RESTORE CMAP Report Series: Task 5

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COUNCIL MONITORING AND ASSESSMENT PROGRAM (CMAP)

A Framework for Using the Monitoring Program Inventory to Conduct Gap Assessments for the Gulf of Mexico Region

A joint collaboration between
National Oceanic and Atmospheric Administration and the U.S. Geological Survey

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NOAA National Ocean Service, National Centers for Coastal Ocean Science, Marine Spatial Ecology Division
NOAA National Marine Fisheries Service, Southeast Regional Office

and

USGS Southeast Region
USGS Wetland and Aquatic Research Center
USGS Oklahoma-Texas Water Science Center
USGS Lower Mississippi-Gulf Water Science Center

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RESTORE Council Background

The Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act Final Rule at 31 C.F.R. Part 34) was signed into law on July 6, 2012. The RESTORE Act calls for a regional approach to restoring the long-term health of the valuable natural ecosystem and economy of the Gulf Coast region. The RESTORE Act dedicates 80 percent of civil and administrative penalties paid under the Clean Water Act, after the date of enactment, by the responsible parties in connection with the Deepwater Horizon oil spill to the Gulf Coast Restoration Trust Fund (Trust Fund) for ecosystem restoration, economic recovery, and tourism promotion in the Gulf Coast region. In addition to creating the Trust Fund, the RESTORE Act established the Gulf Coast Ecosystem Restoration Council (Council). The Council includes the Governors of the states of Alabama, Florida, Louisiana, Mississippi, and Texas, the Secretaries of the U.S. Departments of Agriculture, the Army, Commerce, Homeland Security, and the Interior, and the Administrator of the U.S. Environmental Protection Agency. The Council plays a key role in developing strategies and implementing projects that help ensure the Gulf's natural resources are sustainable and available for future generations. This has included the development of a Comprehensive Plan to restore the ecosystem and the economy of the Gulf Coast region (RESTORE Council, 2016). Approved in 2013 and updated in 2016, the Comprehensive Plan provides a framework to implement a coordinated, Gulf Coast region-wide restoration effort in a way that restores, protects, and revitalizes the Gulf Coast. The Comprehensive Plan identifies five goals for Gulf Coast restoration: Restore and Conserve Habitat, Restore Water Quality, Replenish and Protect Living Coastal and Marine Resources, Enhance Community Resilience, and Restore and Revitalize the Gulf Economy. Under the Council-Selected Restoration Component of the RESTORE Act, the Council develops Funded Priority Lists (FPLs) that describe the projects and programs it will fund. Projects and programs funded through this component must be in furtherance of the goals and objectives of the Council's Comprehensive Plan.

The Initial FPL, finalized in December of 2015, had a strong emphasis on watershed and estuary restoration and foundational cross-Gulf projects. The Council Monitoring and Assessment Program (CMAP) was approved as a Gulf-wide investment in the 2015 Initial FPL, and was administered jointly by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS). Funded activities include the organization of basic, foundational components for a Gulf-wide monitoring network to measure the efficacy of investments in Gulf restoration by the Council. The program, in coordination with the Gulf of Mexico Alliance (GOMA) and through collaboration with the Gulf States, federal and local partners, academia, non-governmental organizations, and business and industry, has leveraged existing resources, capacities, and expertise and built on existing monitoring programs and their data.

Project Team

We would like to thank the project team for their participation and expertise.

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Executive Summary

Under the Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (RESTORE Act), the Gulf Coast Ecosystem Restoration Council (RESTORE Council or Council) is required to report on the progress of funded projects and programs. Systematic monitoring of restoration at the project-specific and programmatic-levels (watershed and Gulf of Mexico) enables consistent reporting and gives the public confidence that the restoration investments selected by the RESTORE Council will be evaluated and adaptively managed accordingly. Monitoring information that has been collected at different spatial and temporal scales can be used as the foundation to illustrate progress towards comprehensive ecosystem restoration goals and objectives that promote holistic Gulf of Mexico recovery (see 'RESTORE Council Background' at the beginning of this report for additional Council information).

Currently, federal, state and local agencies, universities, private industry, and non-governmental organizations (NGOs) are conducting monitoring activities at various scales around the Gulf of Mexico. In addition, each RESTORE Council-funded project will, at a minimum, perform project-specific monitoring. This collection of monitoring activities was inventoried and coordinated into a network of existing programs by the Council-funded RESTORE Council Monitoring and Assessment Program (CMAP), which will suggest opportunities for efficiencies and collaborative cross-program review of performance with other Gulf ecosystem recovery efforts. CMAP was designed and funded to inventory and integrate existing monitoring efforts, improve discovery and accessibility of existing monitoring data, and ensure the collected information supports management decisions.

The fundamental approach to building the CMAP Gulf of Mexico water quality monitoring, habitat monitoring, and mapping network was to:

1. Adopt, or construct as needed, a comprehensive inventory of existing habitat and water quality observation, monitoring, and mapping programs in the Gulf of Mexico (hereafter referred to as the "Inventory"; NOAA and USGS, 2019a);
2. Evaluate the suitability/applicability of each program and its existing and prospective data for use in restoration activities;
3. Develop a process to use the Inventory to conduct gap assessments;
4. Develop a catalog of baseline assessments conducted in the Gulf of Mexico (NOAA and USGS, 2019b); and
5. Develop a searchable monitoring information portal/database to enable access to collected information and products.

Report Overview

The CMAP project has developed a set of products and tools to assist in the analytical exercises needed to conduct a data gap analysis, which included: (1) an inventory database; (2) spreadsheets; (3) geospatial data layers and mapping tools; (4) web services; (5) web visualization tools; and (6) monitoring program data links. Monitoring practitioners can use these products and tools to assess the patterns and trends in the data availability and data quality from programmatic metadata, and use that exploration to pinpoint datasets within programs that they want to investigate further to address their objectives. This report is a component of a series for the RESTORE Council (NOAA and USGS, 2019a,b; NOAA and USGS, 2020), and focuses on how the CMAP inventory of existing habitat and water quality observation, monitoring, and mapping programs can be used to conduct targeted gap assessments for different monitoring questions (e.g., exploring changes to specific water quality parameters in an estuary or larger scale study extent).

