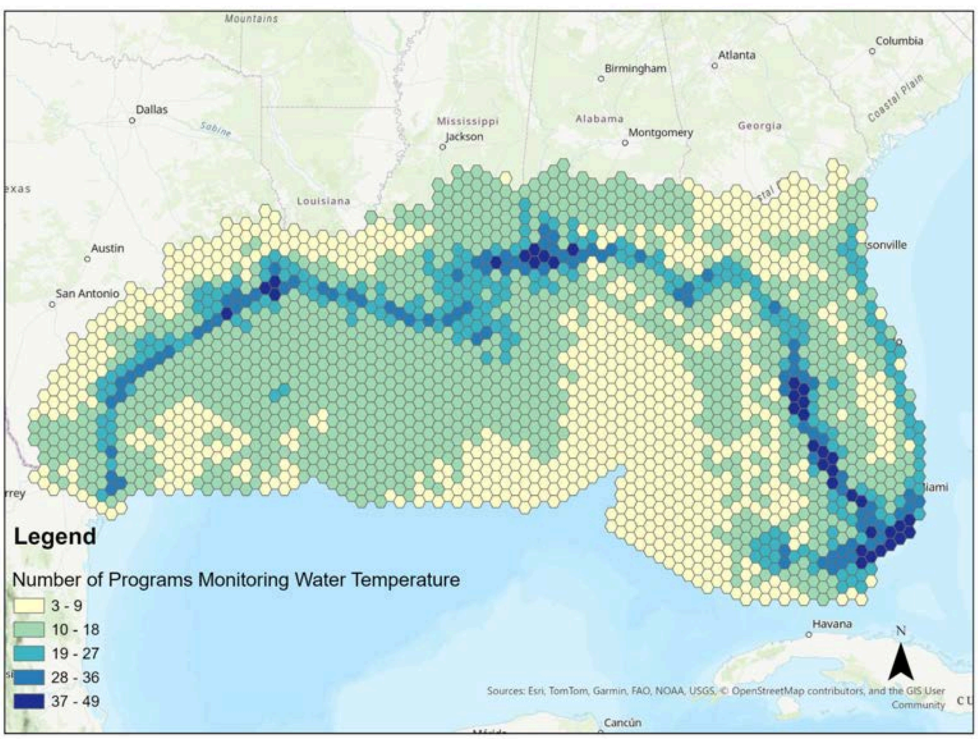

Figure D35. Map visualizing the number of monitoring programs monitoring water temperature across the Gulf.

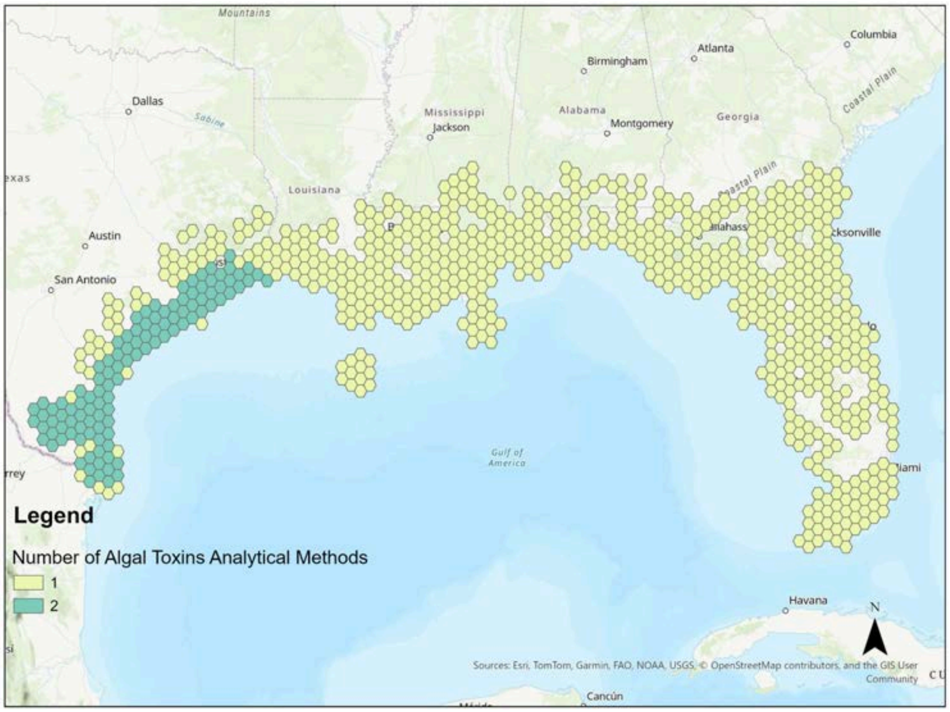

Figure D36. Map visualizing the number of analytical methods used to measure algal toxins across the Gulf.

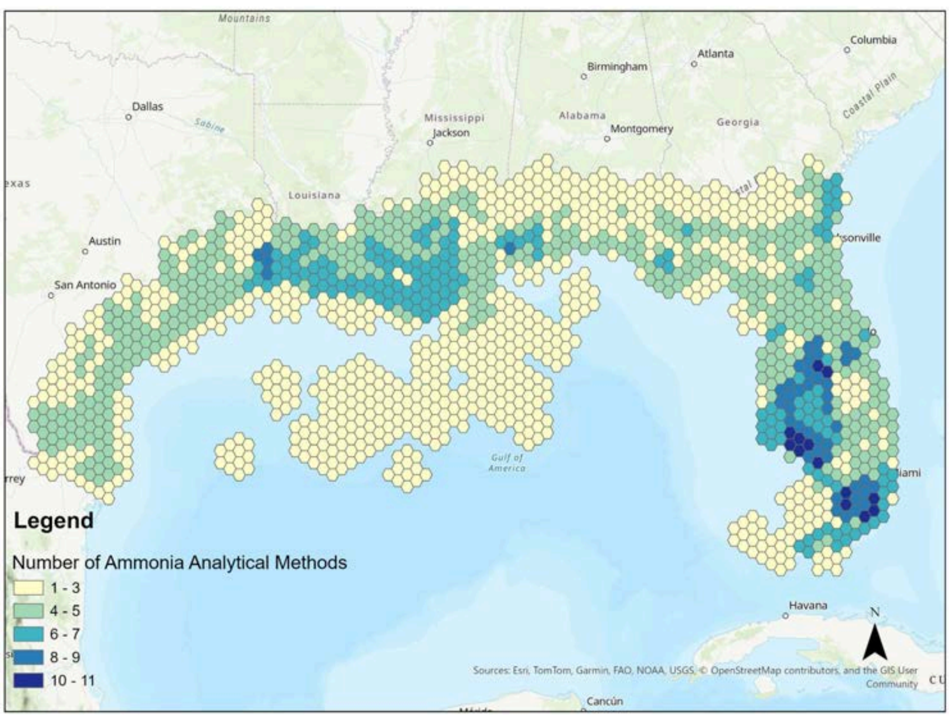

Figure D37. Map visualizing the number of analytical methods used to measure ammonia across the Gulf.

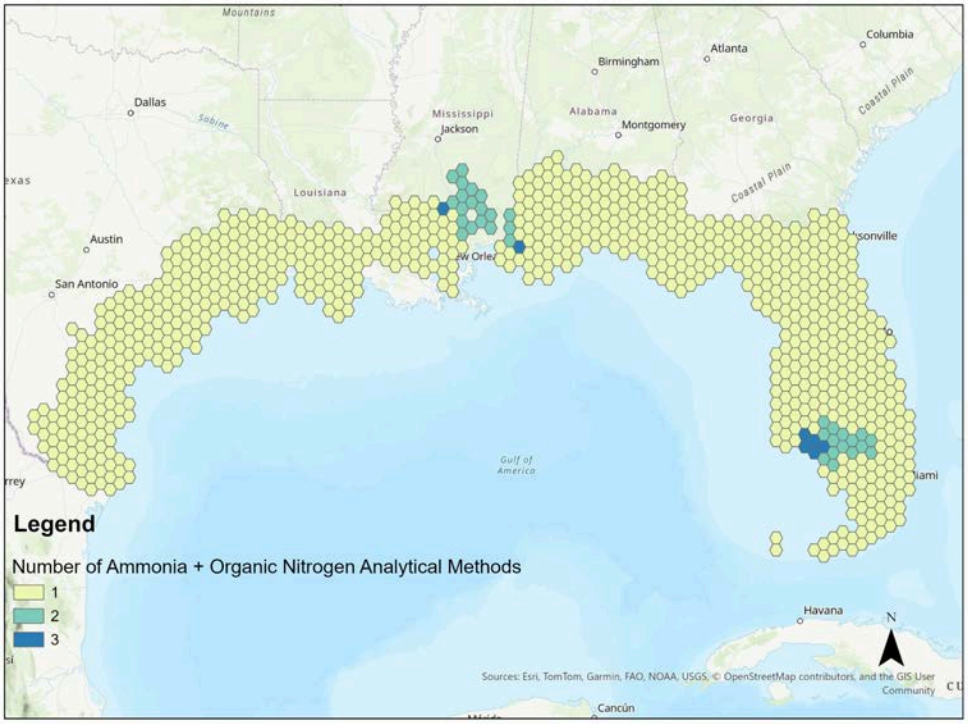

Figure D38. Map visualizing the number of analytical methods used to measure ammonia + organic nitrogen across the Gulf.

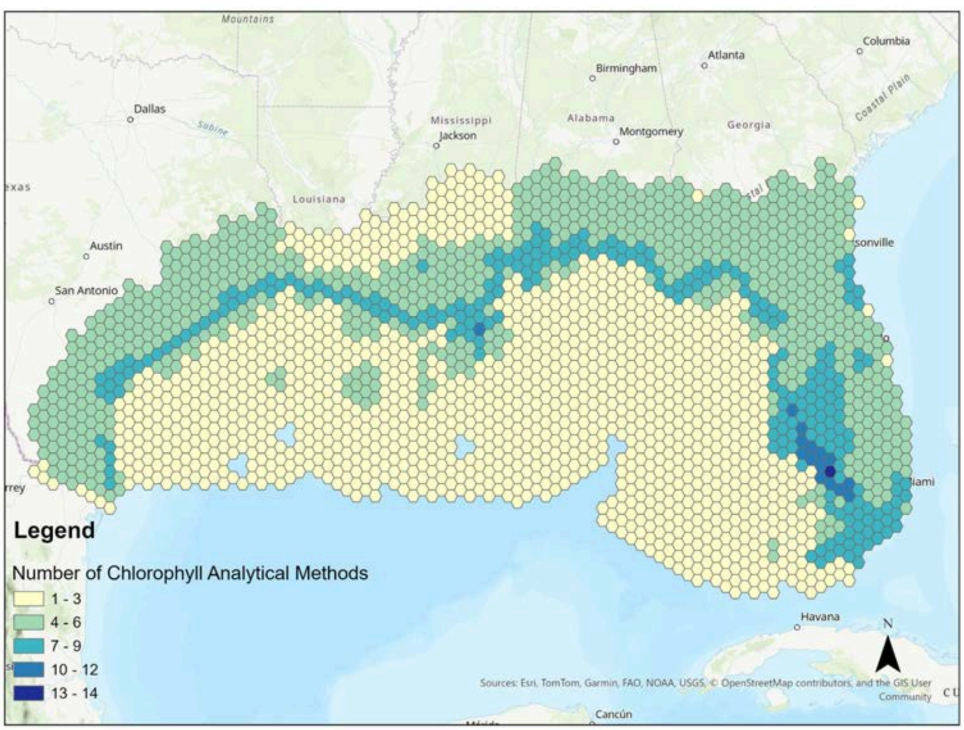

Figure D39. Map visualizing the number of analytical methods used to measure chlorophyll across the Gulf.

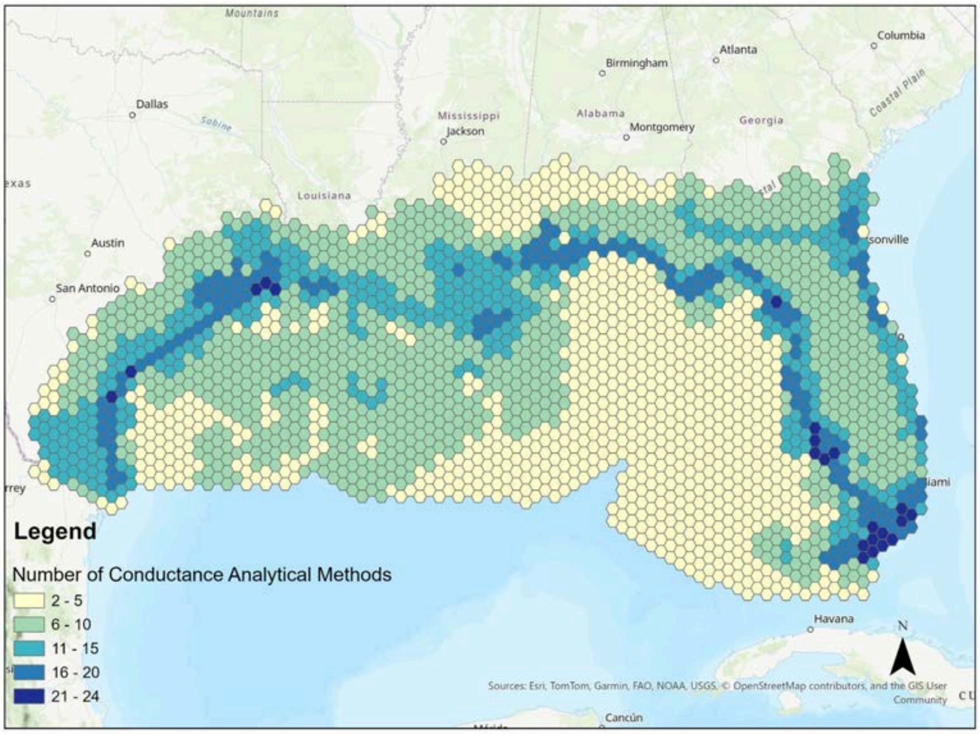

Figure D40. Map visualizing the number of analytical methods used to measure conductance across the Gulf.

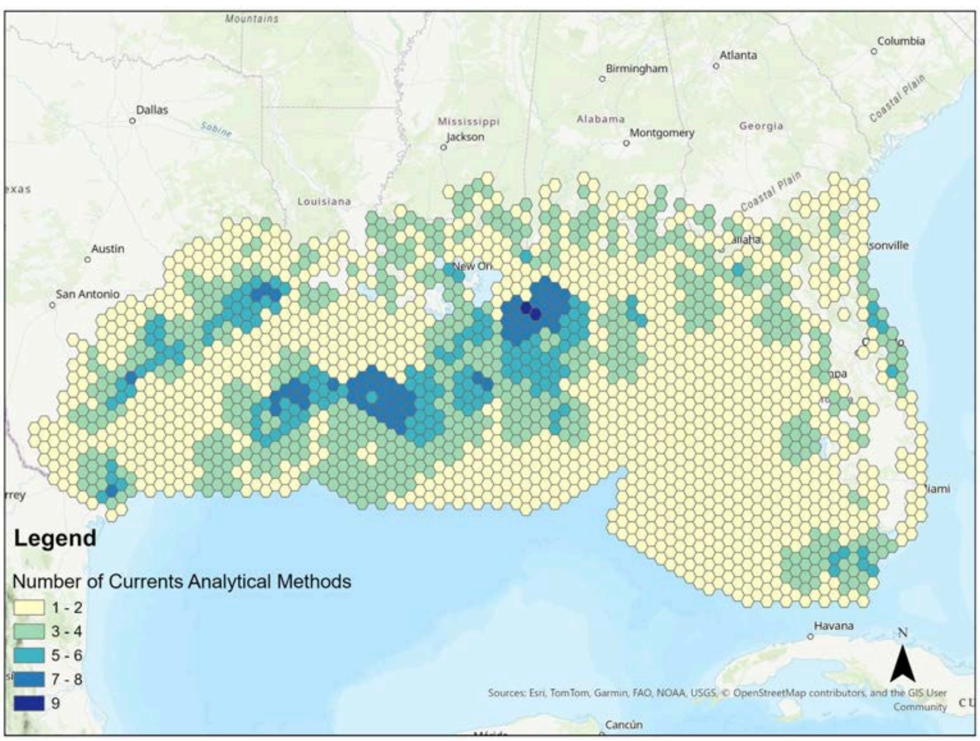

Figure D41. Map visualizing the number of analytical methods used to measure currents across the Gulf.

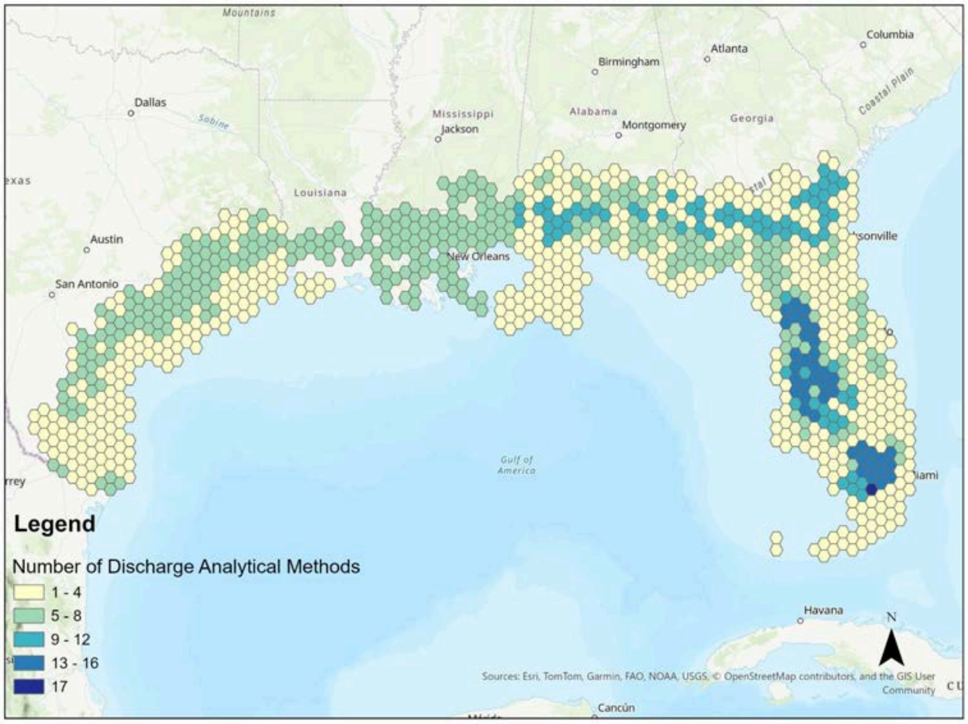

Figure D42. Map visualizing the number of analytical methods used to measure discharge across the Gulf.

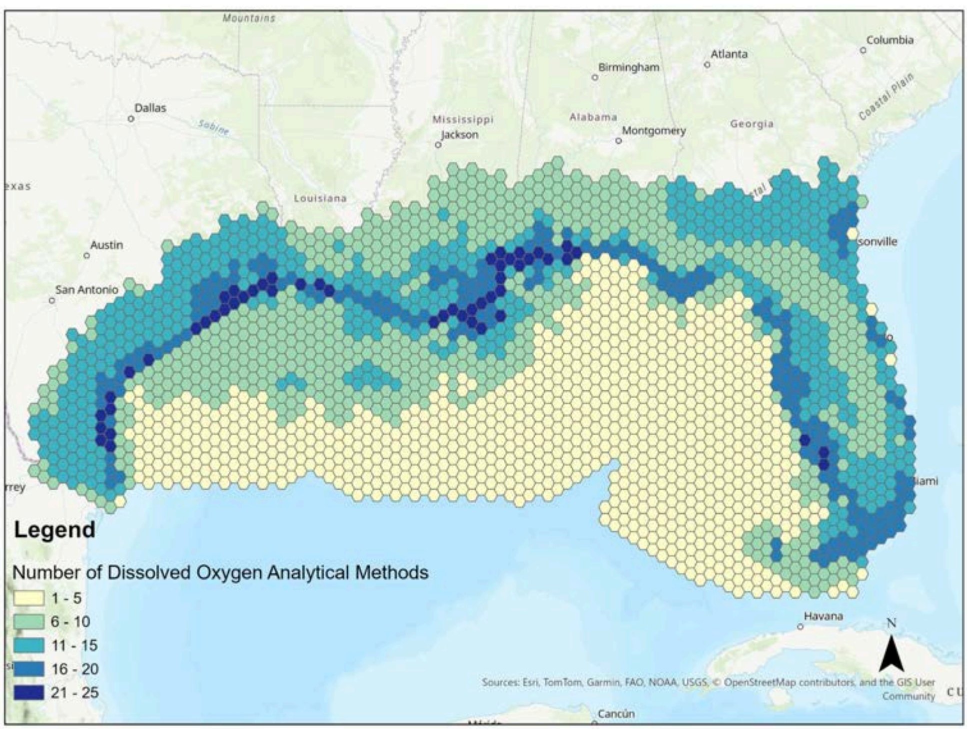

Figure D43. Map visualizing the number of analytical methods used to measure dissolved oxygen across the Gulf.