Credit: Nicholas Enwright (USGS)

Executive Summary

Chapter 1 introduces background information about gap assessments, including some examples of extensive gap assessments that have been completed in the Gulf of Mexico. For a practitioner, the goal of a gap assessment is often to gain a thorough understanding of the “who,” “what,” “when,” “where,” and “how” for programs that are monitoring parameters of interest within a specific area and time period. Building on the work of others, CMAP developed a gap assessment framework that focused on the assessment of three types of gaps: (1) informational (i.e., gaps based on documentation completeness); (2) temporal (i.e., gaps based on duration, frequency, and timing of data collections); and (3) spatial (i.e., gaps in a parameter based on spatial distribution).

Chapter 2 highlights the framework for a gap assessment conducted for three scales, which included a Gulf of Mexico-wide gap assessment of the programs monitoring in the CMAP ‘Water Column’ habitat, a Gulf of Mexico-wide gap assessment of programs monitoring in the CMAP ‘Oyster’ habitat type, and a pilot watershed-level gap assessment. In addition to varying spatial extents, the framework examined a range of spatial units (500-km^2 hexagonal grid and USGS hydrologic unit code level-12 [HUC-12] boundaries) to show examples of how the CMAP information can be visualized and analyzed. Informational gaps were developed using information in the Inventory related to documentation levels. These were coined monitoring program elements (MPEs) and included checks of each program for: (1) the availability of point of contact (POC) information; (2) data accessibility; and (3) documentation of monitoring procedures and data (i.e., metadata, units for water quality parameters). Temporal gaps were assessed by exploring the number of programs monitoring specific parameters prior to 1990, from 1990–2010, and after 2010. Informational, temporal, and spatial gaps were explored concurrently by highlighting how the MPE values have changed over these three time periods.

The Gulf of Mexico-wide assessments of monitoring and mapping gaps uncovered similar spatial trends as those observed by past efforts, but also identified some new areas for further investigation. Chapter 3 highlights the results from the three gap assessments. Since 1980, monitoring and mapping efforts have been concentrated along the terrestrial and estuarine zones of the Gulf of Mexico, leaving major gaps in the depths of the offshore marine zone. In both the Water Column and Oyster habitats across the Gulf of Mexico, most programs from the Inventory were active post-2010, but only a small percentage of those programs were found to be highly accessible with complete documentation. While the number of programs has increased over time, the proportion of programs with readily accessible data, metadata, and protocols or procedures has generally remained unchanged. Additionally, this process identified large-scale informational, temporal, and spatial gaps in the monitoring of oyster density. For example, very few programs monitored oyster density prior to 1990. Most of these programs lacked accessible documentation; however, well documented and highly accessible oyster density data were found along the Louisiana coast. Part of this effort involved pilot gap assessments in each state, which were presented to the MCoP. These gap assessments served as helpful examples of how data could be synthesized from the Inventory. Feedback from the MCoP on the pilot assessments included: (1) highlighting their agencies’ typical process for investigating data gaps; (2) underscoring the importance of accessible and well-documented programmatic metadata; (3) identifying potential applications for the Inventory and gap assessments; (4) pointing to the benefit of using the Inventory for multi-scaled analyses; and (5) providing examples of other potential users of the Inventory.

Chapter 4 highlights the benefits and uses of this information beyond CMAP, as well as limitations and recommendations for future efforts. Knowing what data are being collected, and where, for a region as extensive as the Gulf of Mexico is a daunting task; however, the CMAP products, including this gap assessment framework, provide a means to discover foundational information. Some additional benefits of the CMAP products and gap assessment framework include: (1) avoiding redundant data collection efforts; (2) determining where additional resources should be focused to fill data gaps; (3) identifying where coordination could allow for new data collections that can meet multiple program needs; and (4) facilitating compatibility between new and existing data collections. Also, there are several limitations to the Inventory that could be addressed over time. First, the Inventory is static and in order to stay current the product will require periodic update and maintenance. Second, the Inventory is built from programmatic metadata and does not contain parameter-specific duration and frequency information. Third, while some site locations were included in the spatial data for a specific program in the Inventory, site-level metadata were beyond the scope of this project. Fourth, restoration planning often requires data on faunal monitoring, which is not currently included in the Inventory. Collectively, CMAP products could be used to prioritize updates and enhancements in the Inventory over time and help ensure that these products have enduring value to the Gulf of Mexico restoration and monitoring community.

1 Introduction

To effectively manage ecosystems, best available science is required to make informed decisions across multiple geographic scales throughout the Gulf of Mexico. However, knowing what and where data are being collected is a daunting task. Thus, a spatially and temporally comprehensive inventory of water quality monitoring, habitat monitoring, and habitat mapping is a foundational element that can support scientifically sound decision-making regarding the health and viability of the Gulf of Mexico ecosystem. In the context of Gulf protection and restoration, a coordinated compilation of existing environmental monitoring programs will provide essential information to support the development, selection, and application of effective management and restoration alternatives, and inform adaptive management decisions at the local, state, and regional levels.

Background

Monitoring practitioners commonly rely on their own data collections or those from a few monitoring programs that are trusted and well known. Trust is established by thoroughly understanding the "who," "what," "when," "where," and "how" of those monitoring programs. The top challenges encountered when trying to discover, access, analyze, compare, and otherwise use data from existing monitoring programs include comparability of data, ability to find relevant programs and related data, and accessibility of data. When that information is readily available, users have a stronger measure of the reliability and quality of available data, allowing for meaningful discovery and exploration of the data behind the metadata.

Gap assessments have many uses including discovering historical data, revealing where long-term data are available, and improving integration among existing monitoring efforts. The value of data discovery in assessing and analyzing gaps is evident in recent applications. The Ocean Conservancy, in response to the Deepwater Horizon (DWH) disaster, assessed spatial and temporal monitoring gaps associated with the 12 injured resource categories identified under the DWH Natural Resources Damage Assessment (NRDA; Love et al., 2015). They found many long-term monitoring programs that could be used to assess the impacts of oil/dispersant exposure to species and habitats, but also noticeable gaps in the geographic and temporal distribution of most monitoring parameters.

Gap analyses have also been conducted in the Gulf of Mexico targeting specific areas and habitats. As part of the system-wide assessment and monitoring program (SWAMP) in Louisiana, Hijuelos and Hemmerling (2016) utilized a comprehensive geodatabase of monitoring programs to conduct a gap analysis of priority parameters to assess whether data were sufficient to address identified objectives. Using a power analysis, they were able to determine the needed sample size and distribute the sites using a probability-based design with a generalized random tessellation sampling approach.

The Florida Coastal Mapping Program assessed spatial gaps in existing seafloor data (e.g., bathymetry, side scan sonar, backscatter intensity, and habitat maps) to support the coordination of mapping efforts in Florida's coastal waters (Hapke et al., 2019). They divided the coast into six geographic regions and found that less than 20 percent of the coastal zone was mapped with high-resolution (minimum resolution of 10 m) data, particularly in the continental shelf zone. The Ocean Conservancy, SWAMP, and Florida Coastal Mapping Program applications had access to robust spatial and temporal information in relation to parameters of interest, but had limited information in their geodatabases with regard to data quality.

The RESTORE Council Monitoring and Assessment Program (CMAP) metadata inventory of habitat and water quality monitoring and mapping programs (the Inventory) in the Gulf of Mexico region is comprised of 544 programs (NOAA and USGS, 2019a), and provides a wealth of information that can be used by the monitoring community to understand where, geographically, data are rich and poor, where records are temporally adequate or inadequate, and where informational documentation of monitoring programs is robust or less robust. The ability to assess gaps (e.g., spatial, temporal, informational) using the metadata as a screening tool makes the discovery process meaningful, and much more efficient. For example, if the user did not have informational documentation on quality components of the data (e.g., quality assurance protocol) and only had metadata on the spatial locations of monitoring sites and time periods of collection for particular parameters of interest, the user may spend a lot of time accessing, downloading, and analyzing the data only to find out that there are data incompatibility issues.

The completeness of metadata documentation has been identified as a key determinant in conducting successful gap analyses (Ariño et al., 2016; Sprague et al., 2017). Incomplete or non-existent metadata result from technical barriers, complex data formats, and a lack of standardization. This can lead to limited access to data and can make the utilization of available scientific information cumbersome and daunting. As a consequence, existing data are underutilized and often have not undergone quality assurance (Jones et al., 2018). Sprague et al. (2017) examined over 25 million nutrient data records across the U.S. collected by 488 organizations since the late 1800s. Nearly 60% (14.5 million) of those records lacked metadata information, such as parameter name, unit of measurement, and numerical values, which are necessary to synthesize and analyze these data. A recovery of this missing information would be time-intensive, expensive, and, in some cases, inaccurate or impossible; however, without it, these data are unavailing in an analysis of monitoring gaps. In contrast, Jones et al. (2018) used extensive metadata records to conduct a cross-disciplinary analysis of spill-impacted regions of the Gulf of Alaska after the Exxon Valdez oil spill.

Purpose and Scope

The objective of this report is to describe how the monitoring user community can use the Inventory to screen attributes to support the identification of informational, temporal, and spatial gaps. The definition of gaps and the types of analyses that can be performed vary and are dependent on the question being asked as well as the source and structure of the data to be examined. The three categories of gaps defined within the context of CMAP were:

Informational Gaps: Informational gaps are assessed according to essential elements which may be lacking in descriptive metadata captured for each program documented within the Inventory.

Temporal Gaps: Temporal gaps are defined as a deficiency in the time frame, frequency of collection, or continuity of collections of data over time.

Spatial Gaps: Spatial gaps are defined by a program's limited spatial coverage or an inadequate number of monitoring stations to capture environmental variability to address a question of interest.

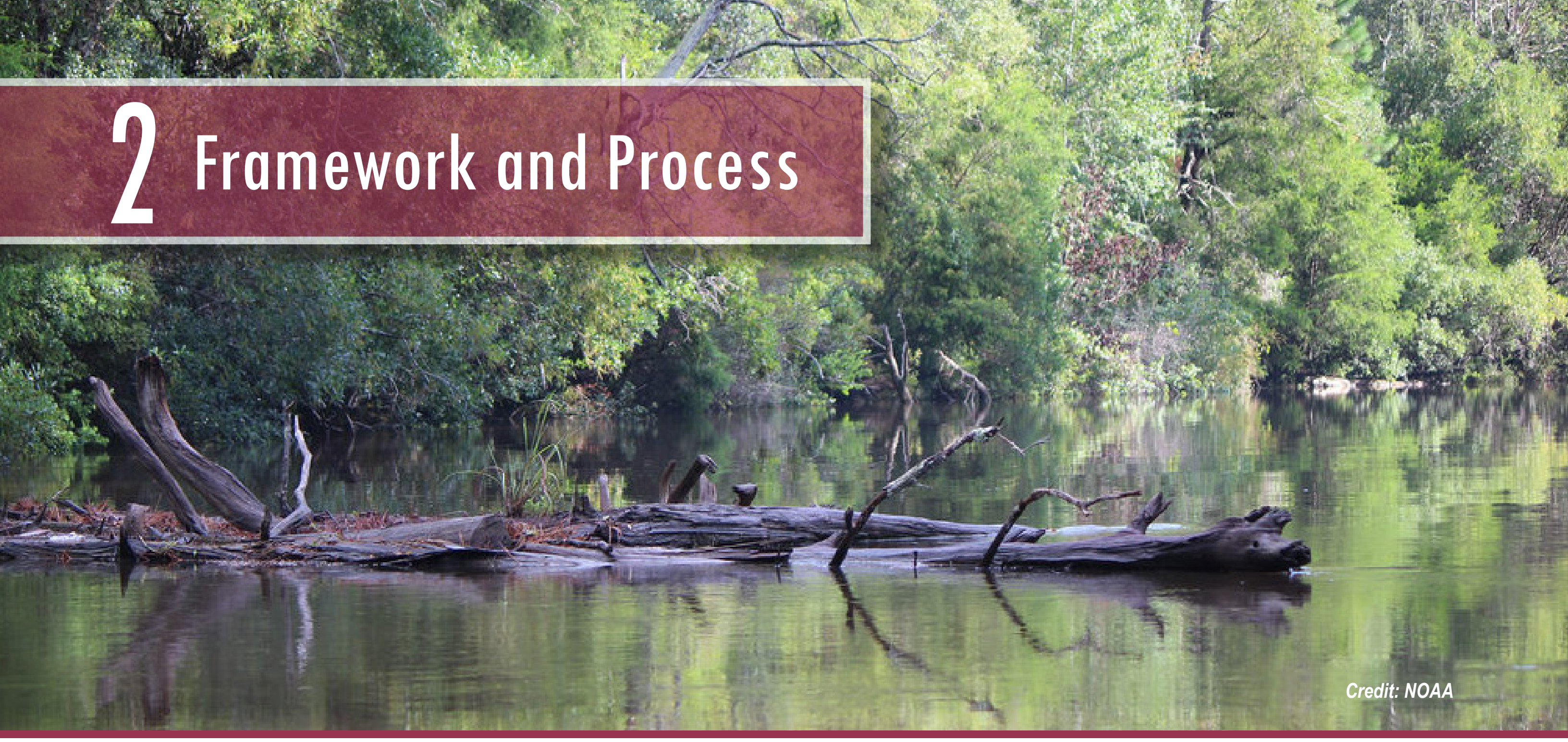
The gap assessment process, defined within this report, can identify patterns and trends of parameters of interest over space and time, and can suggest data availability and quality from supporting documentation, but it was not intended to be a gap analysis. A gap analysis, in the context of CMAP, is an analytical exercise where the user pinpoints the data they want to explore using the metadata assessment process to investigate an outcome they desire (e.g., management, research, restoration). The user then obtains and analyzes the available data and determines whether data are sufficient to address the outcome, and if any spatial and temporal gaps exist.