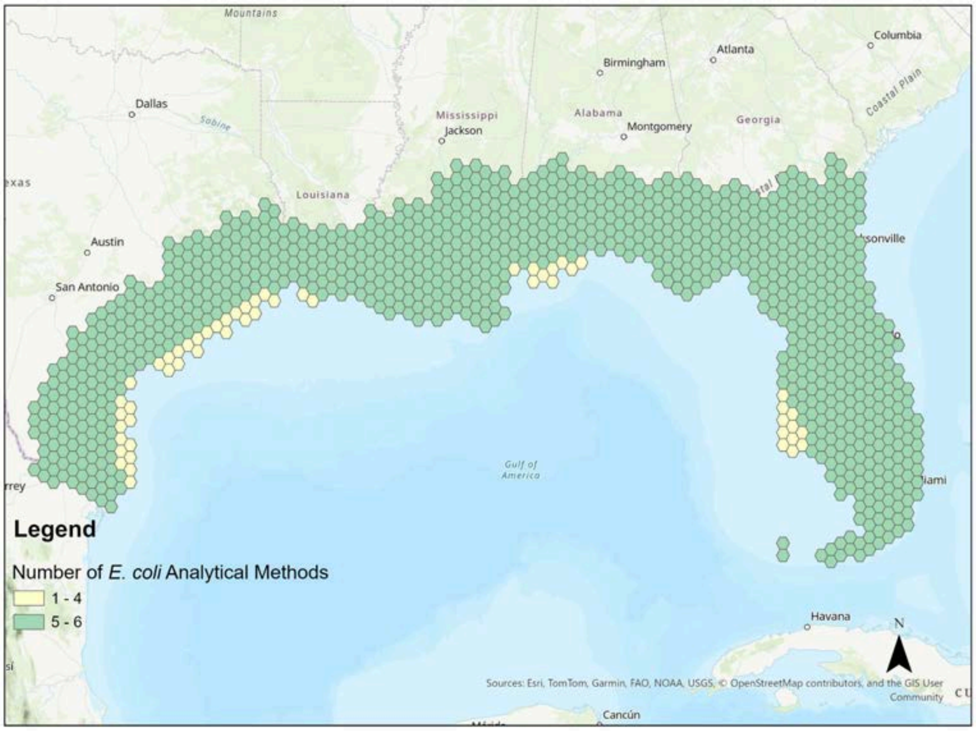

Figure D44. Map visualizing the number of analytical methods used to measure *E. coli* across the Gulf.

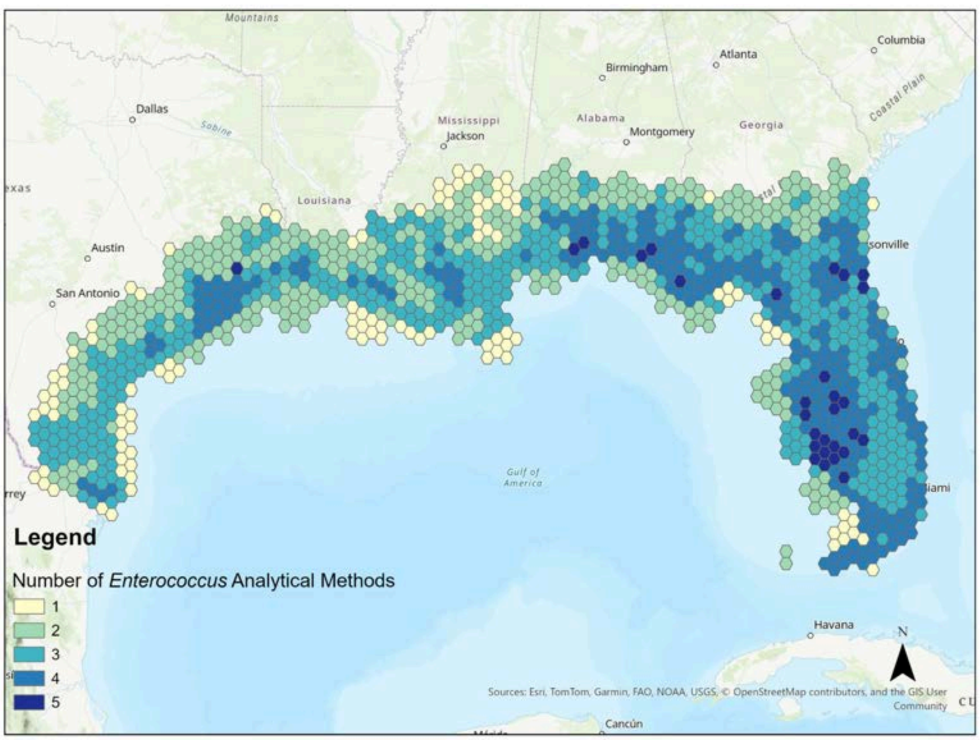

Figure D45. Map visualizing the number of analytical methods used to measure *Enterococcus* across the Gulf.

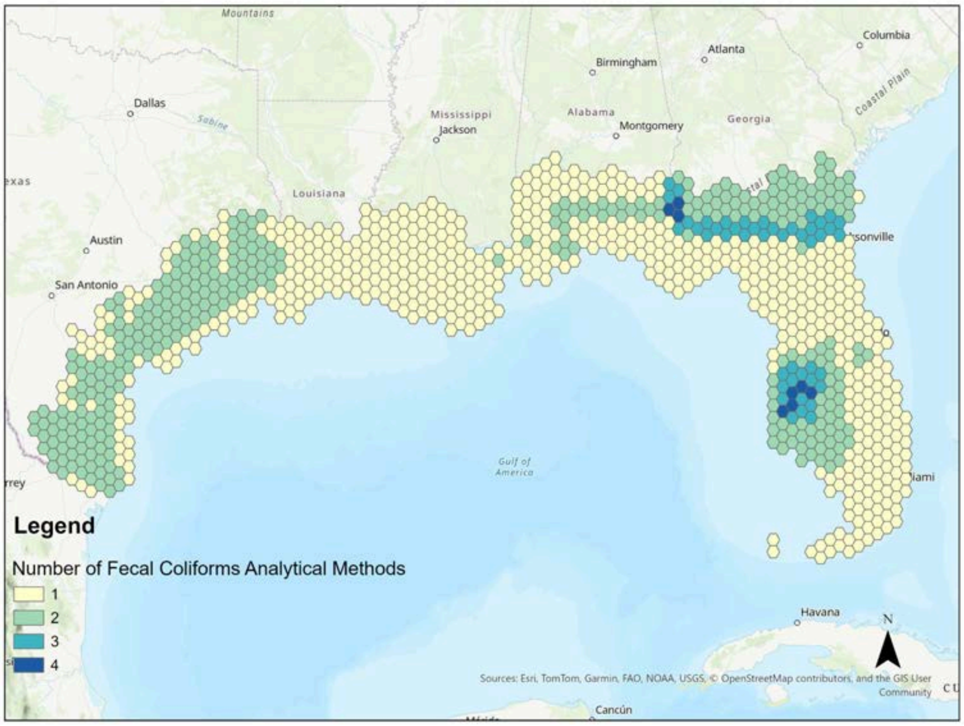

Figure D46. Map visualizing the number of analytical methods used to measure fecal coliforms across the Gulf.

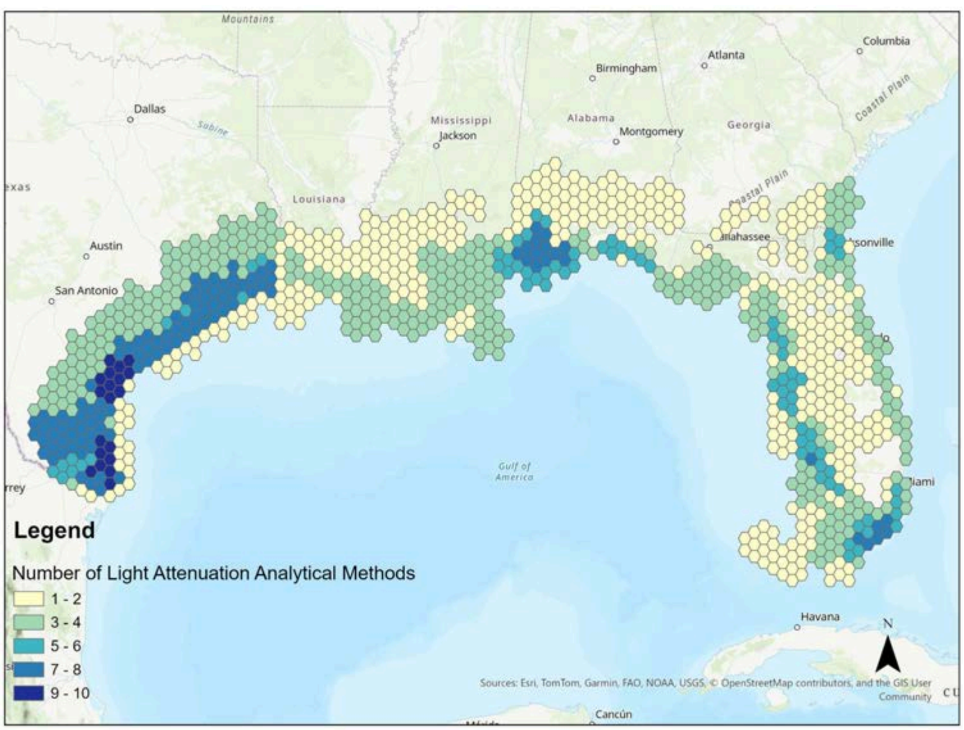

Figure D47. Map visualizing the number of analytical methods used to measure light attenuation across the Gulf.

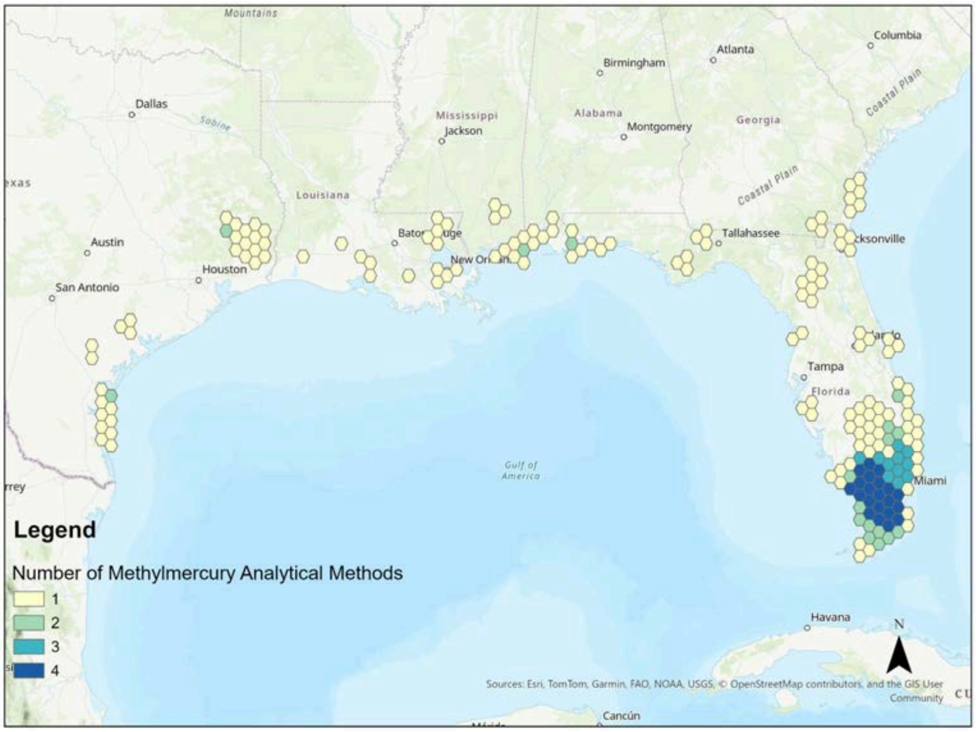

Figure D48. Map visualizing the number of analytical methods used to measure methylmercury across the Gulf.

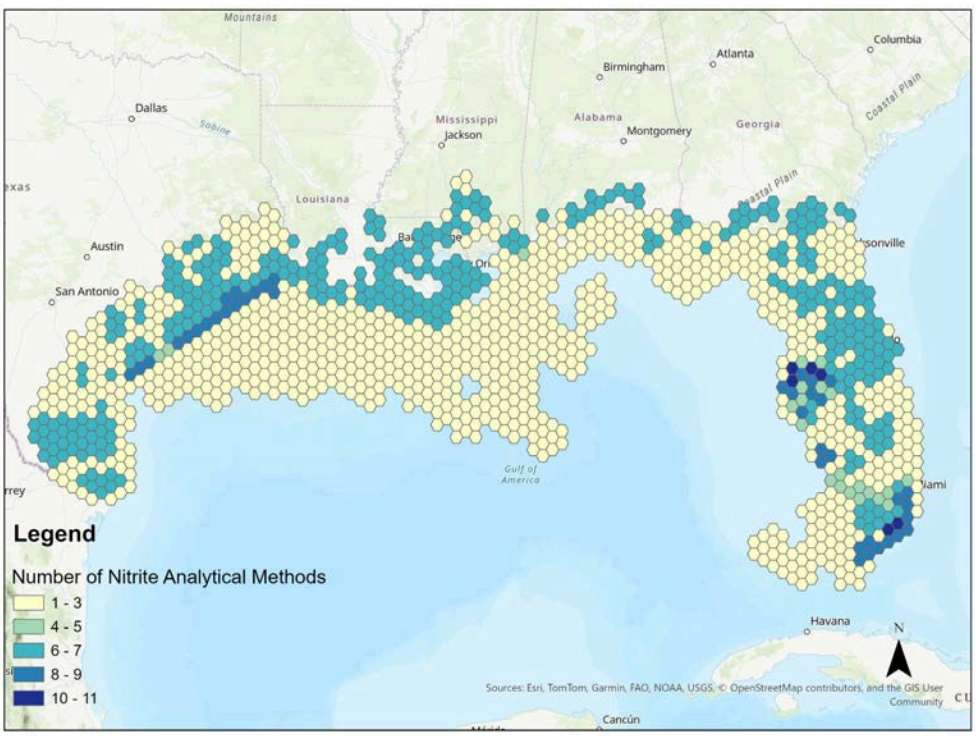

Figure D49. Map visualizing the number of analytical methods used to measure nitrite across the Gulf.

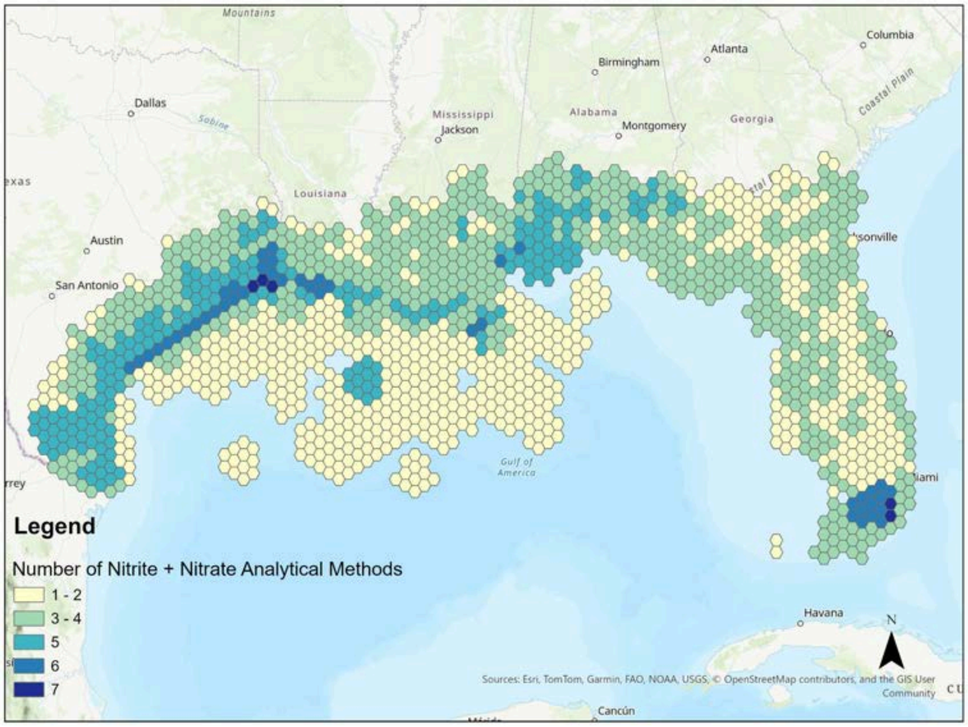

Figure D50. Map visualizing the number of analytical methods used to measure nitrite + nitrate across the Gulf.

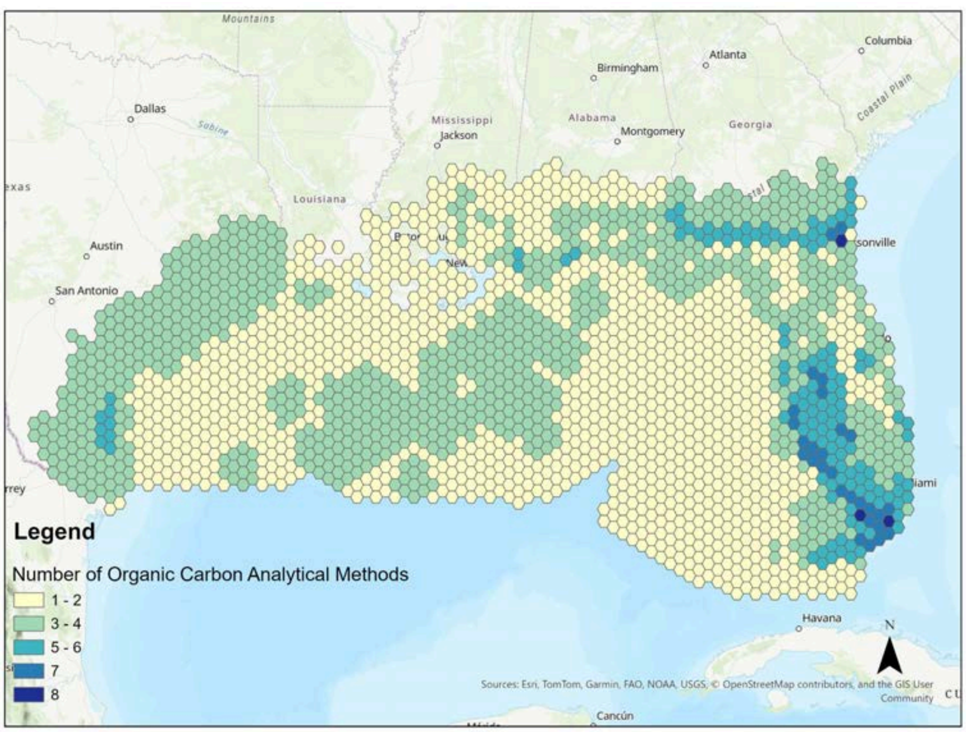

Figure D51. Map visualizing the number of analytical methods used to measure organic carbon across the Gulf.

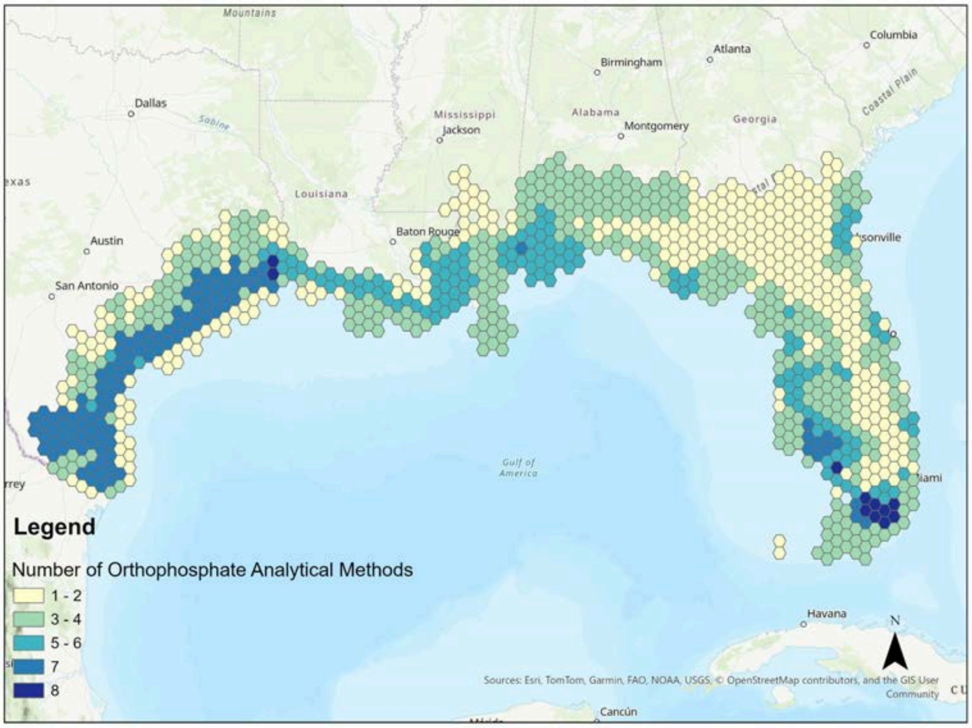

Figure D52. Map visualizing the number of analytical methods used to measure orthophosphate across the Gulf.

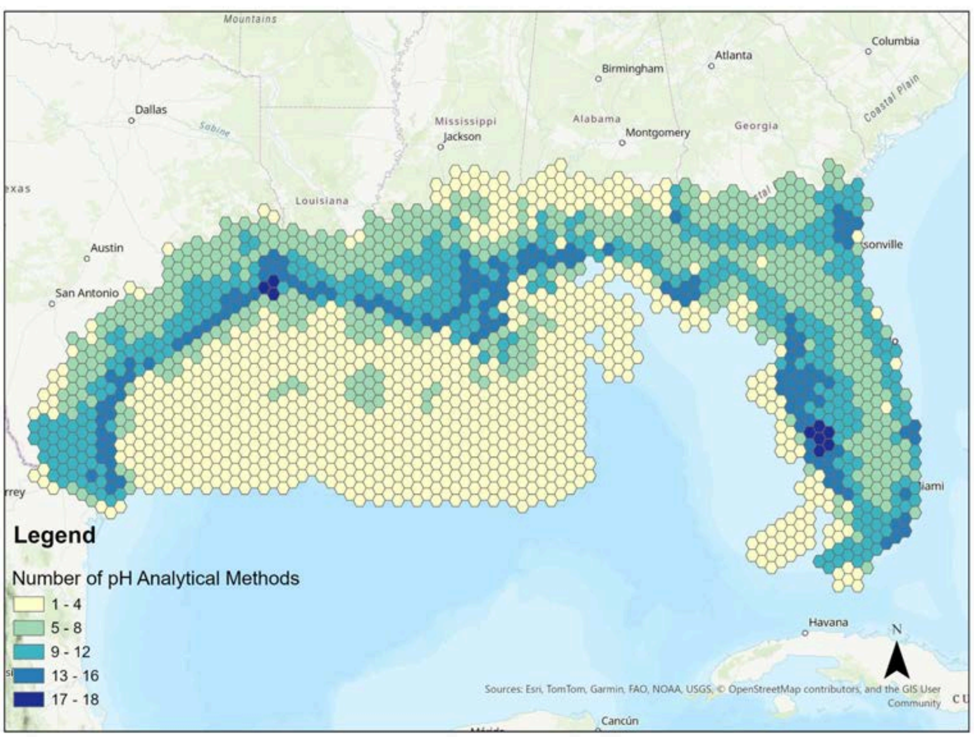

Figure D53. Map visualizing the number of analytical methods used to measure pH across the Gulf.

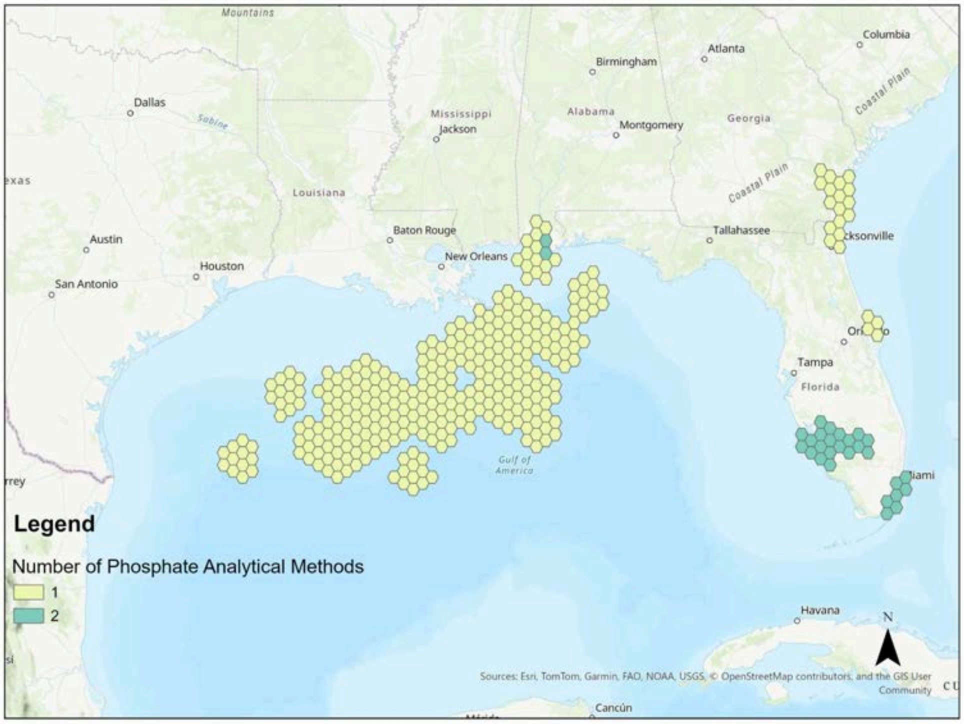

Figure D54. Map visualizing the number of analytical methods used to measure phosphate across the Gulf.

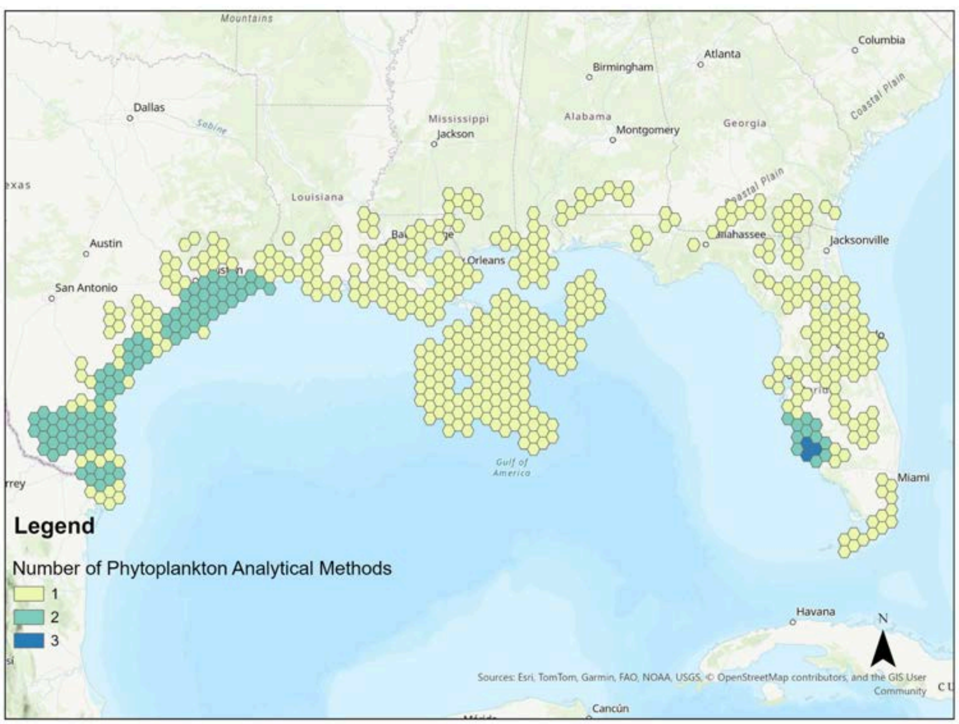

Figure D55. Map visualizing the number of analytical methods used to measure phytoplankton across the Gulf.

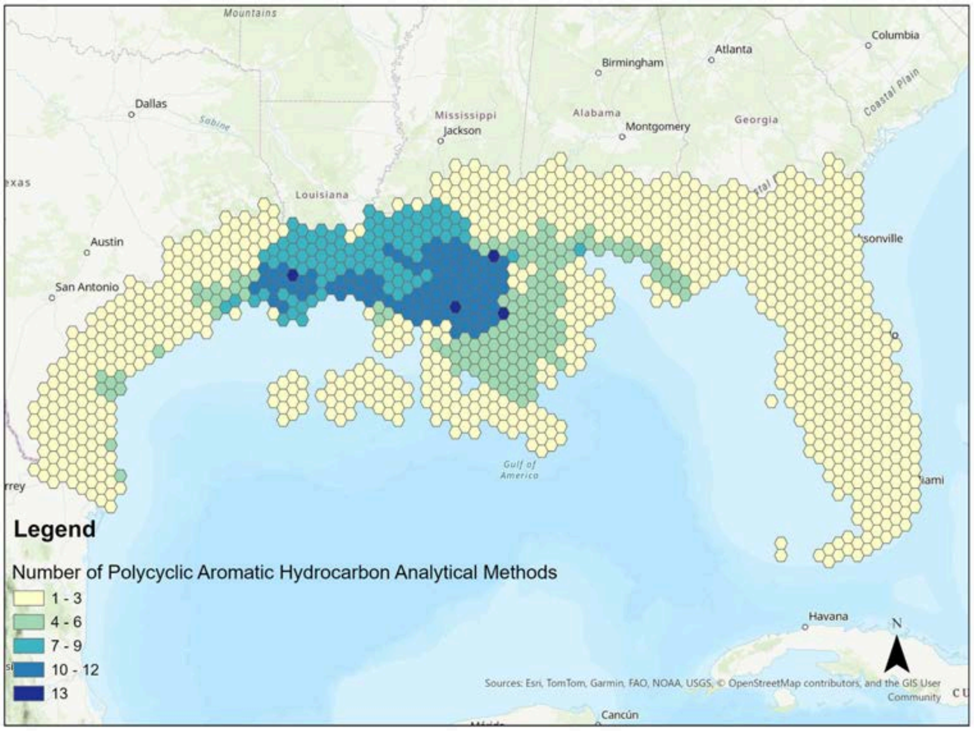

Figure D56. Map visualizing the number of analytical methods used to measure polycyclic aromatic hydrocarbons across the Gulf.

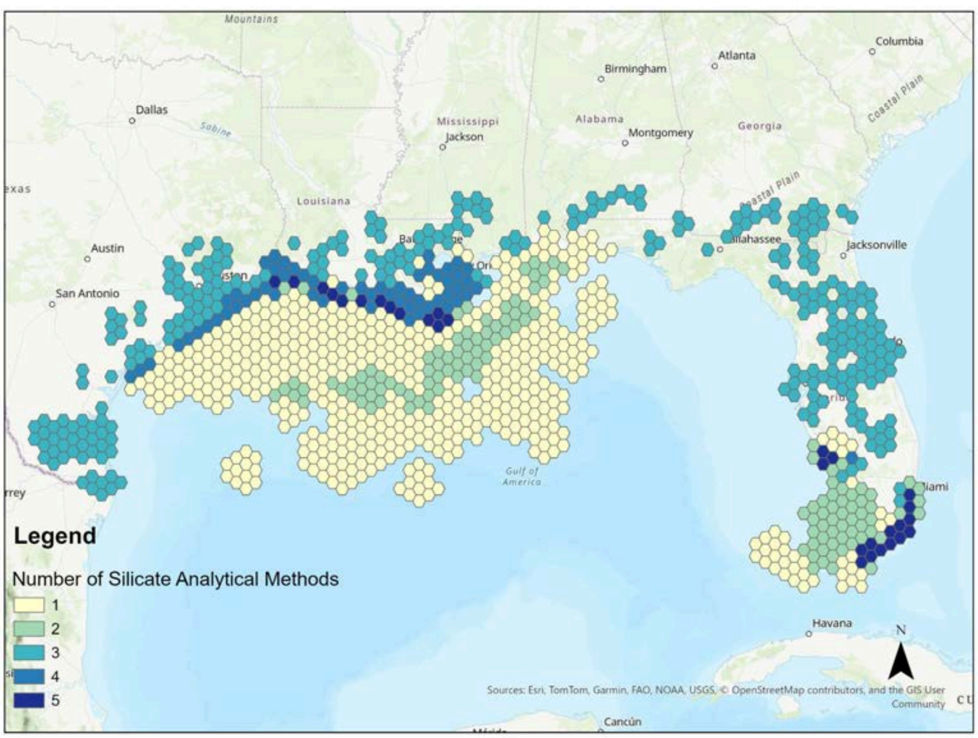

Figure D57. Map visualizing the number of analytical methods used to measure silicate across the Gulf.

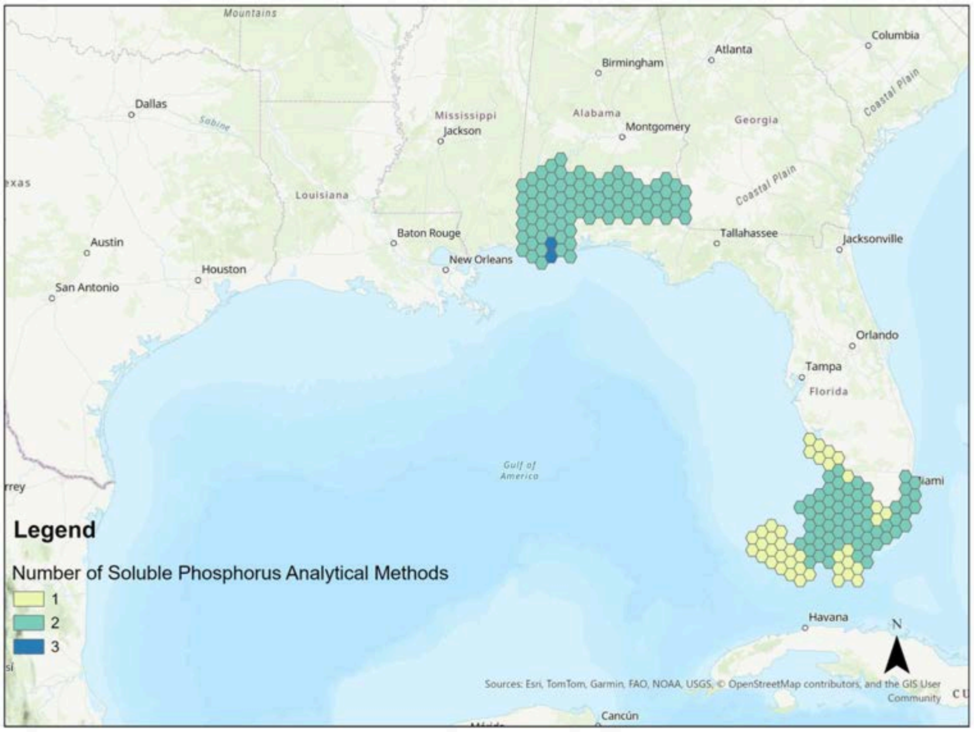

Figure D58. Map visualizing the number of analytical methods used to measure soluble phosphorus across the Gulf.

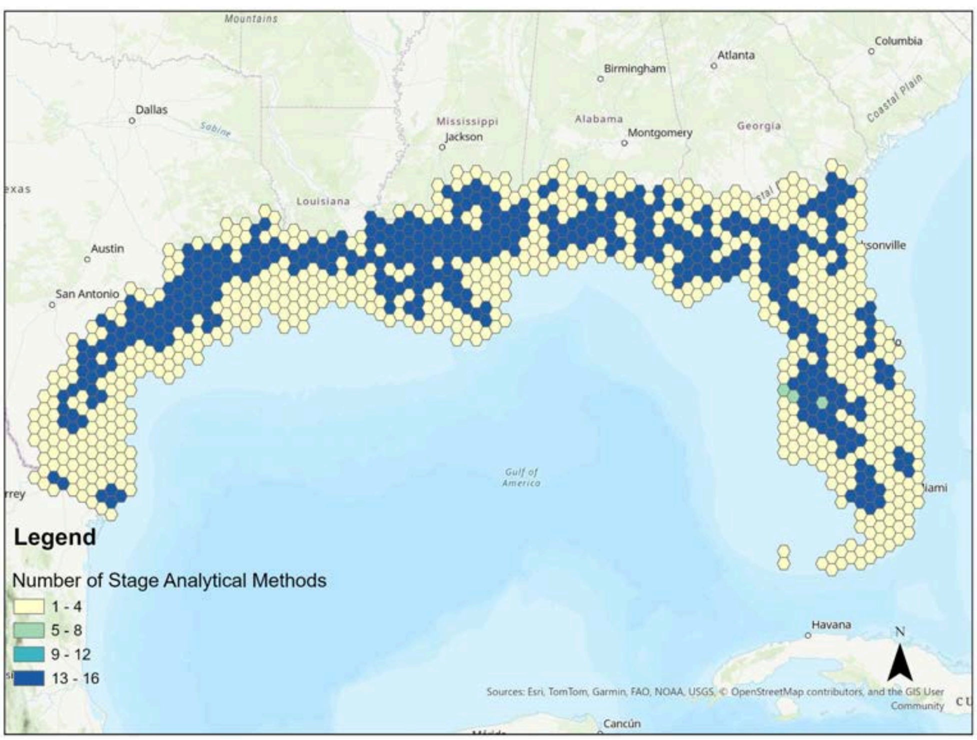

Figure D59. Map visualizing the number of analytical methods used to measure stage across the Gulf.

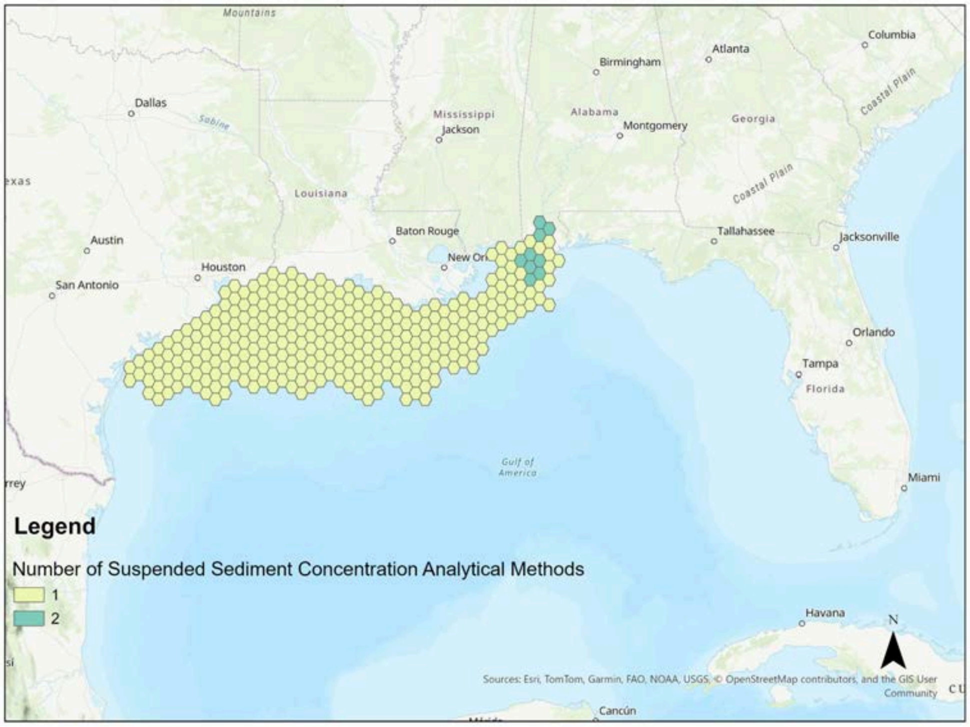

Figure D60. Map visualizing the number of analytical methods used to measure suspended sediment concentration across the Gulf.

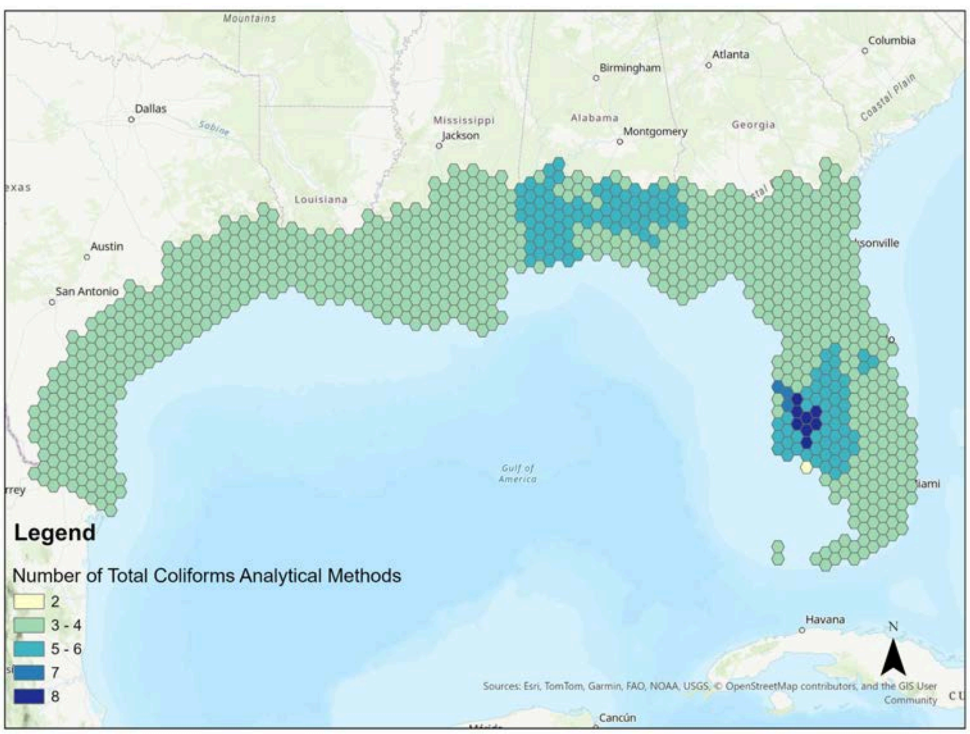

Figure D61. Map visualizing the number of analytical methods used to measure total coliforms across the Gulf.