Process for Assessing Gaps

The Inventory is accessible online via a searchable webtool (https://restorethegulf.gov/cmap). Users can search by location or query inventoried programs by multiple criteria. The process for conducting a general query of the Inventory to screen for spatial, temporal, and informational gaps is as follows:

1. Identify the question to be answered;
2. Become familiarized with the Inventory and its contents, data dictionary, and structure;
3. Filter the Inventory spatially to limit to the area of interest;
4. Filter by attributes that may help address the question (e.g., parameters, program duration, measurement frequency, data availability, protocol availability, etc.);
5. View and/or analyze the programs which meet the specified criteria; and
6. If a higher level of detail is needed, such as site-specific metadata for unique parameters, find data access points (e.g., website, point of contact [POC], data access web address [URL], or metadata access [URL]) for each program and incorporate supplementary data.

2 Framework and Process



Application of the Process

Three gap assessment examples are presented and discussed in this report and include:

1. Gulf of Mexico-wide gap assessment of the 'Water column' habitat
2. Gulf of Mexico-wide gap assessment of the 'Oyster' habitat
3. Watershed-level gap assessment of the Perdido River basin

Collectively, these examples are based on questions that natural resource managers may be interested in, and include water quality, habitat, and mapping parameters across multiple scales. Each example examines the informational, temporal, and spatial gaps of monitoring or mapping of four parameters within a specific habitat and study area. The first two examples highlight how CMAP products, in particular the Inventory, can be used to address broad, Gulf of Mexico-wide gap assessments of particular habitat types. The third example is a watershed-level assessment which demonstrates how this process could help address locally relevant management questions. These three gap assessment examples were informed and developed through an exploratory pilot process that engaged the Gulf of Mexico community and the Council Monitoring and Assessment Workgroup (CMAWG) representatives from each Gulf state.

Informational Gaps

Informational gaps within CMAP were assessed according to essential elements that were identified to be lacking in the descriptive metadata captured for each program within the Inventory (NOAA and USGS, 2019a). The Inventory served as the foundation for these gap assessments. It contains metadata that describe general programmatic information, program type (i.e., water quality monitoring, habitat monitoring, mapping), POC information, program timeline, information on accessibility and documentation, habitat types (e.g., mangrove, water column, emergent marsh) with aquatic settings (e.g., estuarine, palustrine, marine nearshore), and a list of parameters monitored for each program (NOAA and USGS, 2019a). While all programmatic metadata in the Inventory were reviewed internally for accuracy, over half (61%) of the inventoried program records were also reviewed and verified by a program POC.

Parameters of Interest

A comprehensive gap assessment of monitoring and mapping efforts within a specific habitat type or location could have many parameters. While there are several water quality, habitat, and mapping parameters documented within the Inventory, CMAP chose to focus on a set of key parameters for this exercise. Per habitat type, CMAP grouped parameters into multiple tiers based on programmatic frequency of occurrence and crosswalked with "core" (i.e., primary) parameters from other monitoring guidance sources (e.g., NRDA Trustees, 2017; NOAA and USGS, 2020). All the parameters highlighted in the Gulf of Mexico-wide gap assessment examples are CMAP Tier 1 parameters (i.e., most commonly measured within the Inventory and suggested by guidance sources) for those respective habitat types. The parameters chosen for the watershed-level assessment were identified and linked to a locally relevant management question, which is discussed in more detail in the following chapter. The parameters, spatial extent, and spatial units for each gap assessment are shown in Table 1.

For more information on the parameters and parameter tiers documented by CMAP, see NOAA and USGS (2020).

Monitoring Program Elements

A variety of programmatic descriptive metadata are captured within the Inventory and detail various elements of each monitoring program. The Inventory contains eight binary elements that are termed the monitoring program elements (MPEs). The MPEs indicate the level of efficacy, comparability, and accessibility of a program or project and include the following:

1. Does the program have a POC?
2. Are data accessible (web accessible or send upon request)?
3. Are data available in a machine-readable format?
4. Are the data collected under this program/project documented with metadata (i.e., any format)?
5. Does the program have documented quality assurance (QA) protocols (i.e., collection and analyses) for the majority of parameters?
6. Does the program have documented collection procedures for the majority of parameters?
7. Does the program have documented analytical procedures for the majority of parameters?
8. Are data units clearly defined and labeled (only documented for programs monitoring water quality)?