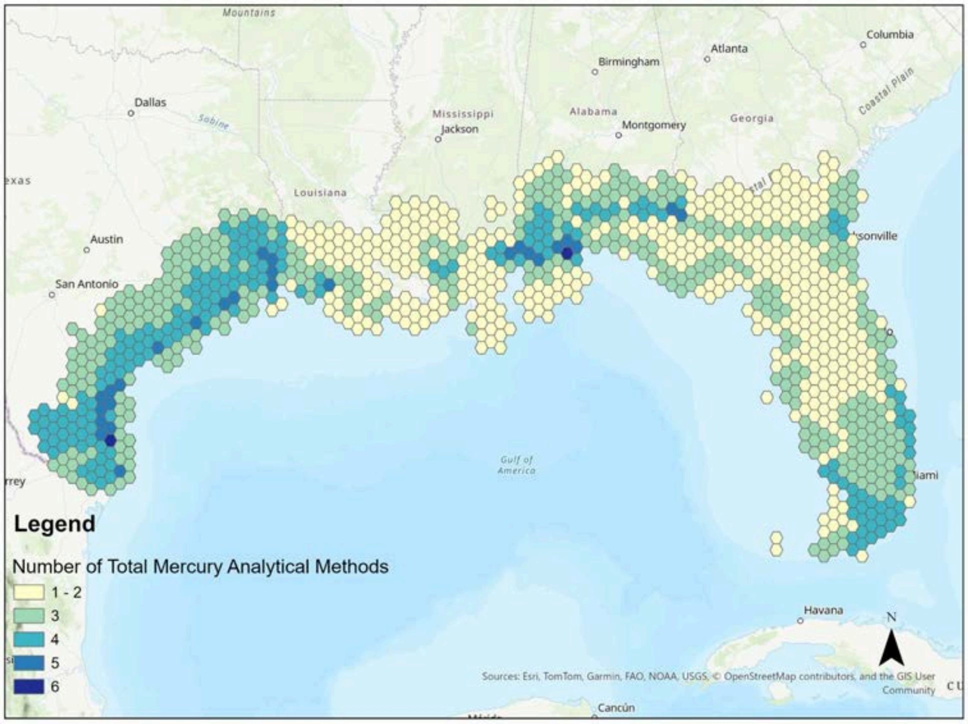

Figure D62. Map visualizing the number of analytical methods used to measure total mercury across the Gulf.

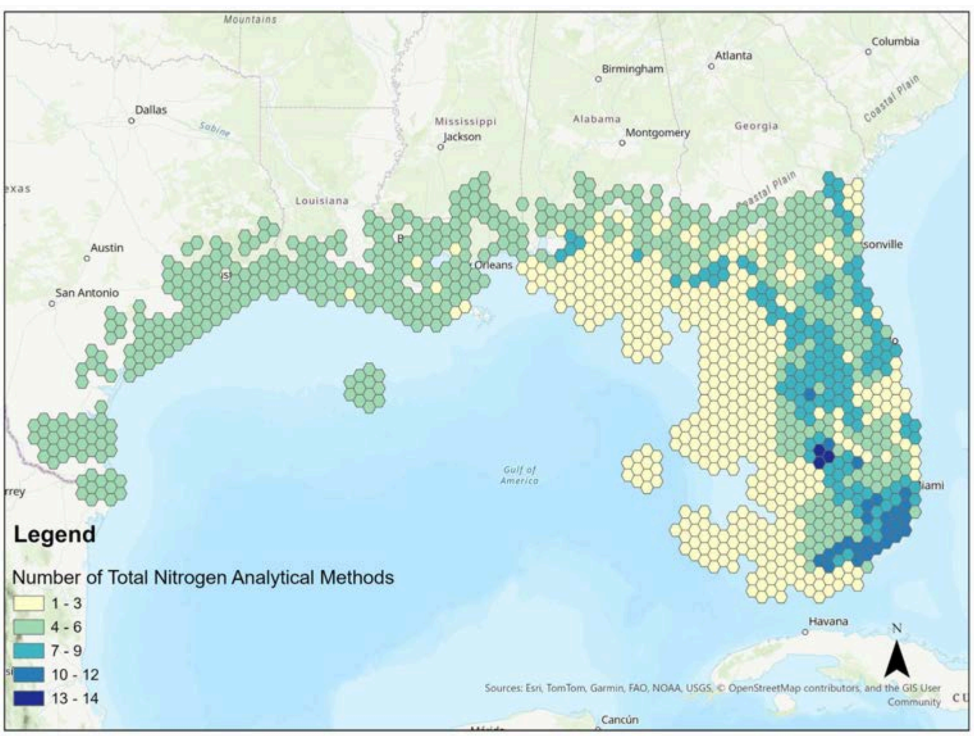

Figure D63. Map visualizing the number of analytical methods used to measure total nitrogen across the Gulf.

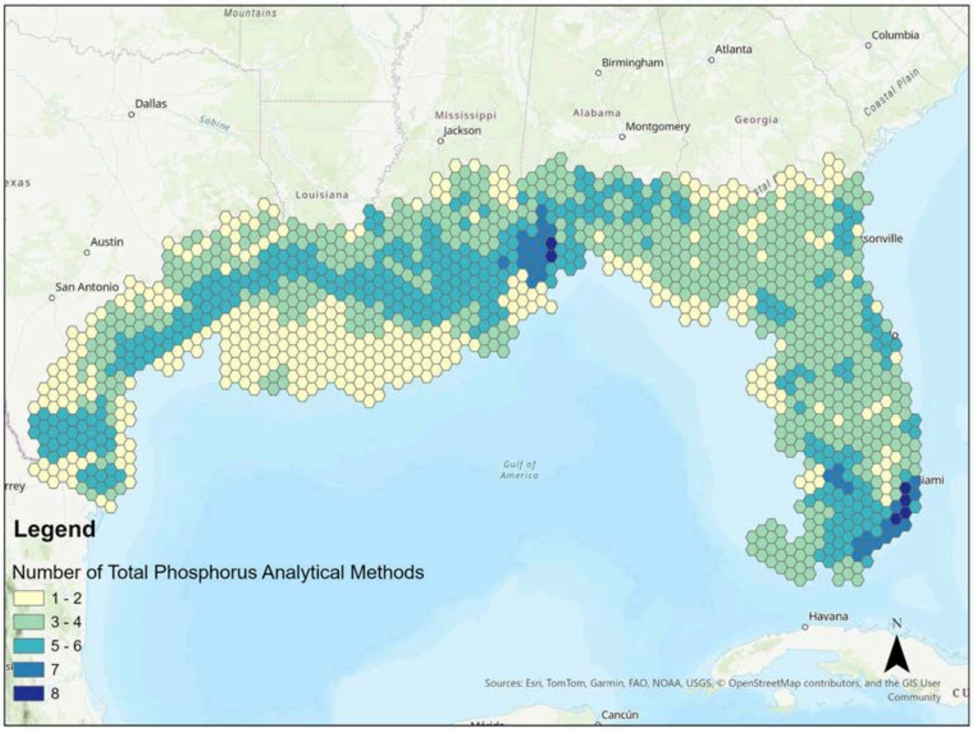

Figure D64. Map visualizing the number of analytical methods used to measure total phosphorus across the Gulf.

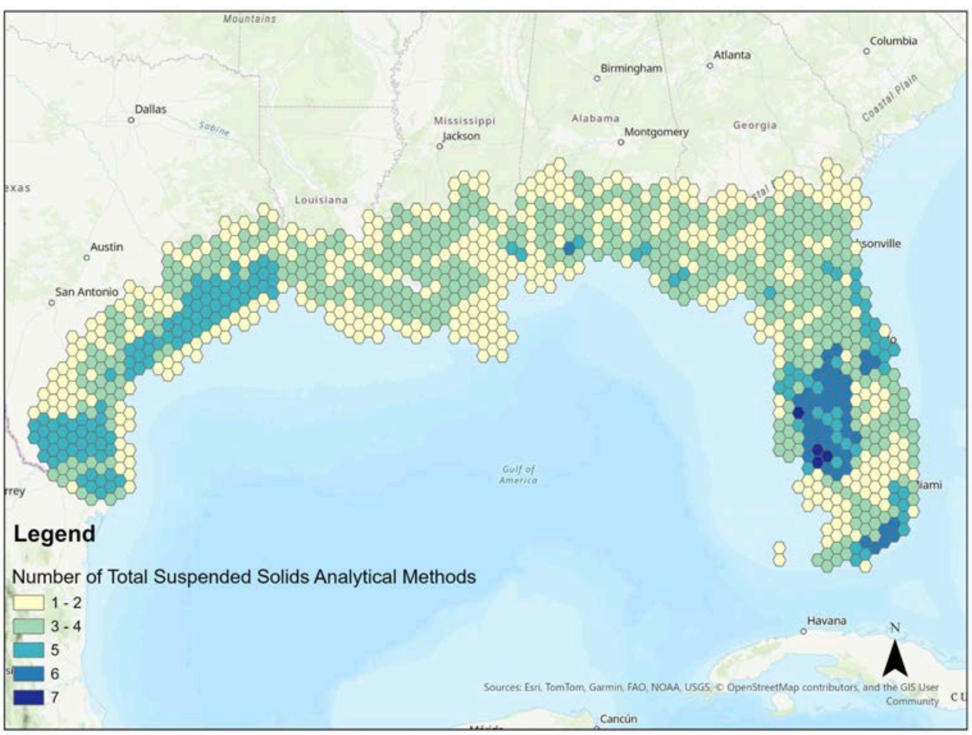

Figure D65. Map visualizing the number of analytical methods used to measure total suspended solids across the Gulf.

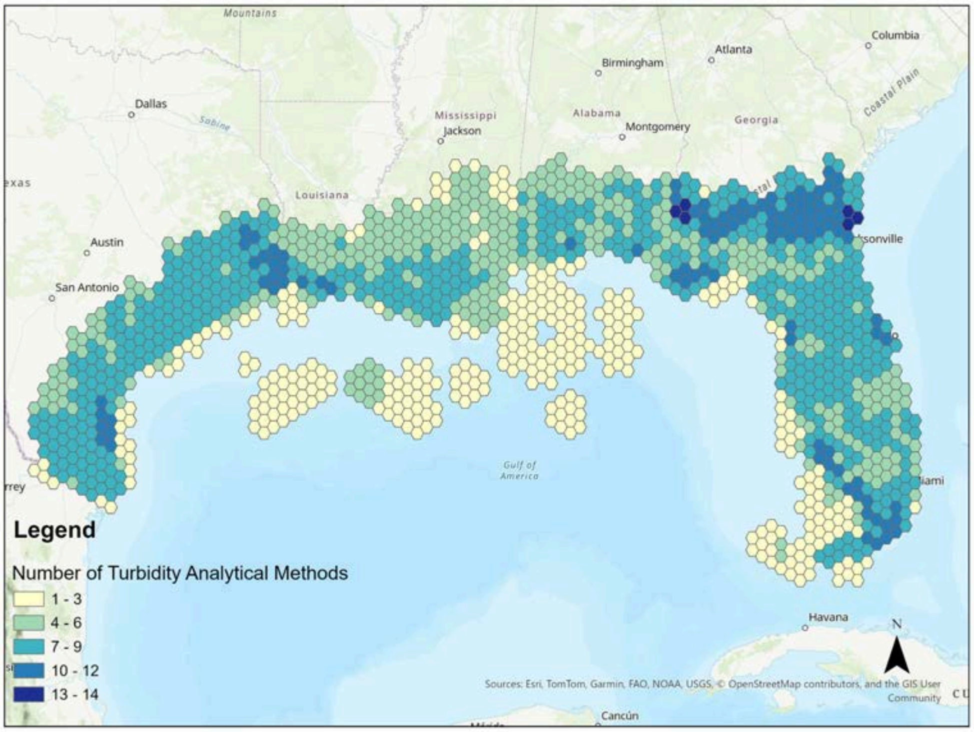

Figure D66. Map visualizing the number of analytical methods used to measure turbidity across the Gulf.

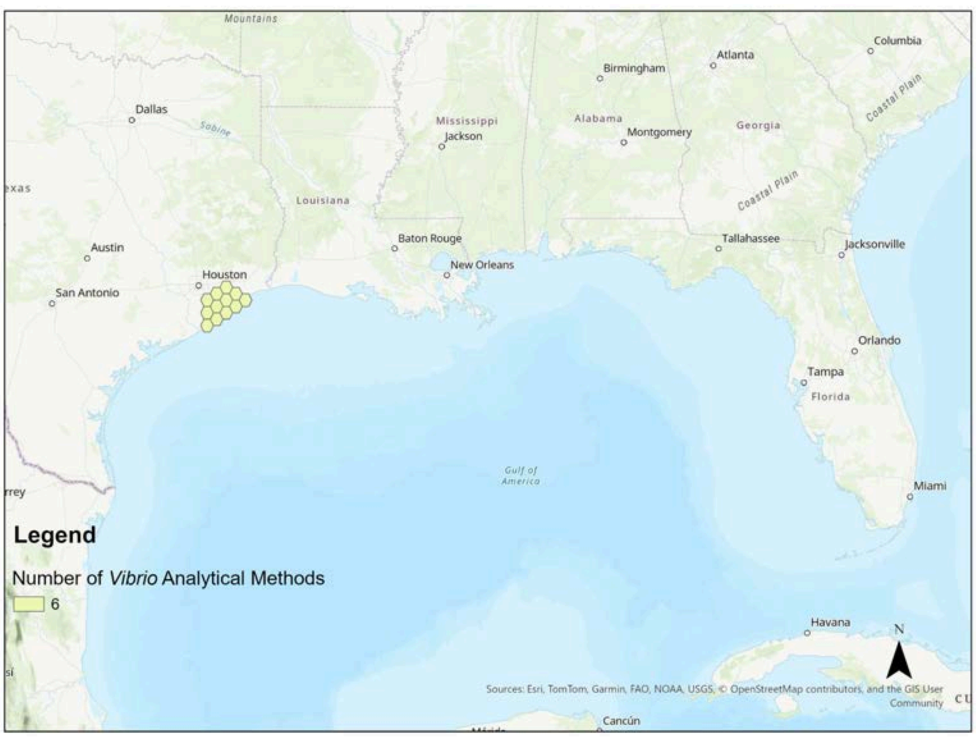

Figure D67. Map visualizing the number of analytical methods used to measure *Vibrio* across the Gulf.

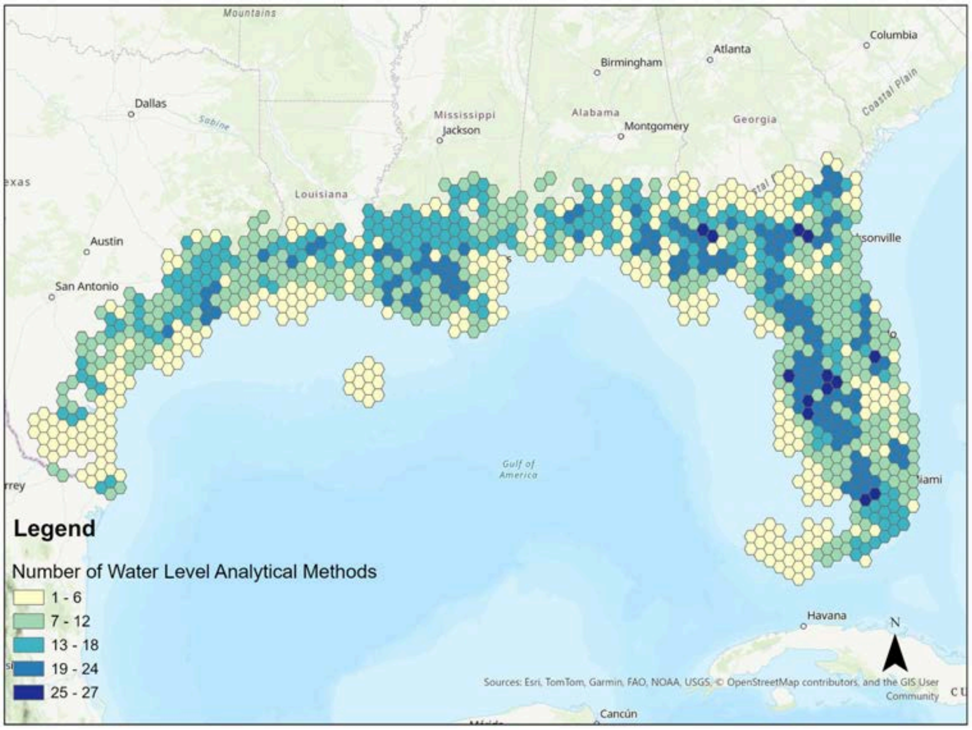

Figure D68. Map visualizing the number of analytical methods used to measure water level across the Gulf.

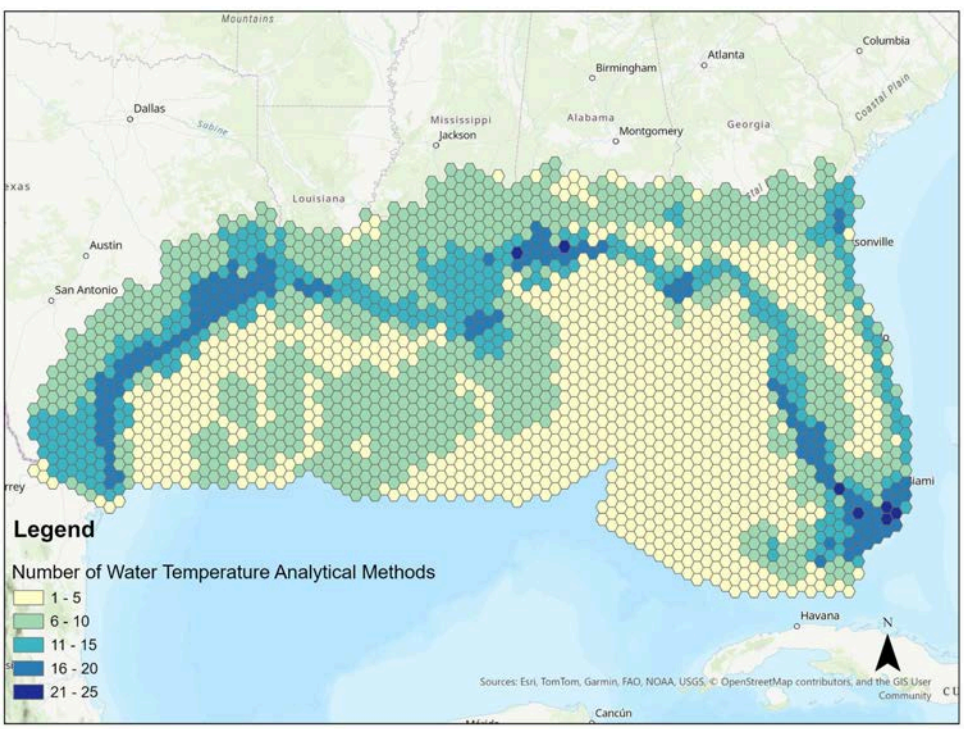

Figure D69. Map visualizing the number of analytical methods used to measure water temperature across the Gulf.

Figure D70. Map visualizing the spatial extents of all the identified analytical methods used to measure algal toxins across the Gulf.

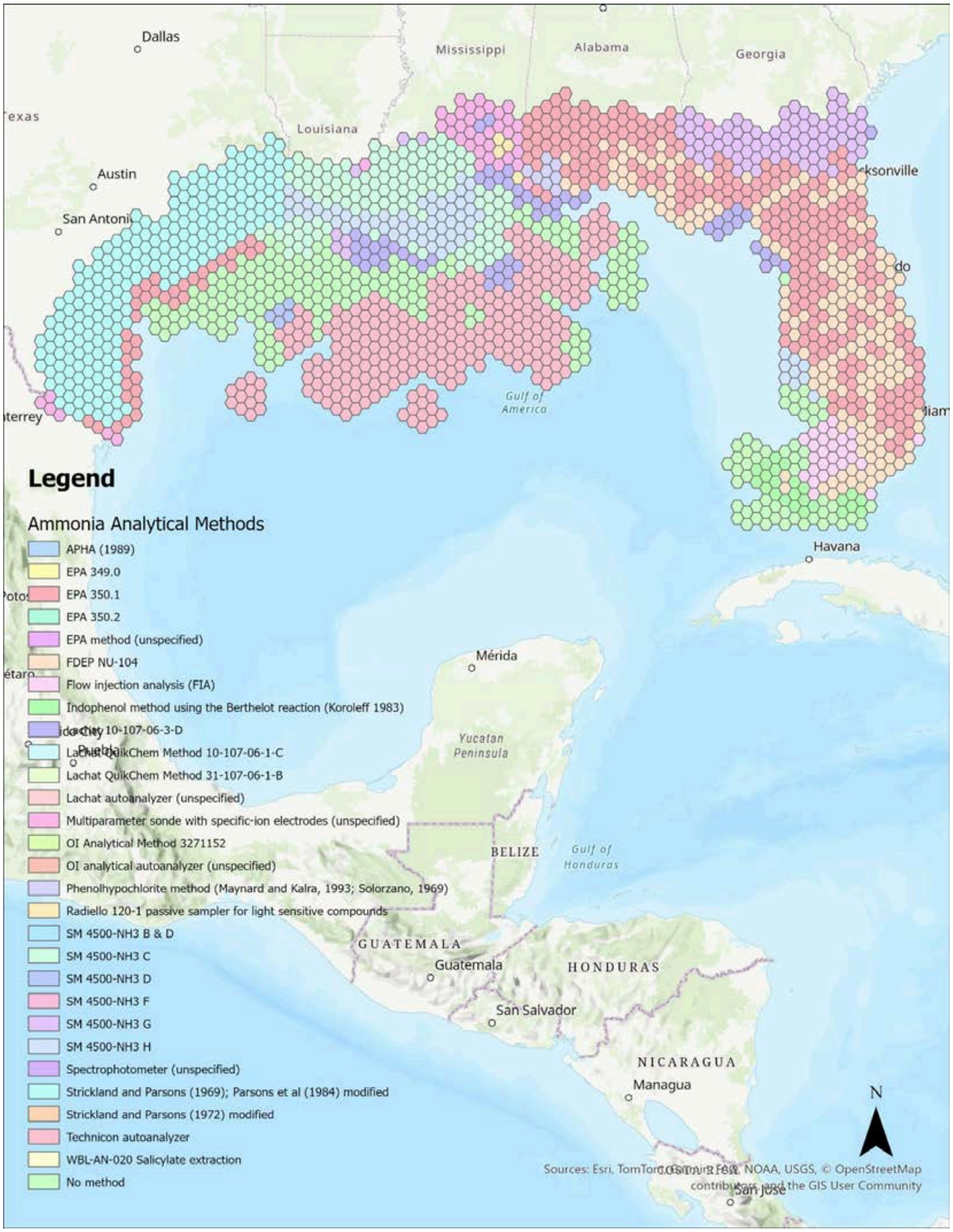

Figure D71. Map visualizing the spatial extents of all the identified analytical methods used to measure ammonia across the Gulf.

Figure D72. Map visualizing the spatial extents of all the identified analytical methods used to measure ammonia + organic nitrogen across the Gulf.

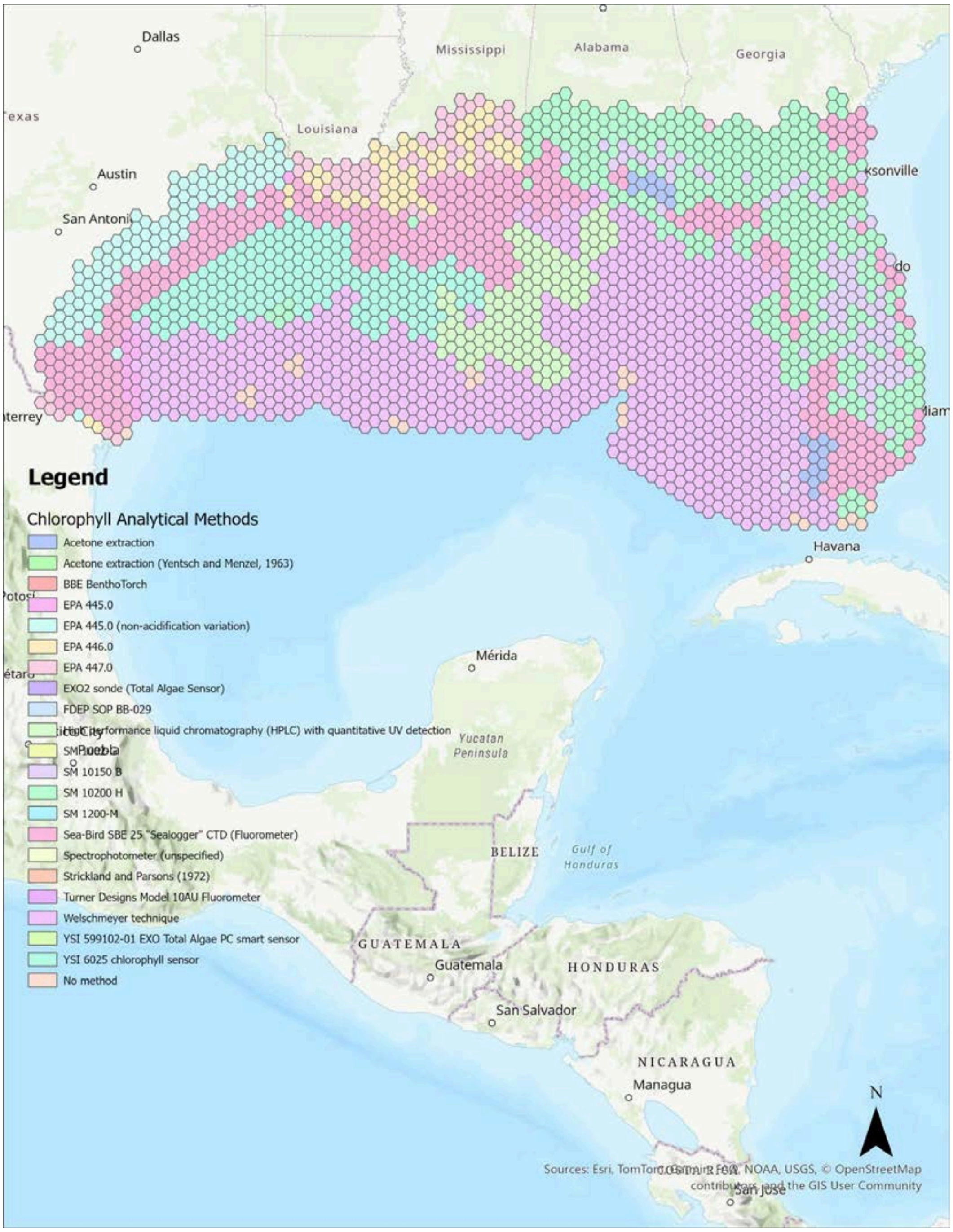

Figure D73. Map visualizing the spatial extents of all the identified analytical methods used to measure chlorophyll across the Gulf.

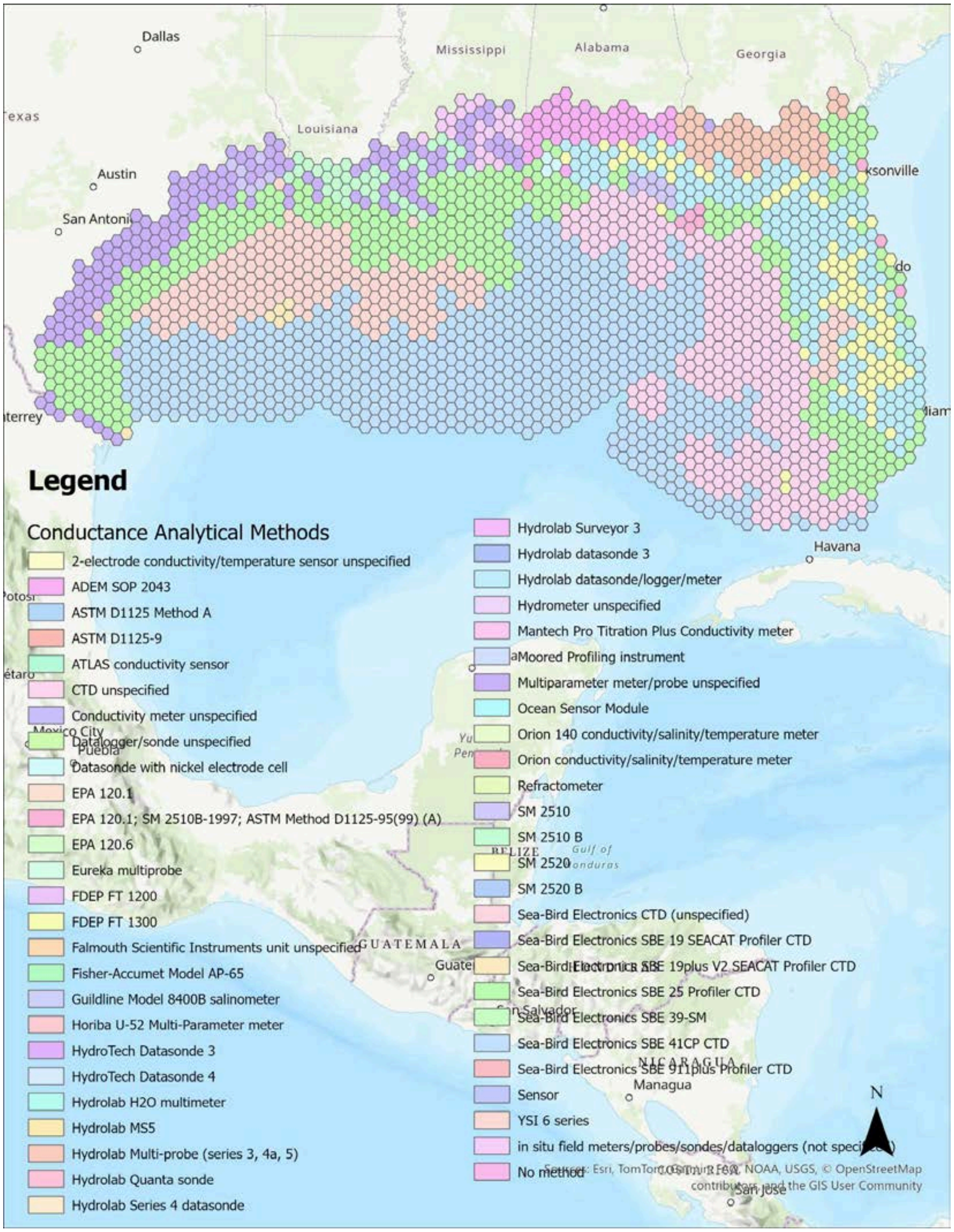

Figure D74. Map visualizing the spatial extents of all the identified analytical methods used to measure conductance across the Gulf.

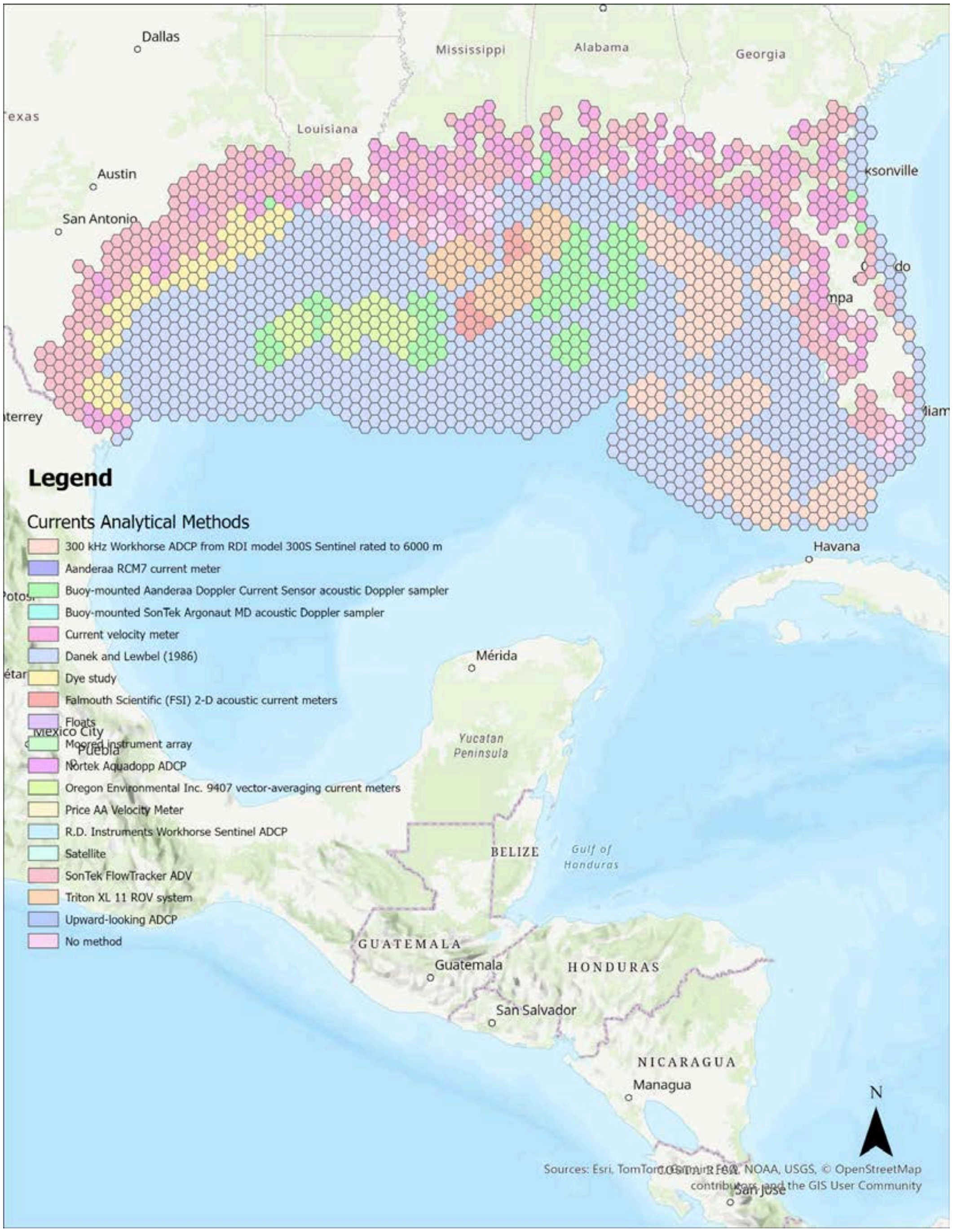

Figure D75. Map visualizing the spatial extents of all the identified analytical methods used to measure currents across the Gulf.

Figure D76. Map visualizing the spatial extents of where analytical methods used to measure cyanobacteria across the Gulf were unable to be identified. Cyanobacteria is the only water quality parameter in the CMAP Inventory for which no analytical methods were identified.

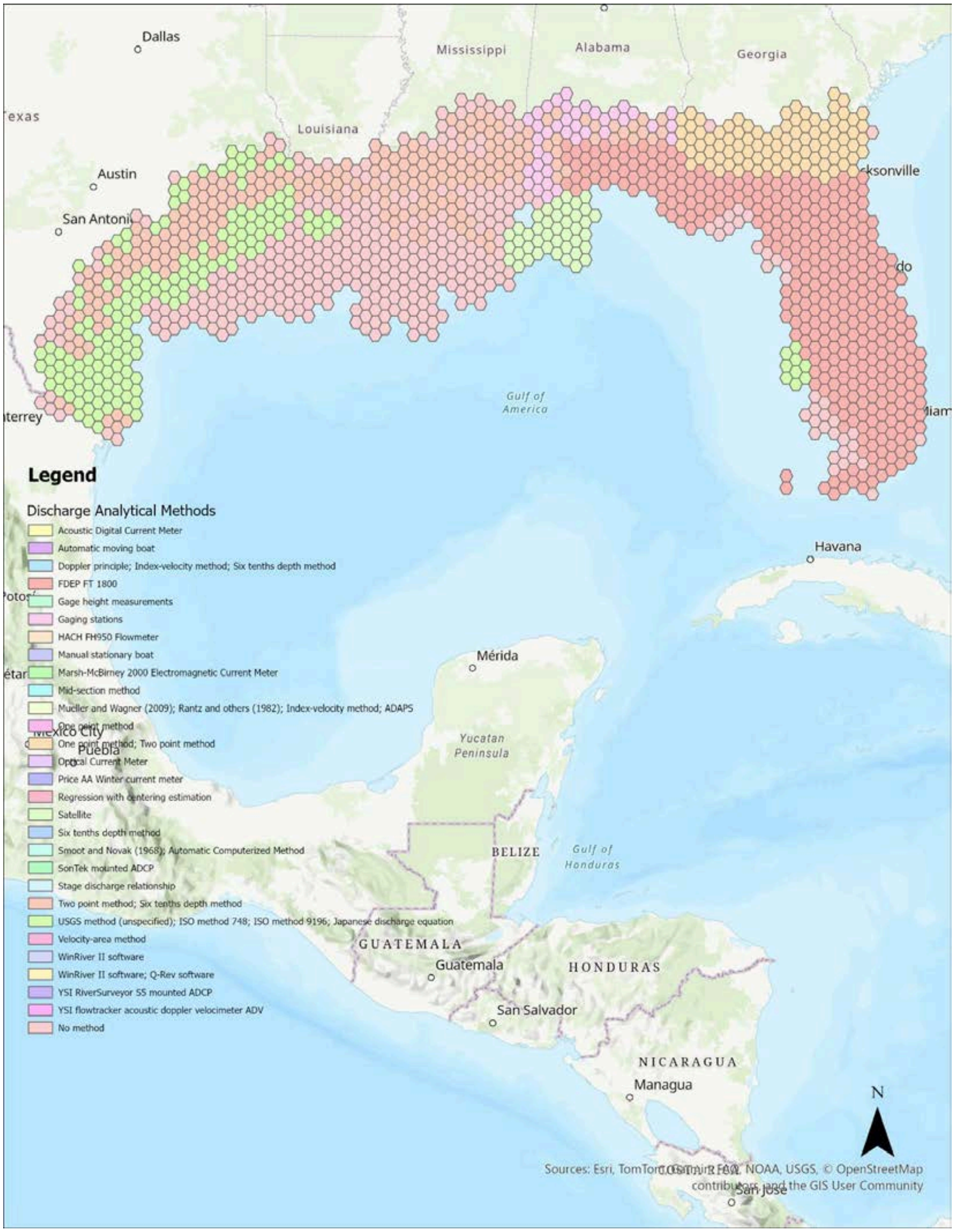

Figure D77. Map visualizing the spatial extents of all the identified analytical methods used to measure discharge across the Gulf.

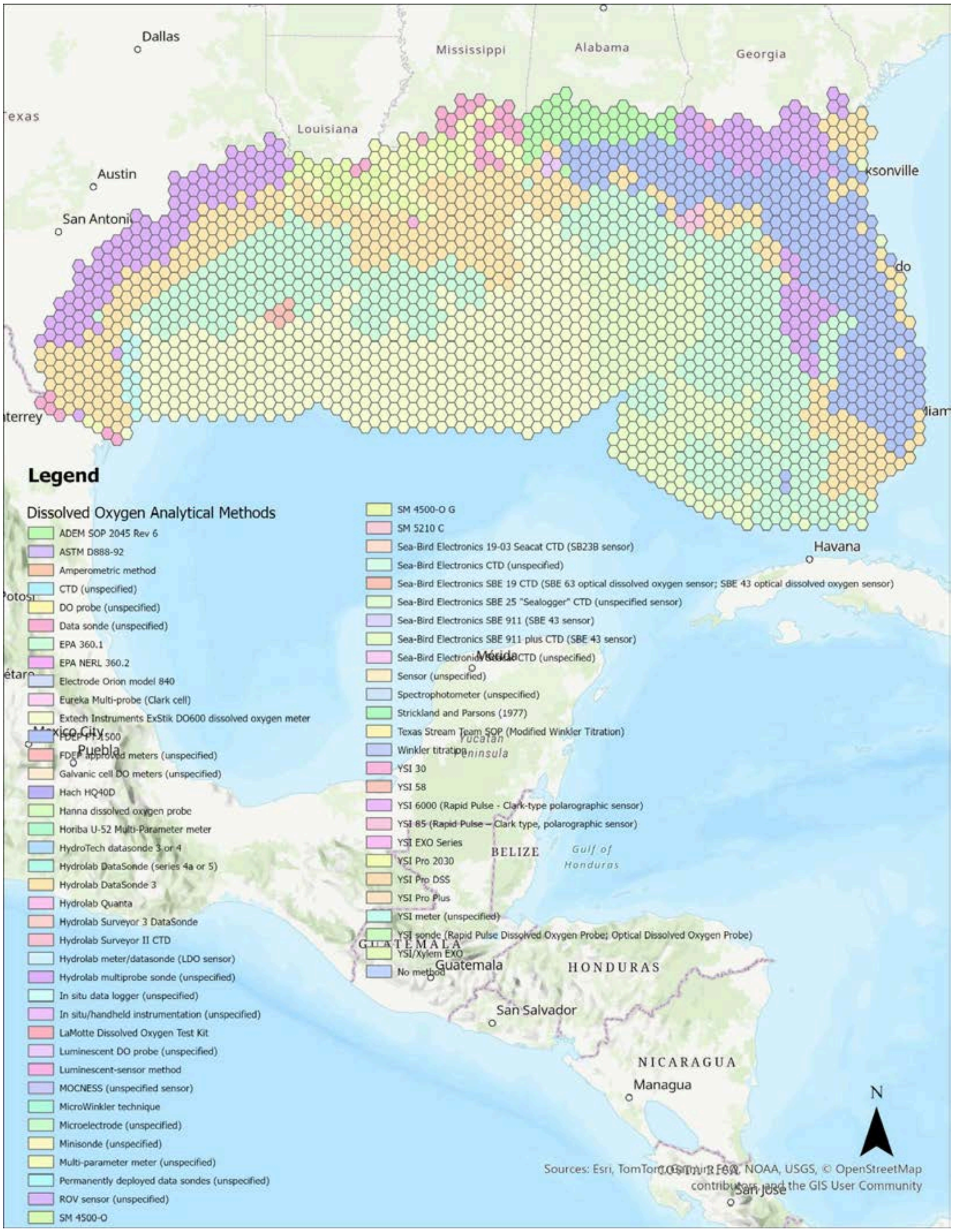

Figure D78. Map visualizing the spatial extents of all the identified analytical methods used to measure dissolved oxygen across the Gulf.