Using these criteria, informational gaps can be assessed for each program within the Inventory. A standardized value was calculated for each program which indicates the percent of MPEs that were answered in the affirmative (e.g., POC information is available, data are accessible, protocols and procedures are documented). Eight MPEs were assessed for water quality monitoring programs, while only seven were assessed for habitat monitoring and mapping programs; this was due to the lack of unit information in the Inventory for habitat monitoring and mapping efforts. As an example, a water quality program that only has a single MPE would have an MPE percentage of 12.5% (1 of 8) and a habitat monitoring program with a single MPE would have an MPE percentage of 14% (1 of 7). For the gap assessment examples provided in this report, CMAP staff chose to focus on all of the MPEs. However, an end user of CMAP products will have the ability to select individual MPEs or attributes customized to the topic of their question or analysis. It is important to point out that some programs may have materials for MPEs 5–7, but these materials were either not web-accessible or provided during a POC engagement process, which had a response rate of 61% (NOAA and USGS, 2019a).

Credit: Michael Lee (USGS)

Table 1. Spatial extent, spatial units, and parameters for the map-based and temporal gap assessment examples.

	Gap Assessment Examples		
	Gulf of Mexico-wide Water Column Habitat	*Gulf of Mexico-wide Oyster Habitat*	*Watershed-level*
Spatial Extent	Full CMAP study area	Estuarine zone	Perdido River basin
Spatial Units	500-km^2 hexagons	500-km^2 hexagons	HUC-12s
Parameters	Conductance Total nitrogen Total phosphorus Water temperature	Area of habitat types Conductance Dissolved oxygen SHBA density	Area of habitat types Total nitrogen Total phosphorus Total suspended solids

SHBA – Submerged habitat-building animal
HUC-12s – USGS hydrologic unit code level-12 boundaries

Temporal Gaps

The Inventory also contains a set of fields which can be used to identify temporal gaps in monitoring or mapping for any given area across the Gulf of Mexico. For a given program, the duration and time period of activity as well as the frequencies at which measurements are made throughout the program's lifetime are described. This comes with a caveat that, for each program documented within the Inventory, measurement frequencies or time periods are not linked to specific parameters, but rather to the program in general.

For each example, temporal gaps were assessed for the four parameters identified in Table 1 by categorizing the count of program activity by time range and three different MPE levels: (1) limited documentation (<60% MPEs); (2) moderate documentation (60–90% MPEs); and (3) complete documentation (100% MPEs). This assessment summarized what programs are monitoring and the MPE levels for each time bin, and did not distinguish between new and existing programs.

Spatial Gaps

Programmatic Geospatial Data

Every program within the Inventory is georeferenced and linked to spatial data representing the footprint or general area in which that program operates. These data were developed from a variety of sources including other inventory databases (Love et al., 2015; U.S. Geological Survey [USGS] Global Change Monitoring Portal, https://my.usgs.gov/gcmp/), program websites, and program POCs. Whenever possible, the spatial delineation for a program was represented by custom, or program-generated, footprints that were either provided by the POC or readily available online (Figure 1). For instances where this was not possible, the CMAP team developed a grid to capture a general footprint of the program. This grid includes USGS hydrologic unit code level-12 (HUC-12) boundaries for estuarine and upland areas merged with a marine zone hexagonal grid developed by the Ocean Conservancy (Love et al., 2015). If custom footprints were not available for a program, then the best available information (e.g., graphic on website, program description, site or transect locations, state boundaries) was used to develop a general footprint with either the CMAP grid or other data (e.g., state boundaries).