Figure D79. Map visualizing the spatial extents of all the identified analytical methods used to measure *E. coli* across the Gulf.

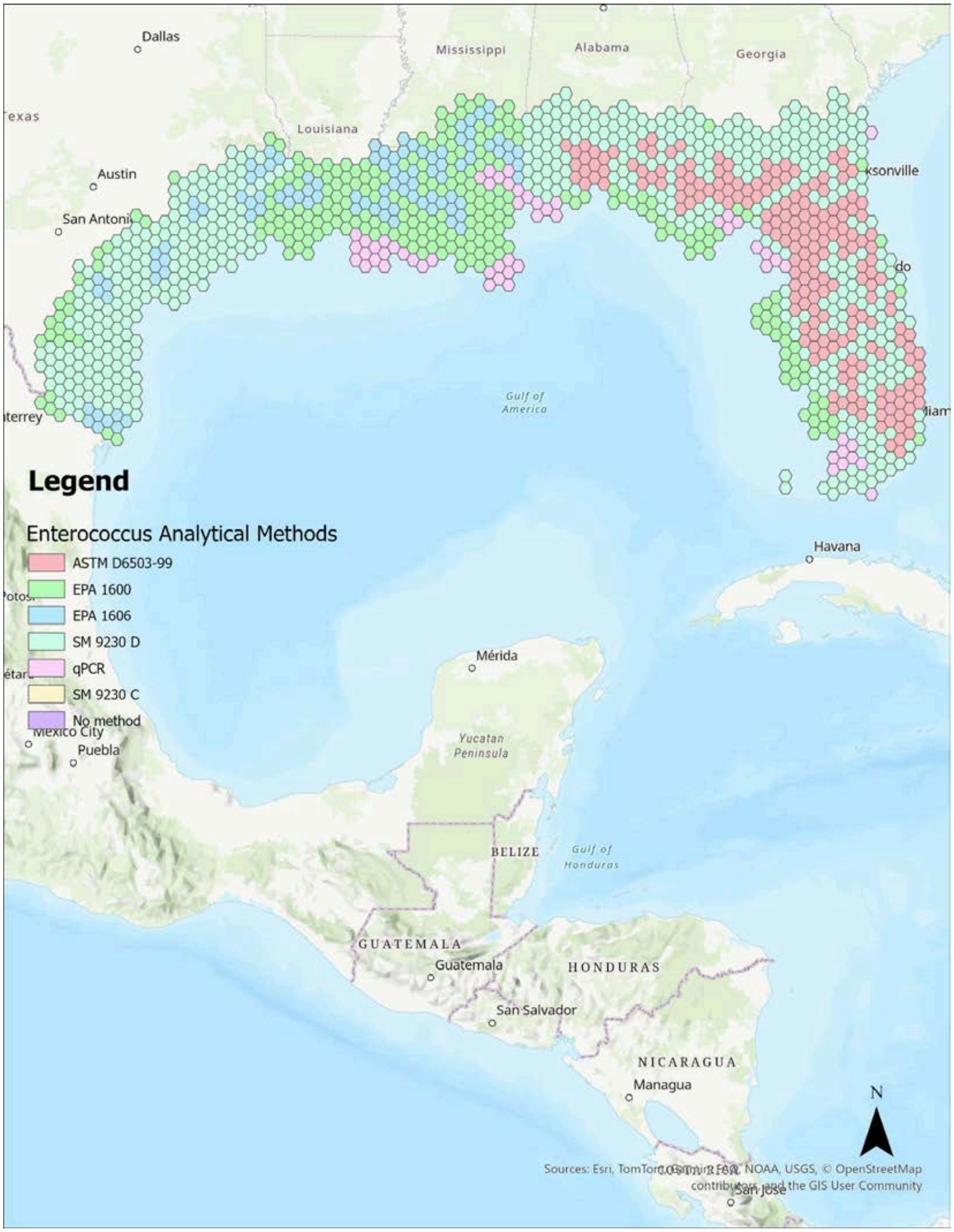

Figure D80. Map visualizing the spatial extents of all the identified analytical methods used to measure *Enterococcus* across the Gulf.

Figure D81. Map visualizing the spatial extents of all the identified analytical methods used to measure fecal coliforms across the Gulf.

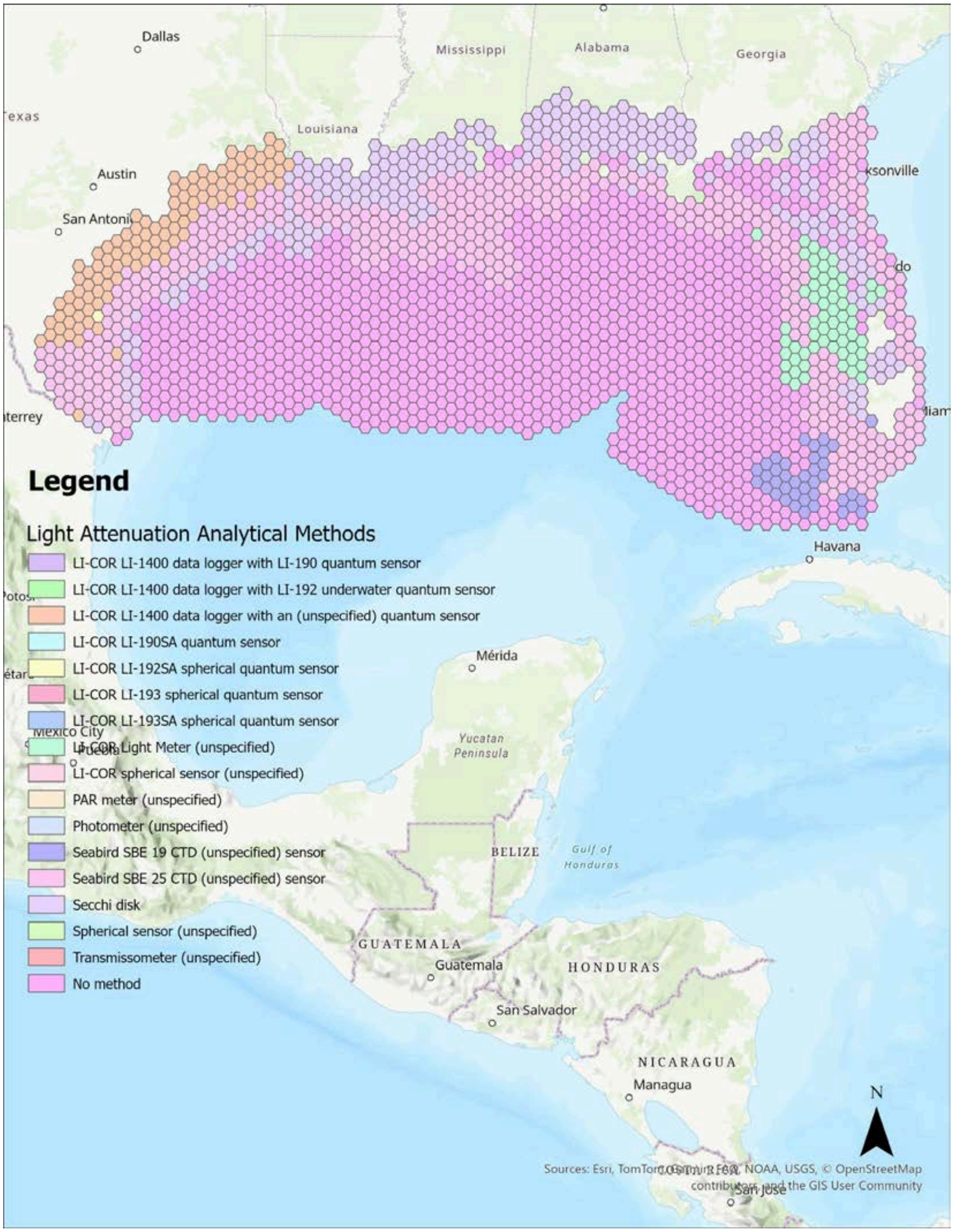

Figure D82. Map visualizing the spatial extents of all the identified analytical methods used to measure light attenuation across the Gulf.

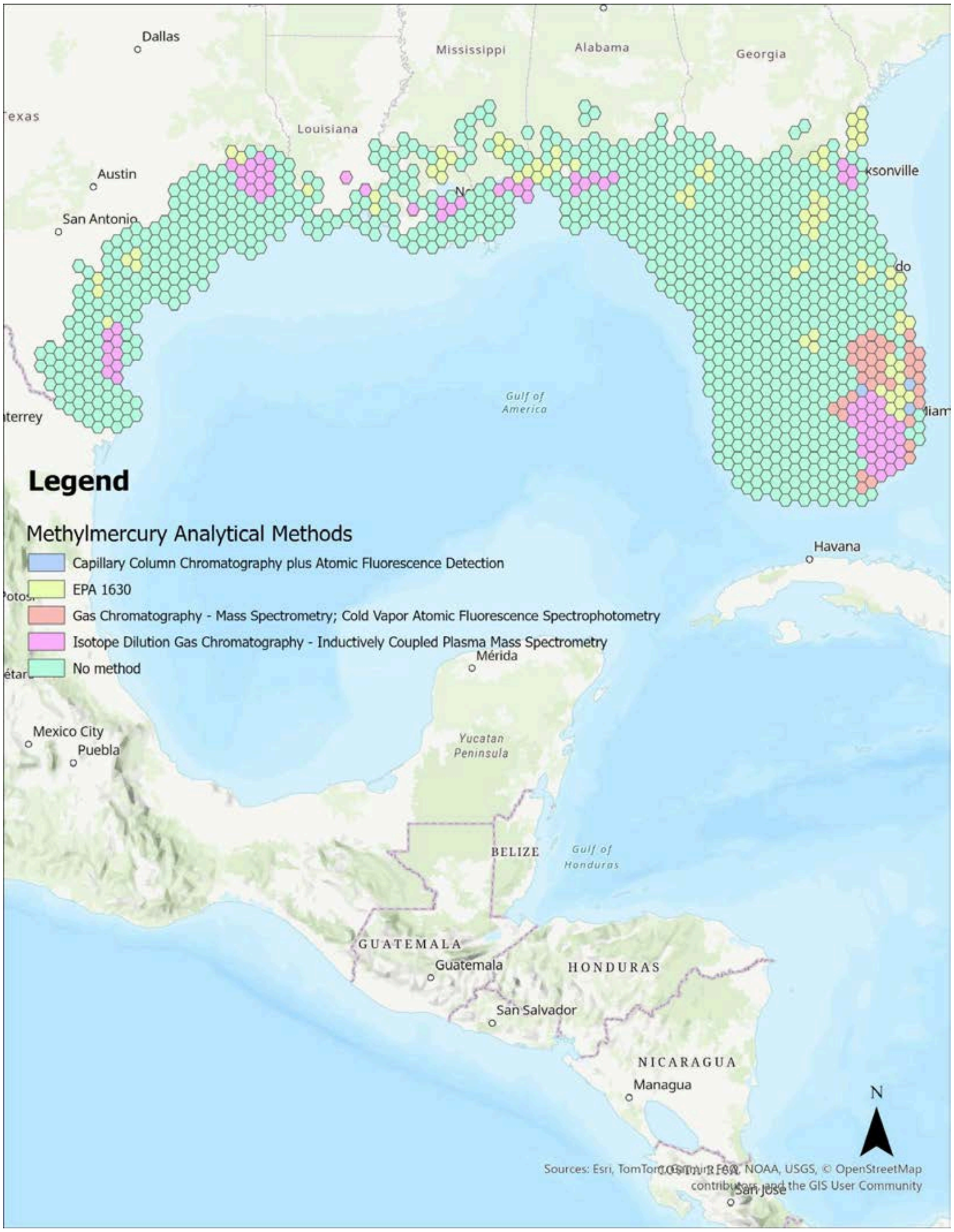

Figure D83. Map visualizing the spatial extents of all the identified analytical methods used to measure methylmercury across the Gulf.

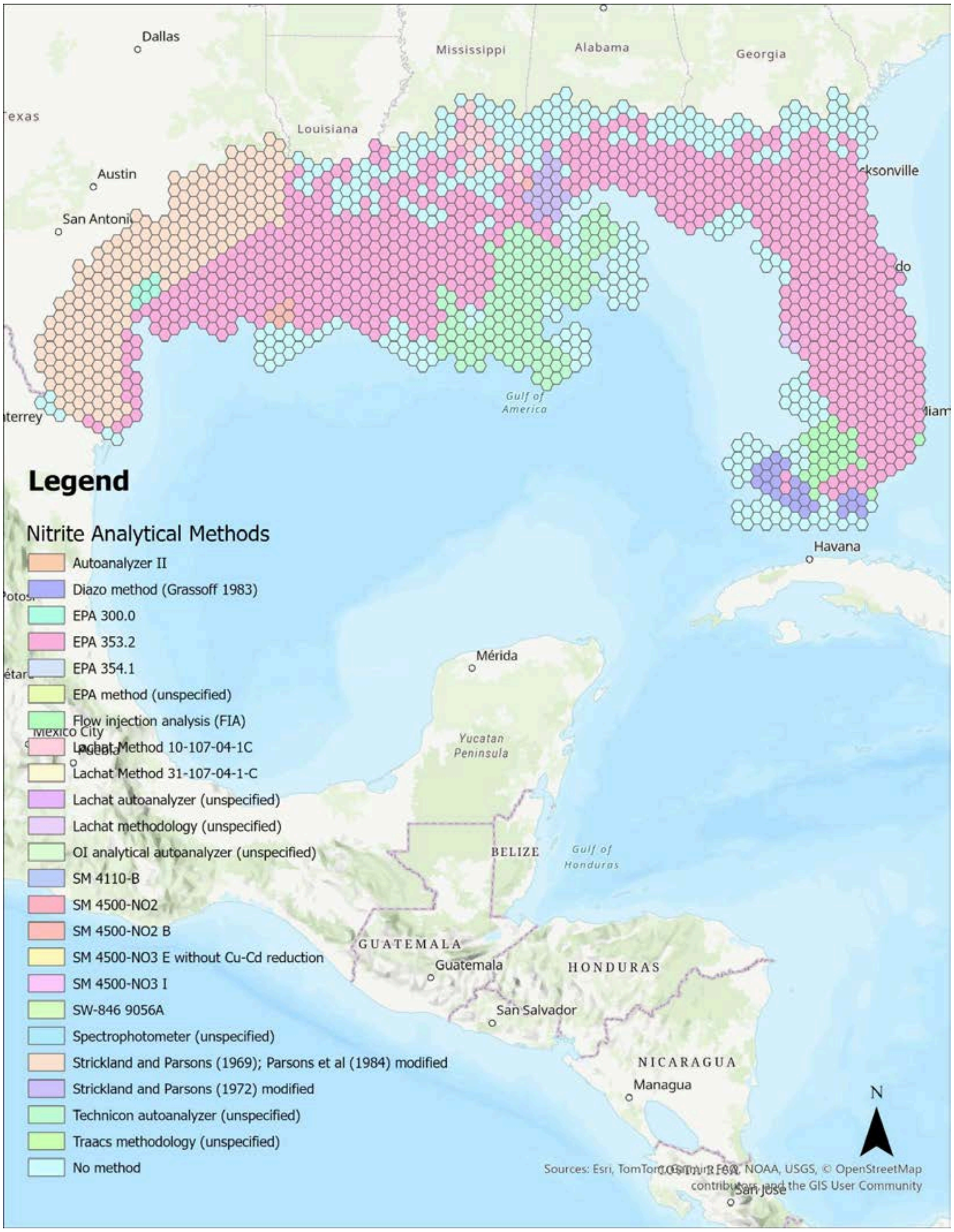

Figure D84. Map visualizing the spatial extents of all the identified analytical methods used to measure nitrite across the Gulf.

Figure D85. Map visualizing the spatial extents of all the identified analytical methods used to measure nitrite + nitrate across the Gulf.

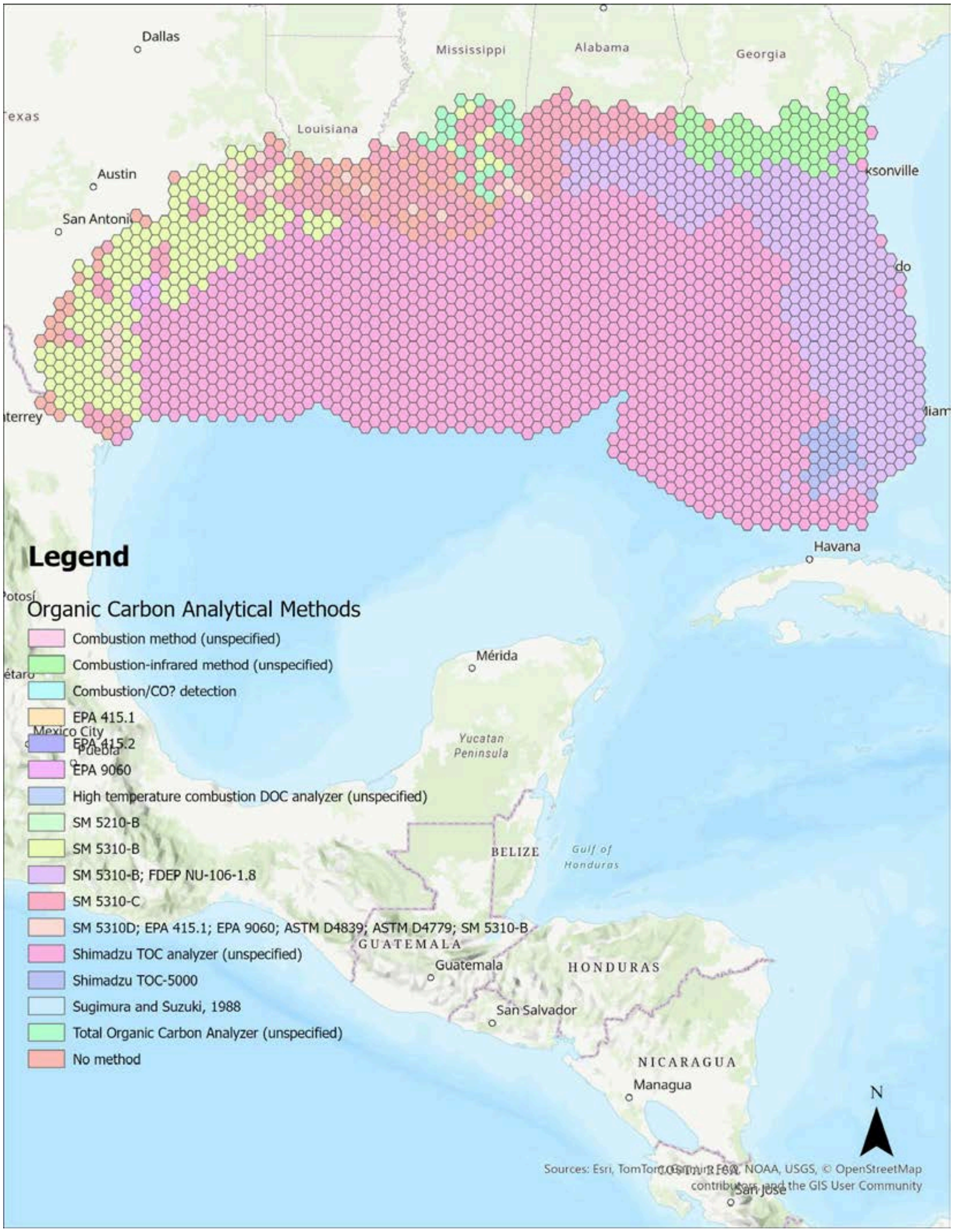

Figure D86. Map visualizing the spatial extents of all the identified analytical methods used to measure organic carbon across the Gulf.

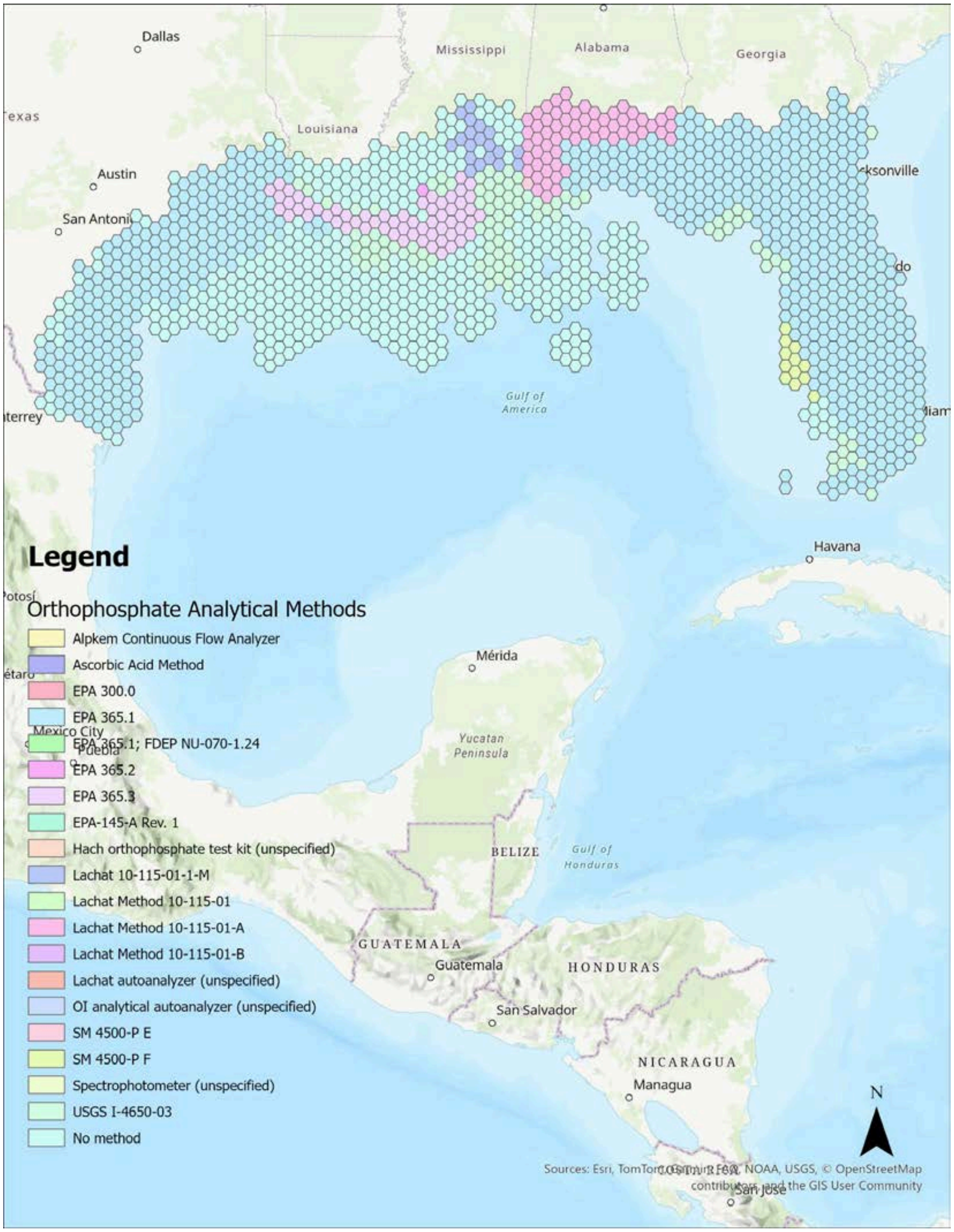

Figure D87. Map visualizing the spatial extents of all the identified analytical methods used to measure orthophosphate across the Gulf.

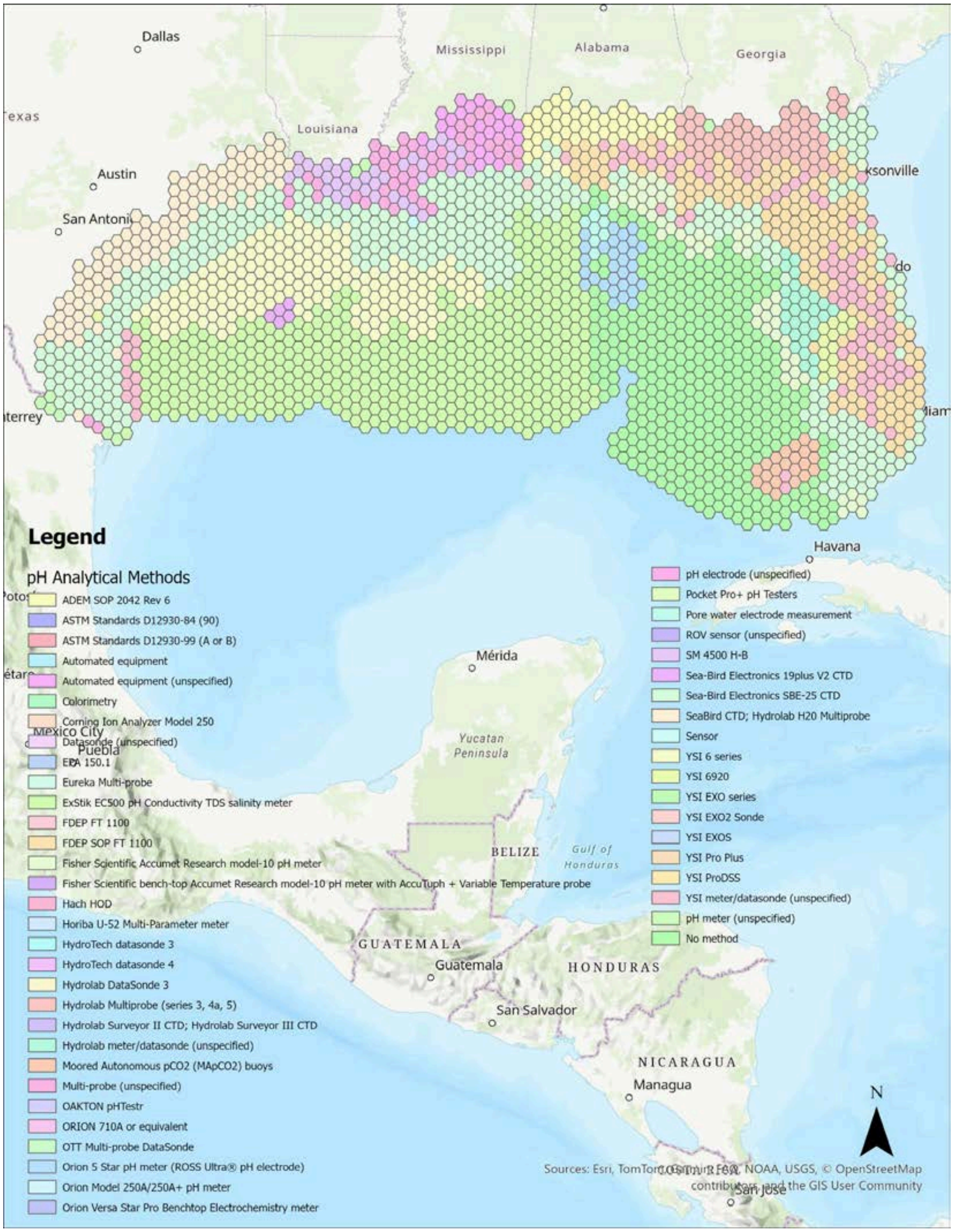

Figure D88. Map visualizing the spatial extents of all the identified analytical methods used to measure pH across the Gulf.

Figure D89. Map visualizing the spatial extents of all the identified analytical methods used to measure phosphate across the Gulf.

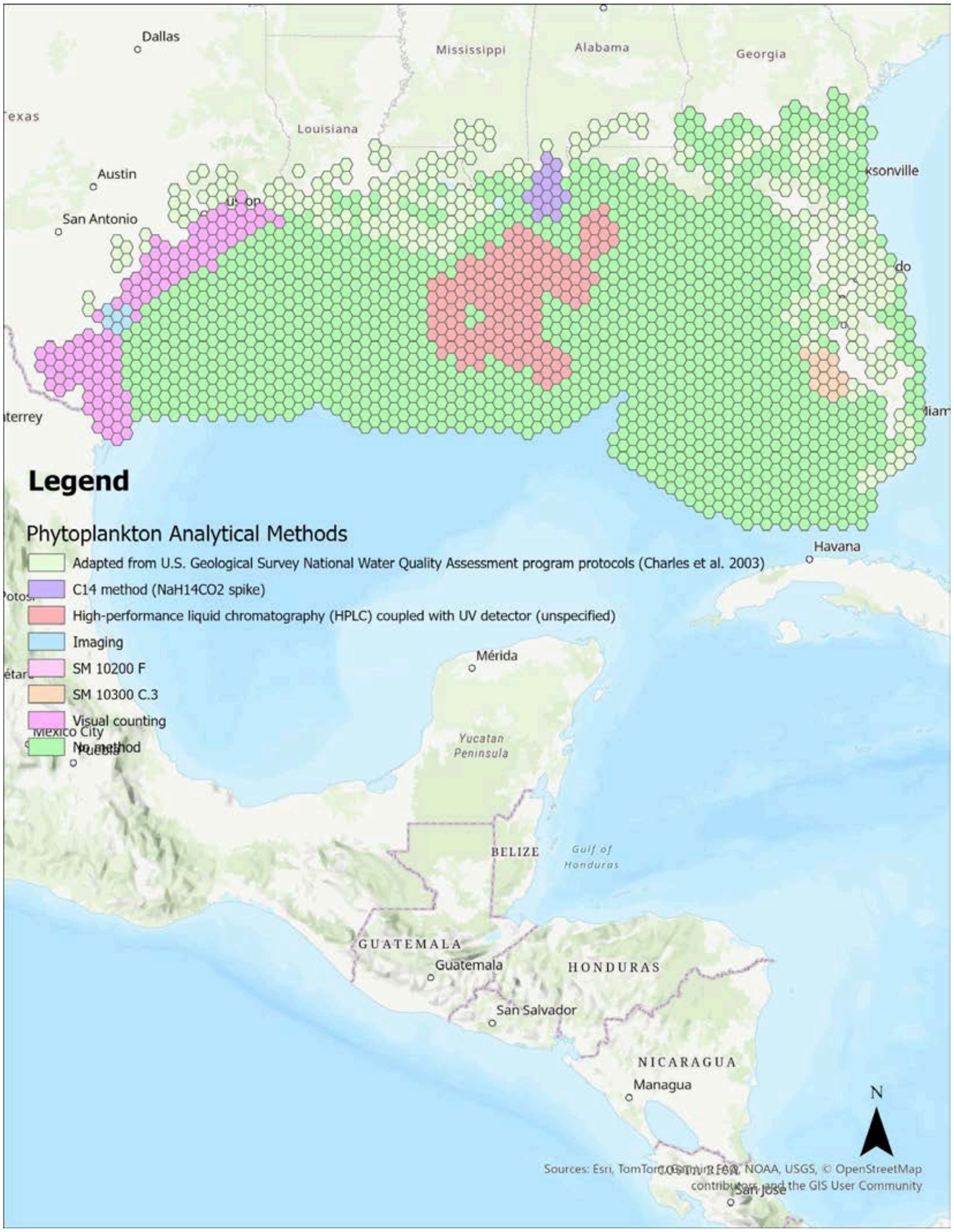

Figure D90. Map visualizing the spatial extents of all the identified analytical methods used to measure phytoplankton across the Gulf.

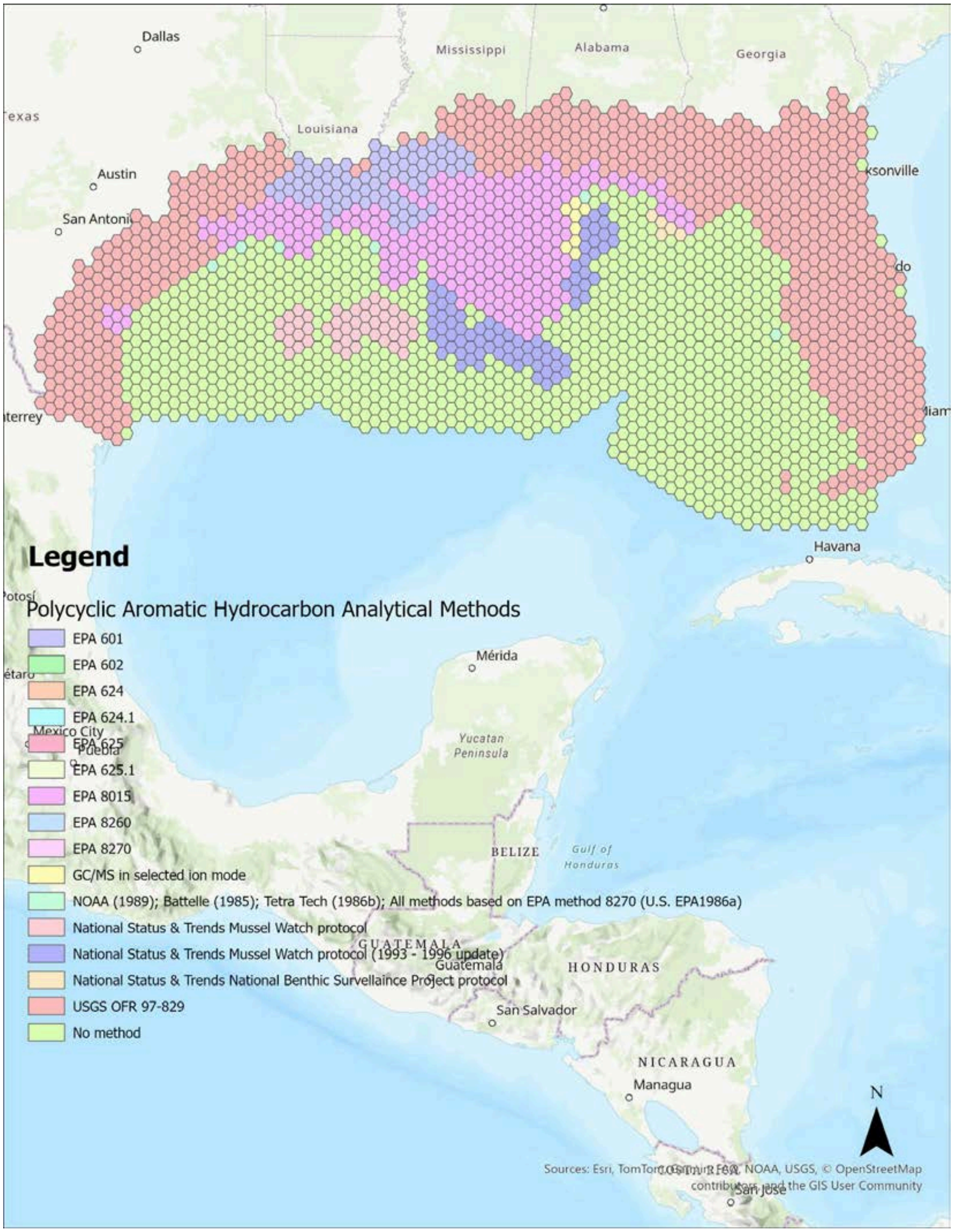

Figure D91. Map visualizing the spatial extents of all the identified analytical methods used to measure polycyclic aromatic hydrocarbons across the Gulf.

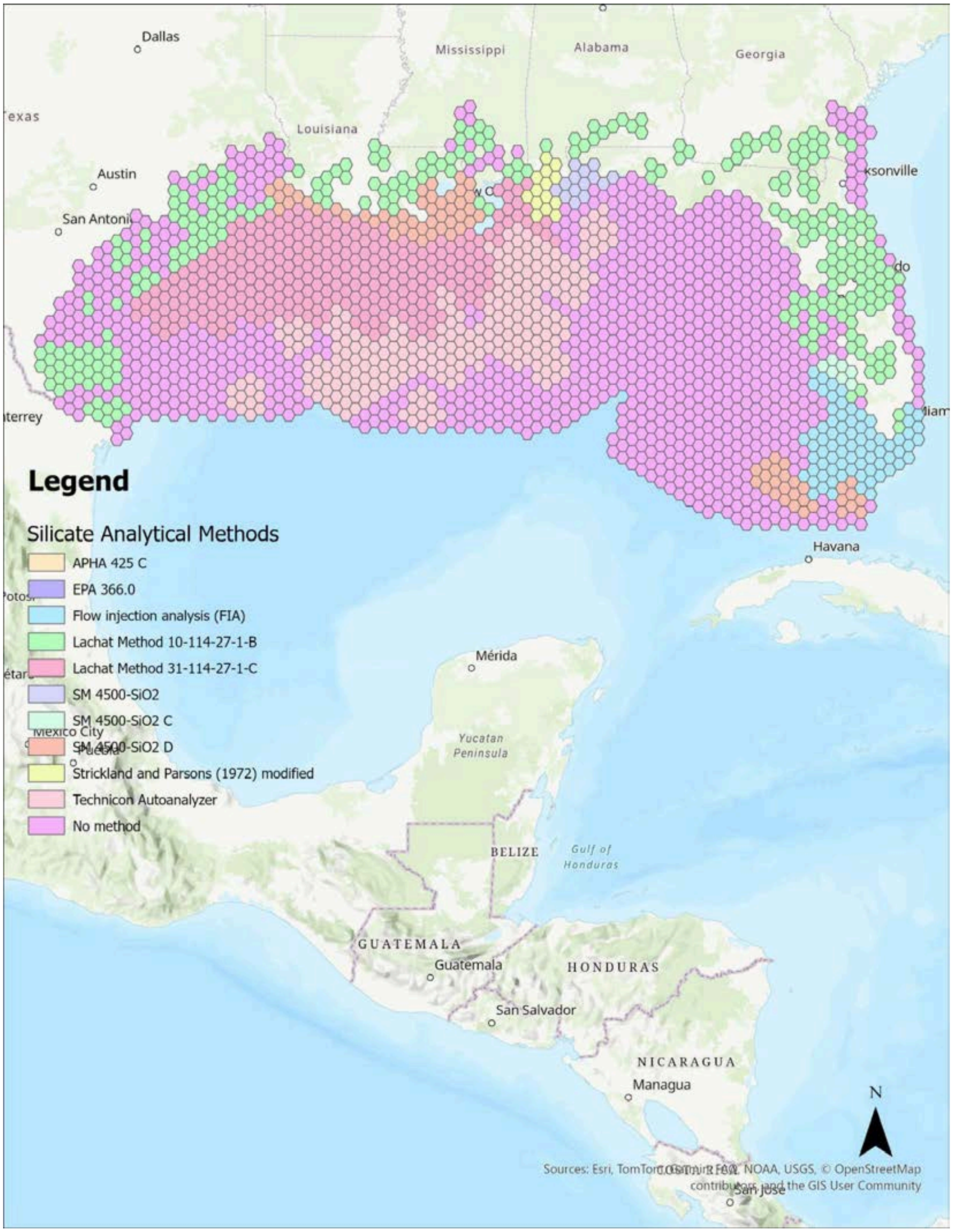

Figure D92. Map visualizing the spatial extents of all the identified analytical methods used to measure silicate across the Gulf.

Figure D93. Map visualizing the spatial extents of all the identified analytical methods used to measure soluble phosphorus across the Gulf.

Figure D94. Map visualizing the spatial extents of all the identified analytical methods used to measure suspended sediment concentration across the Gulf.

Figure D95. Map visualizing the spatial extents of all the identified analytical methods used to measure stage across the Gulf.

Figure D96. Map visualizing the spatial extents of all the identified analytical methods used to measure total coliforms across the Gulf.

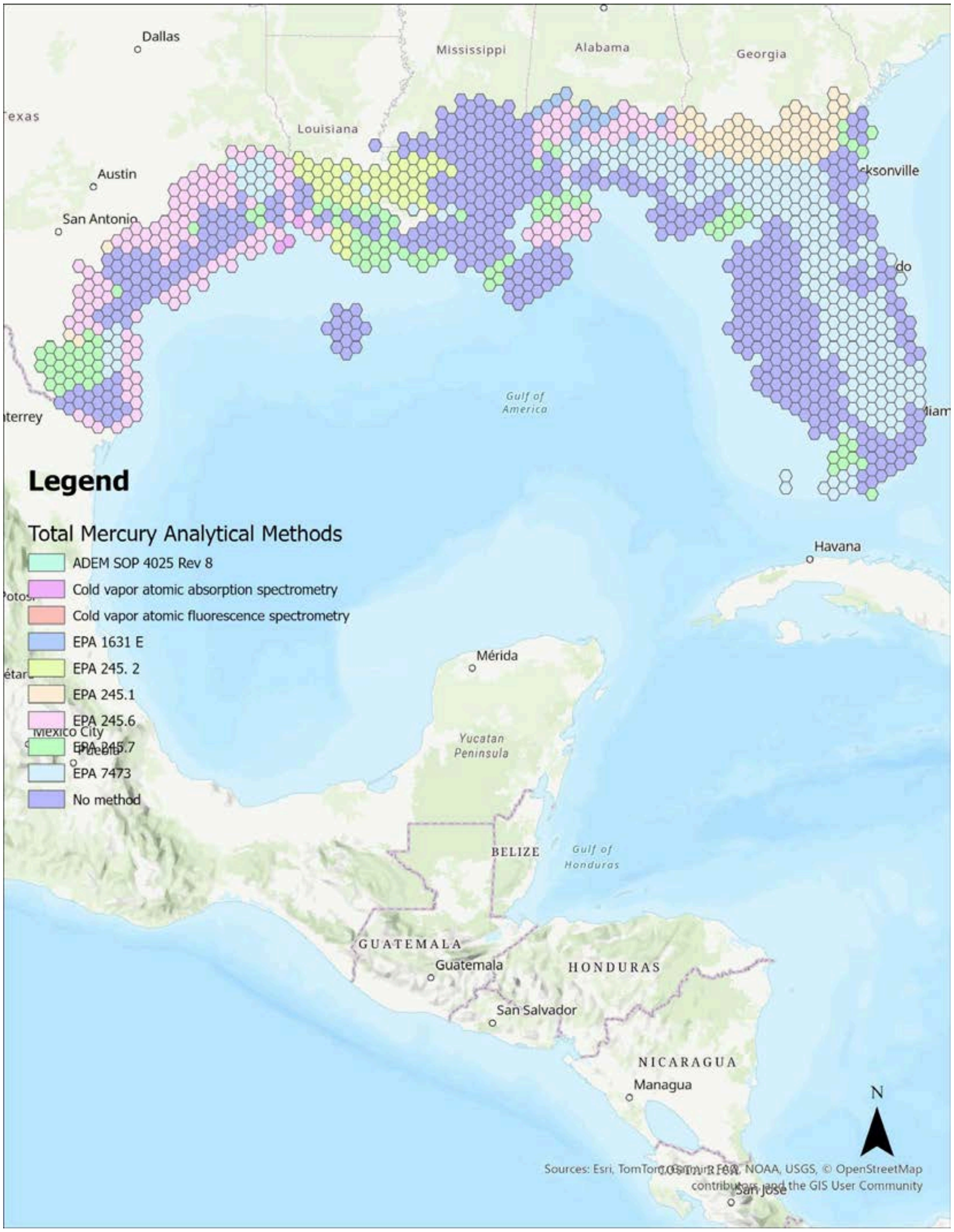

Figure D97. Map visualizing the spatial extents of all the identified analytical methods used to measure total mercury across the Gulf.