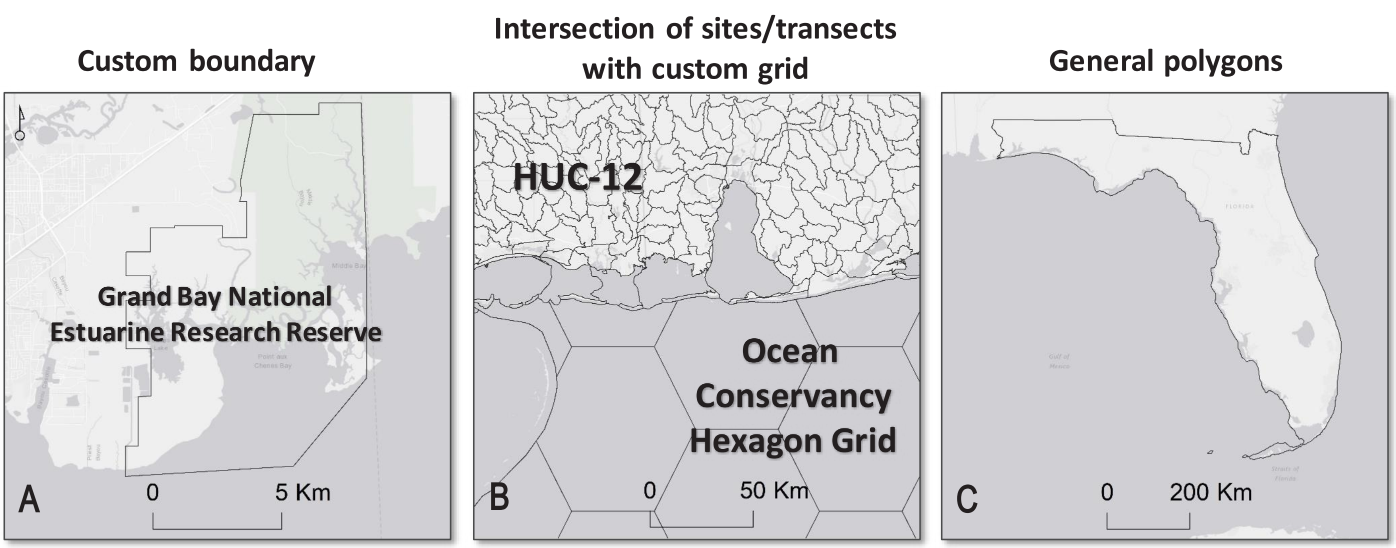


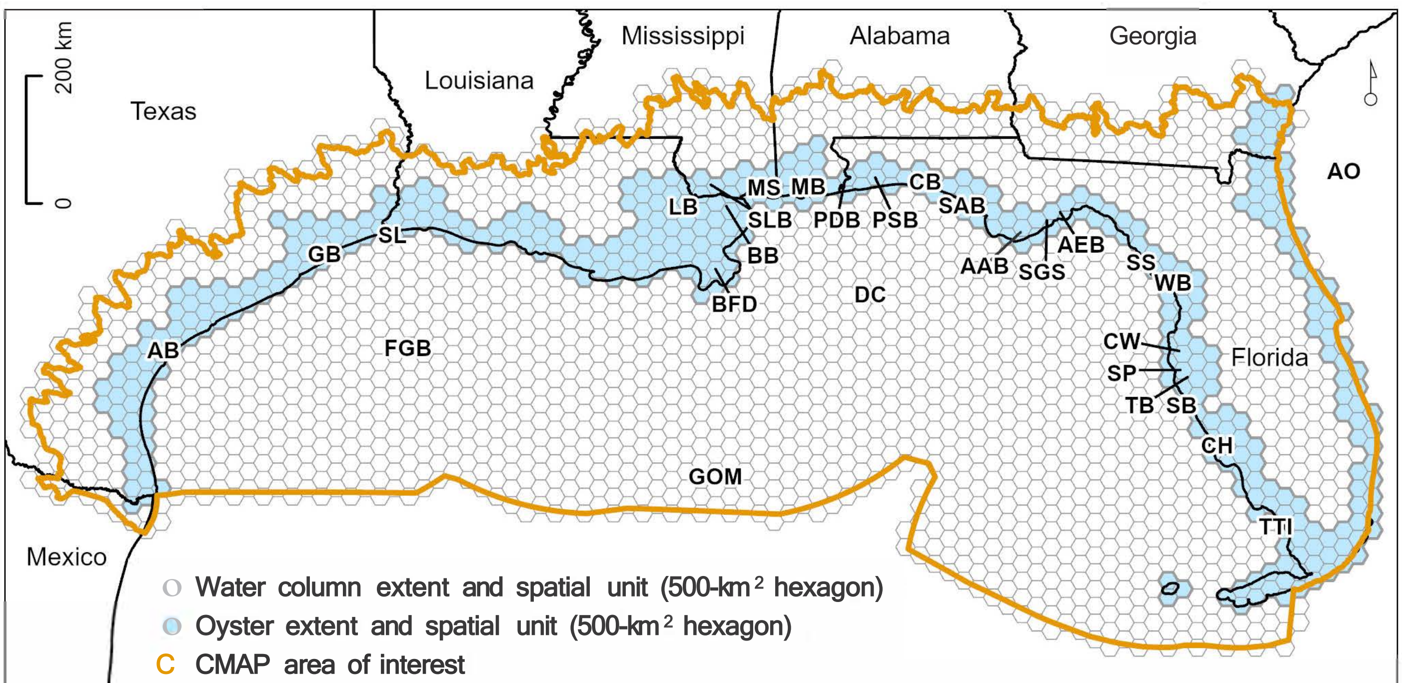
Figure 1. Program footprints were processed using a variety of methods, which included (a) custom boundaries (e.g., National Estuarine Research Reserve boundaries), (b) polygons derived from a custom grid using site or transect locations, and (c) general polygons (e.g., jurisdictional boundaries).

For some programs, site and/or transect locations were available and used to develop a program's footprint. Using the previously mentioned CMAP grid, all HUC-12 watersheds or grid cells that contained or intersected the site or transect locations were merged to create a program's polygon footprint. While some of the inventoried programs' metadata includes information on site (299 programs) or transect (16 programs) locations, it does not provide specific monitoring activities linked to those unique sites. For instance, throughout a monitoring or mapping program's lifecycle, parameters, measurement frequencies, and often the locations in which those are measured vary over time and space. This is a level of detail not directly provided by CMAP products; however, access points to such information are available should the end user desire to assess gaps at this level of detail. For more information on the Inventory, see NOAA and USGS (2019a).

Spatial Extent

The three gap assessments presented in this report were applied at varying scales within the Gulf of Mexico study area. The scale of the Gulf of Mexico-wide Water Column assessment spans the entire CMAP area of interest extending from 25 miles inland from the Coastal Zone Management Boundary (NOAA OCM, 2019) to the U.S. Exclusive Economic Zone (EEZ; 48 Fed. Reg. 10605 [Mar. 14, 1983]; Figure 2).

The scale of the Gulf of Mexico-wide Oyster assessment spanned the entire Gulf of Mexico as well, but was confined to the estuarine zone (Figure 2). The rationale for this constraint was to restrict programs with parameters of interest (Table 1), especially submerged habitat-building animal (SHBA) density which includes all bivalves, to estuarine areas where oysters are located. To accomplish this, the CMAP team developed a generalized estuarine zone from the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) dataset. First, estuarine wetlands were extracted from these data and were then buffered by 2 km to produce a generalized estuarine zone. This buffer was used to account for any issues with the NWI having variable dates and quality across the Gulf of Mexico. In addition to the spatial extent of the two Gulf of Mexico-wide gap assessments, Figure 2 shows the location of key waterbodies throughout the study area.



Code	Name	Code	Name	Code	Name	Code	Name	Code	Name
AAB	Apalachicola Bay	CB	Choctawhatchee Bay	GOM	Gulf of Mexico	SAB	St. Andrew Bay	SS	Suwannee Sound
AB	Aransas Bay	CH	Charlotte Harbor	LB	Lake Borgne	SB	Sarasota Bay	TB	Tampa Bay
AEB	Apalachee Bay	CW	Clearwater	MB	Mobile Bay	SGS	St. George Sound	TTI	Ten Thousand Islands
AO	Atlantic Ocean	DC	Desoto Canyon	MS	Mississippi Sound	SL	Sabine Lake	WB	Waccasassa Bay
BB	Bay Boudreau	FGB	Flower Garden Banks	PDB	Perdido Bay	SLB	St. Louis Bay		
BFD	Birdsfoot Delta	GB	Galveston Bay	PSB	Pensacola Bay	SP	Saint Petersburg		

Figure 2. Map of the CMAP area of interest and the Gulf of Mexico-wide gap assessment extents. Key waterbodies and features mentioned within the report are labeled for reference.

The watershed-level assessment of the Perdido River basin was conducted within a smaller extent. The Perdido River basin crosses the Alabama and Florida state border and encompasses an area of just over 3,000 km^2 (Figure 3). Major waterbodies within this watershed include the Perdido River, Blackwater River, Styx River, Elevenmile Creek, Brushy Creek, Perdido Bay, Big Lagoon, and Little Lagoon. The boundary for the Perdido River basin was developed by the RESTORE Council staff by using USGS HUC-12 boundaries (Figure 3). A gap assessment at this small scale allows for a more localized approach and closer examination of the programs operating within the study area.

Spatial Units

A critical decision in any gap assessment is determining the spatial unit of analysis. A few potential choices include: (1) an orthogonal grid (i.e., a square grid); (2) a hexagonal grid; and/or (3) non-arbitrary units, such as areas defined by hydrology (e.g., watersheds) or ecology (e.g., ecoregions).

For the Gulf of Mexico-wide gap assessments, we developed a 500-km^2 hexagon grid. The rationale for using a hexagon grid was largely based on the reduced ambiguity (i.e., outlines of groups of cells in a hexagonal grid form more varied and less rectilinear shapes compared to square grids), the increased aesthetic appeal of hexagonal grids compared to orthogonal grids (Birch et al., 2007), and the frequent use of hexagonal grids for similar studies. For example, hexagonal grids are commonly used in ecologic assessments, including: (1) U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (White, 1992); (2) seagrass monitoring (Dunton et al., 2010); and (3) the Gulf of Mexico Avian Monitoring Network (Wilson et al., 2019). The Gulf of Mexico-wide Water Column assessment included all hexagons that intersected the CMAP area of interest, whereas the Gulf of Mexico-wide Oyster assessment only included hexagons that intersected the generalized estuarine zone (Figure 2). The watershed-level gap assessment of the Perdido River basin was conducted using HUC-12 boundaries (n = 35) as spatial units (Figure 3).

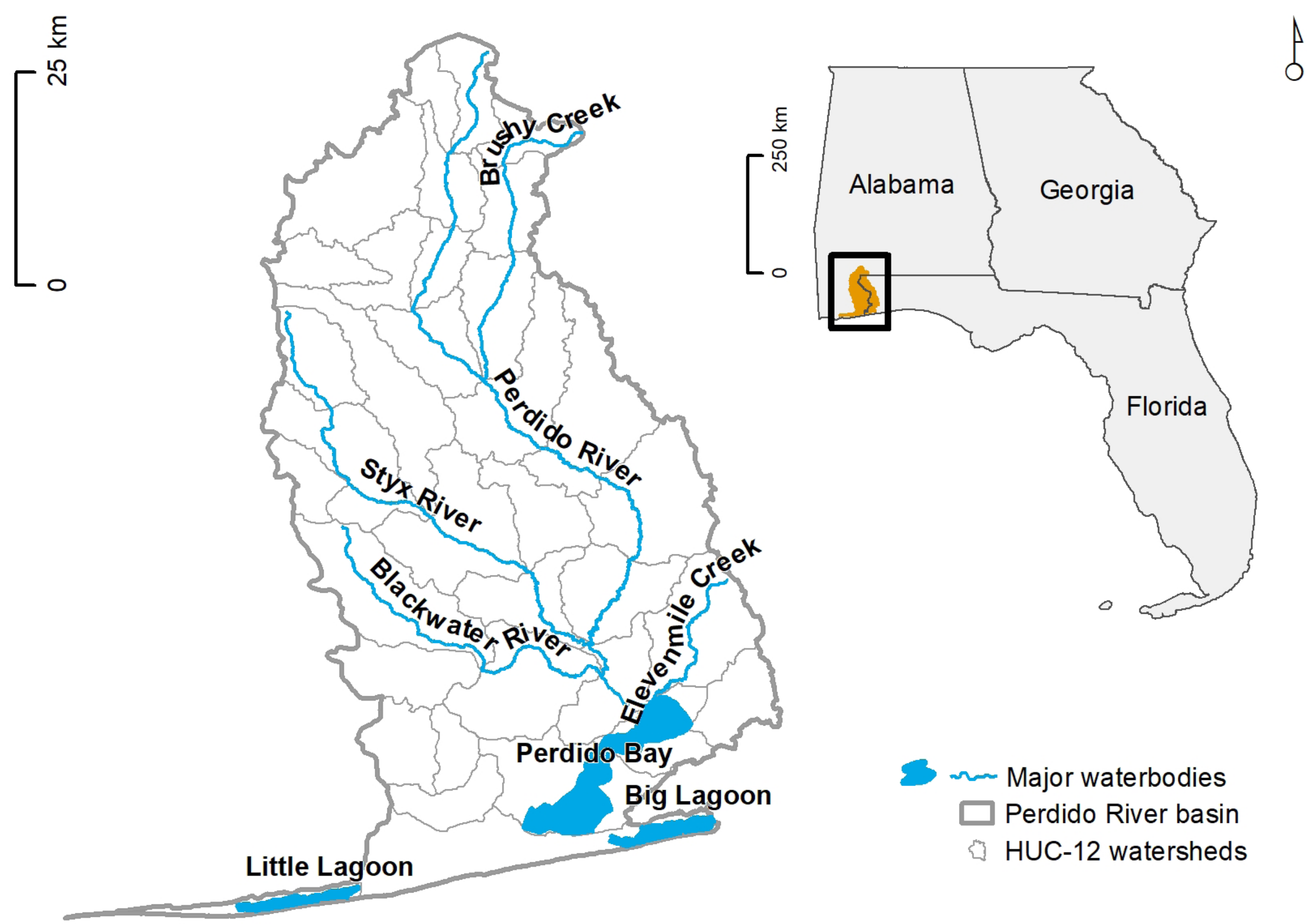


Figure 3. Reference map of the Perdido River basin gap assessment extent and spatial unit.