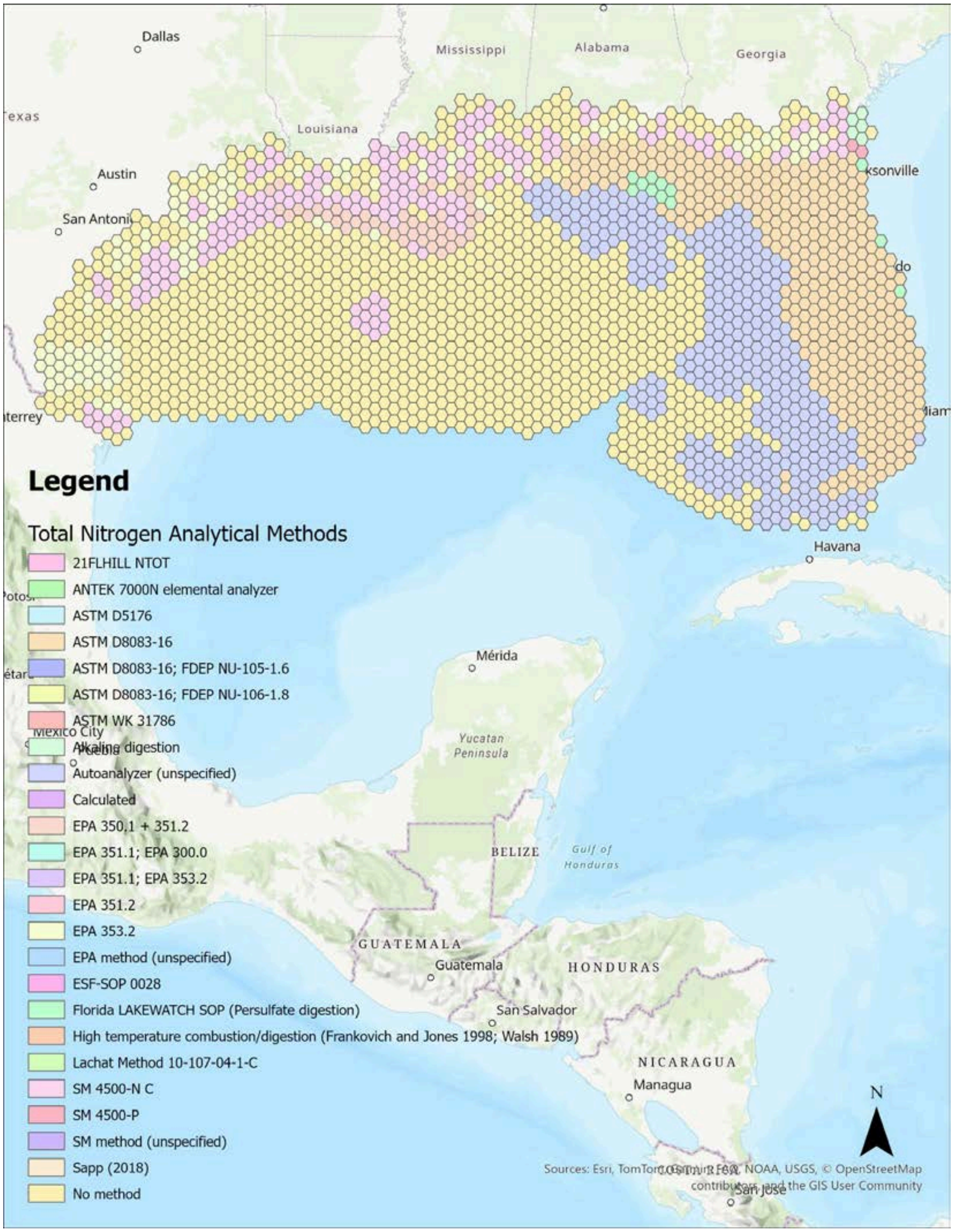

Figure D98. Map visualizing the spatial extents of all the identified analytical methods used to measure total nitrogen across the Gulf.

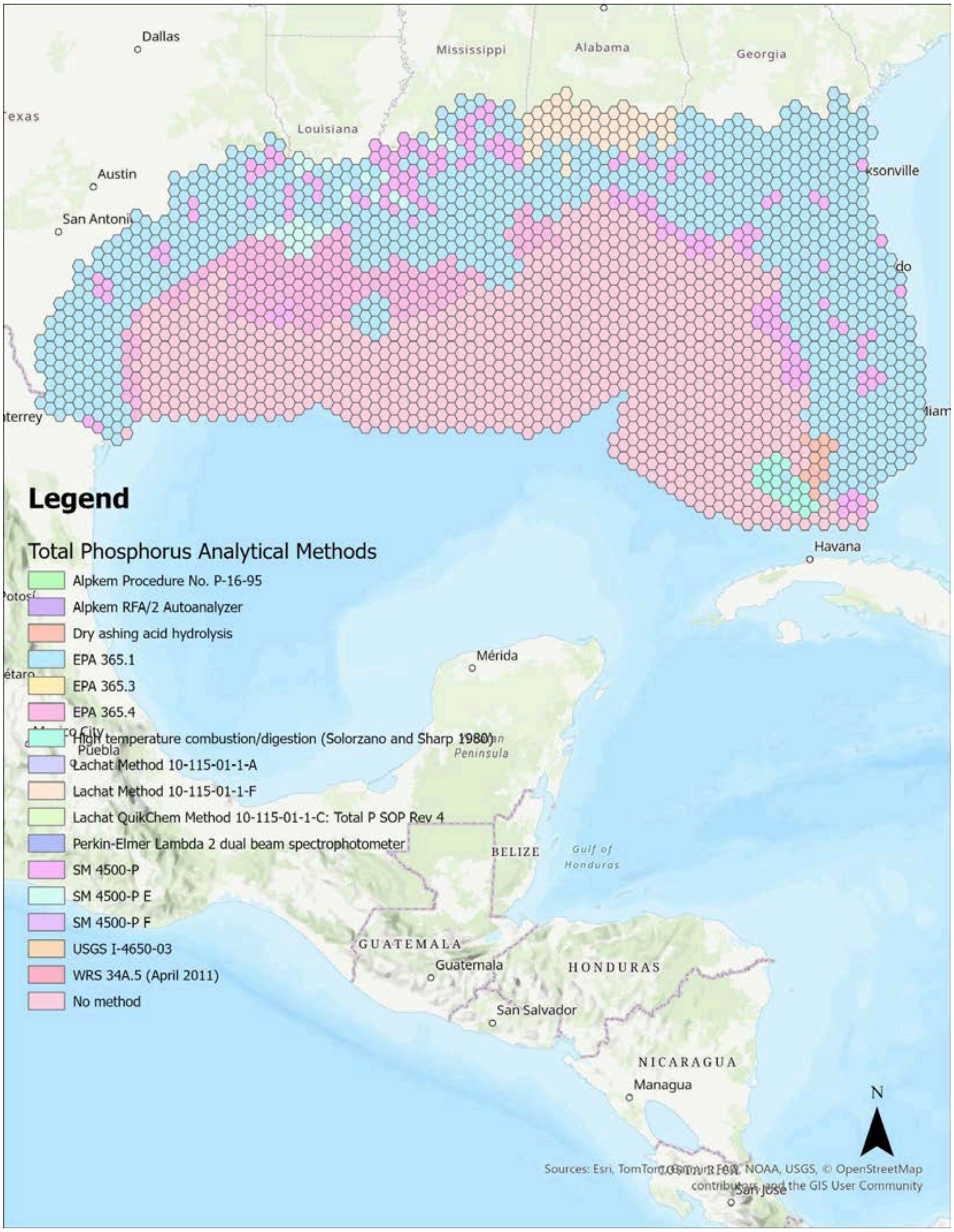

Figure D99. Map visualizing the spatial extents of all the identified analytical methods used to measure total phosphorus across the Gulf.

Figure D100. Map visualizing the spatial extents of all the identified analytical methods used to measure total suspended solids across the Gulf.

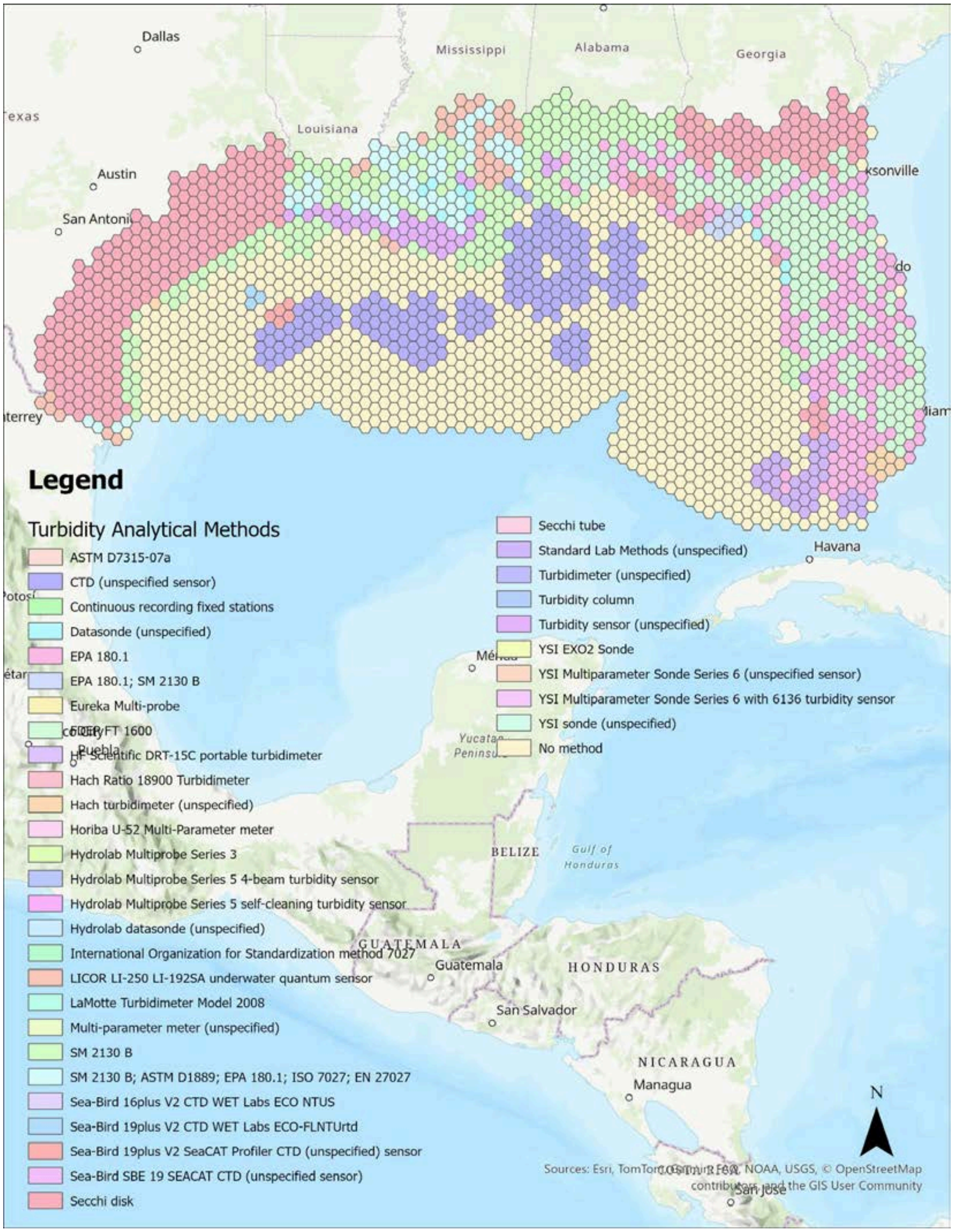

Figure D101. Map visualizing the spatial extents of all the identified analytical methods used to measure turbidity across the Gulf.

Figure D102. Map visualizing the spatial extents of all the identified analytical methods used to measure *Vibrio* across the Gulf.

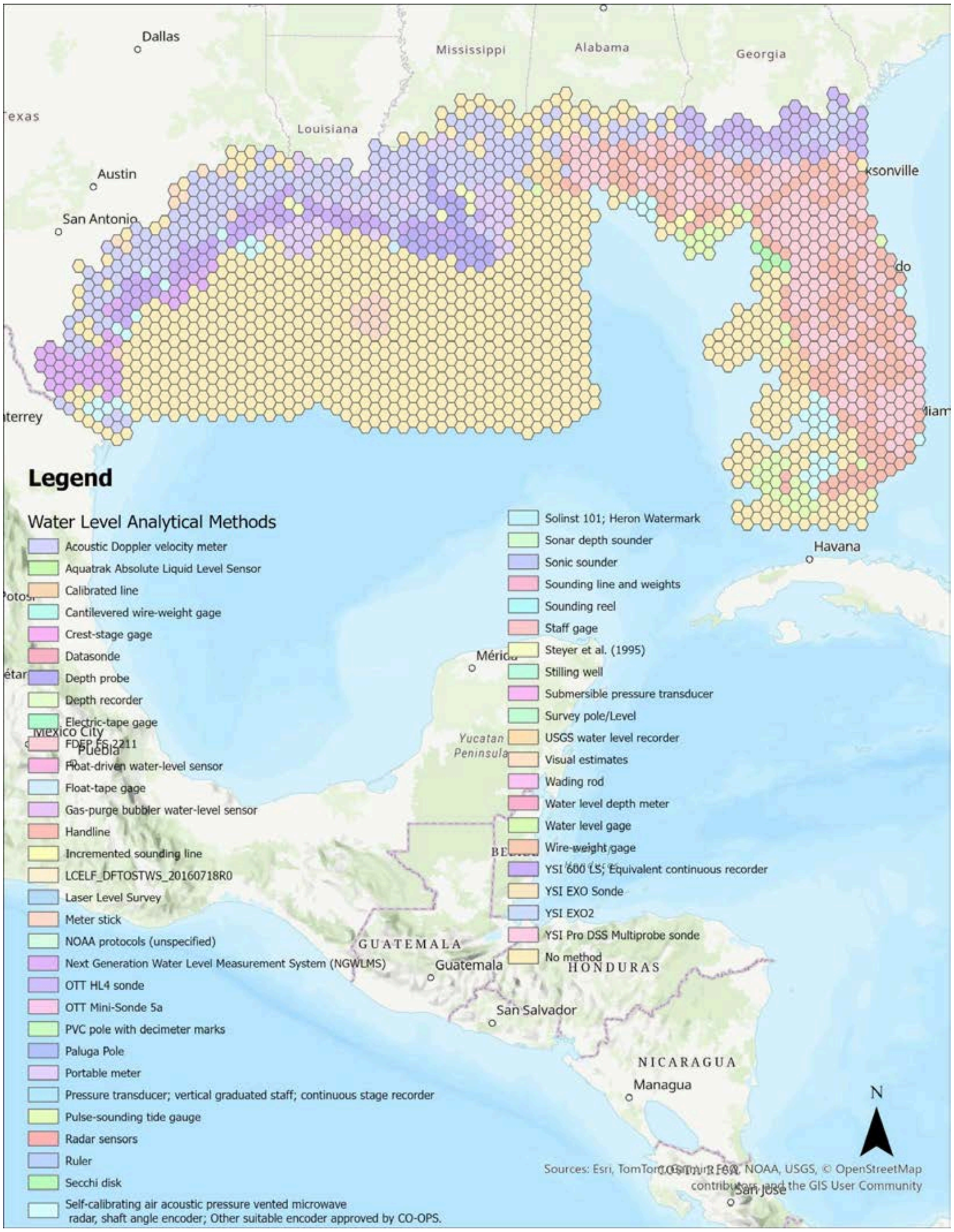

Figure D103. Map visualizing the spatial extents of all the identified analytical methods used to measure water level across the Gulf.

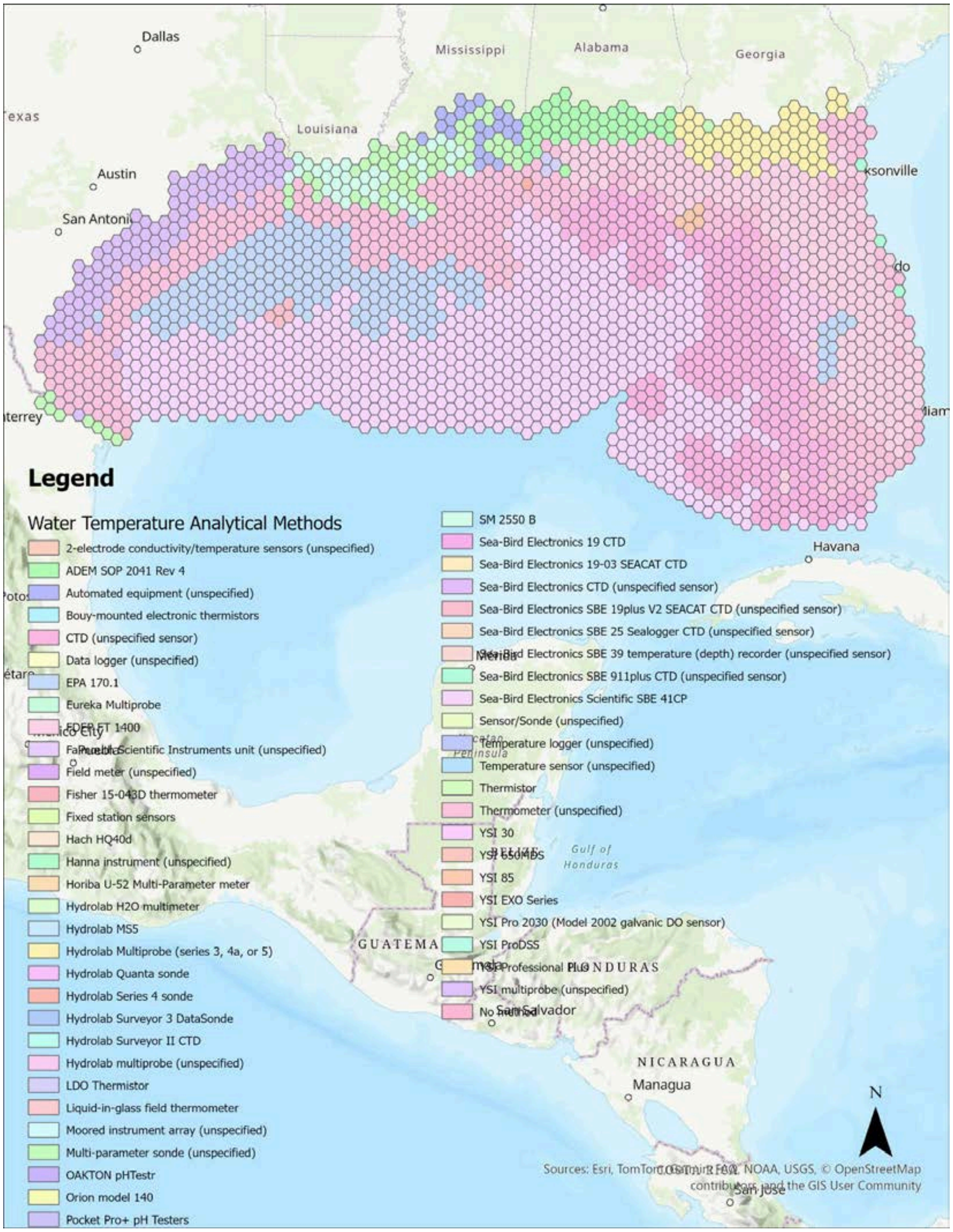

Figure D104. Map visualizing the spatial extents of all the identified analytical methods used to measure water temperature across the Gulf.