It is important to note that the size of the HUC-12 boundaries varies within the basin with a median size of 77.1 km^2 and an interquartile range of 76.3 km^2.

While it is common practice to account for variability in spatial unit size by calculating a rate per unit (e.g., count per square kilometer), the CMAP team opted to use an unadjusted count of programs per spatial unit. The rationale for this was that the objective for the gap assessment was to show where monitoring is occurring within the given spatial extent (i.e., Gulf of Mexico or smaller extent), and, as hydrologic units, HUC-12s are not arbitrary or jurisdictional boundaries (e.g., county boundaries).

Programmatic Geospatial Data Processing

An initial step in assessing spatial monitoring gaps using the Inventory is to link the spatial data (e.g., program footprints, sites, and transects) to relevant Inventory attributes, or programmatic descriptive metadata. In order to perform the following steps, it is important to ensure that the attributes to be analyzed are in a numerical format. By doing so, this enables the user to calculate summary statistics of the various programs which intersect each unit of analysis (e.g., hexagon grid or HUC-12 boundaries). For the examples provided, the Spatial Join tool in Esri ArcMap (v10.7.1, Redlands, CA) was used to calculate two variables for each parameter per unit of analysis. These variables were calculated for each individual grid cell or HUC-12 boundary and include: (1) the count of programs which monitor the parameter of interest; and (2) the median MPE percentage of programs which monitor the parameter of interest.

The spatial resolution of each program footprint is variable depending on the availability of spatial data during geoprocessing. Thus, the spatial footprint generally represents the area where a program may have conducted monitoring activities. For example, a water quality program may operate a network of geographically distributed sites; however, the spatial footprint of the program would be represented by any HUC-12 boundary that contained at least one site.

For each parameter, choropleth maps of program count were created by classifying all the spatial units into three quantiles (i.e., each class accounts for one-third of the spatial units). This process was repeated to create choropleth maps for median MPE percentage. Prior to classifying these data into quantiles, spatial units (i.e., grid cells or HUC-12 boundaries) with a value of zero for program count and/or median MPE percentage were excluded.

An effective way to visualize the spatial intersection between two variables is by using bivariate choropleth maps (Olson, 1981). This allows for two variables, represented by univariate choropleth symbologies, to be examined concurrently. For a given parameter, these visualizations help users easily gauge the spatial distribution of the magnitude a parameter is monitored with relation to programmatic documentation levels. Figure 4 provides an overview of how to interpret the maps presented in Chapter 3.

For example, spatial units symbolized by a bright yellow color (top left corner of Figure 4) indicate that informational gaps are prevalent in this area; these are areas with a high number of monitoring programs with low median MPE percentages.


Credit: Michael J. Osland (USGS)

Spatial units symbolized by a medium hue of blue (lower right corner of Figure 4) indicate that while there are fewer monitoring programs operating in that area, they are all well-documented with higher median MPE percentages. Lastly, spatial units that have a black symbology (upper right corner of Figure 4) have a high number of monitoring programs and high median MPE percentages. A summary of the gap assessment process to visualize gaps is shown in Figure 5.

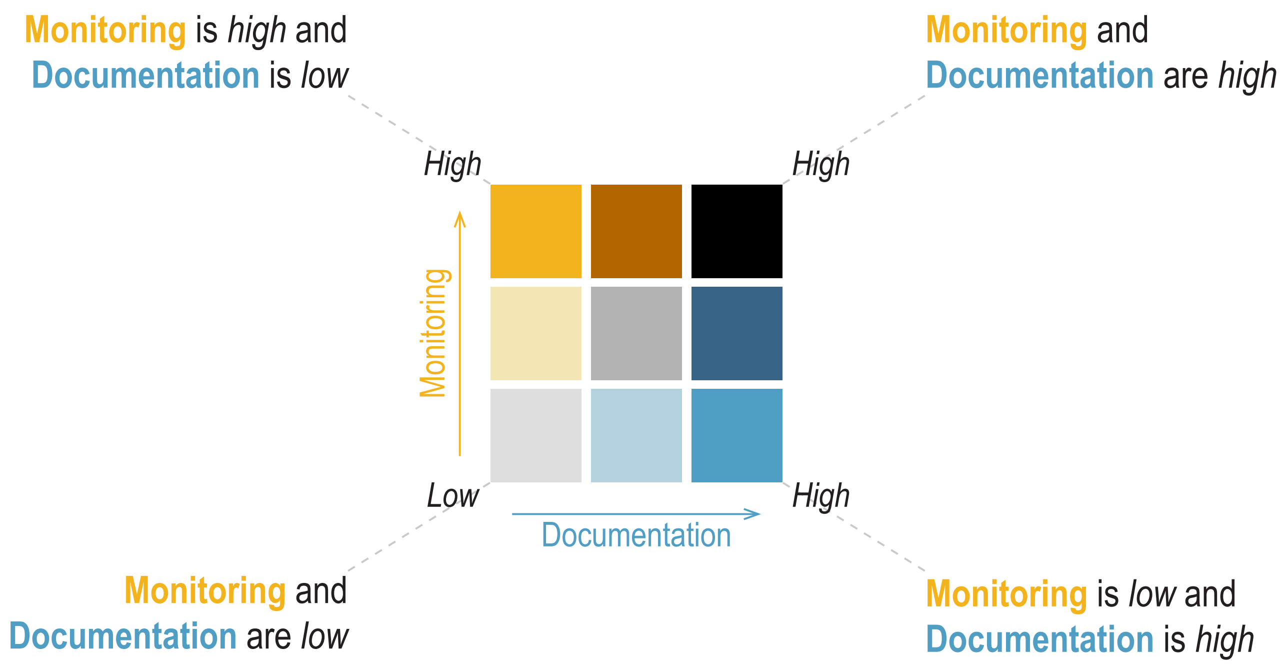


Figure 4. Overview of how to interpret bivariate choropleth symbology.

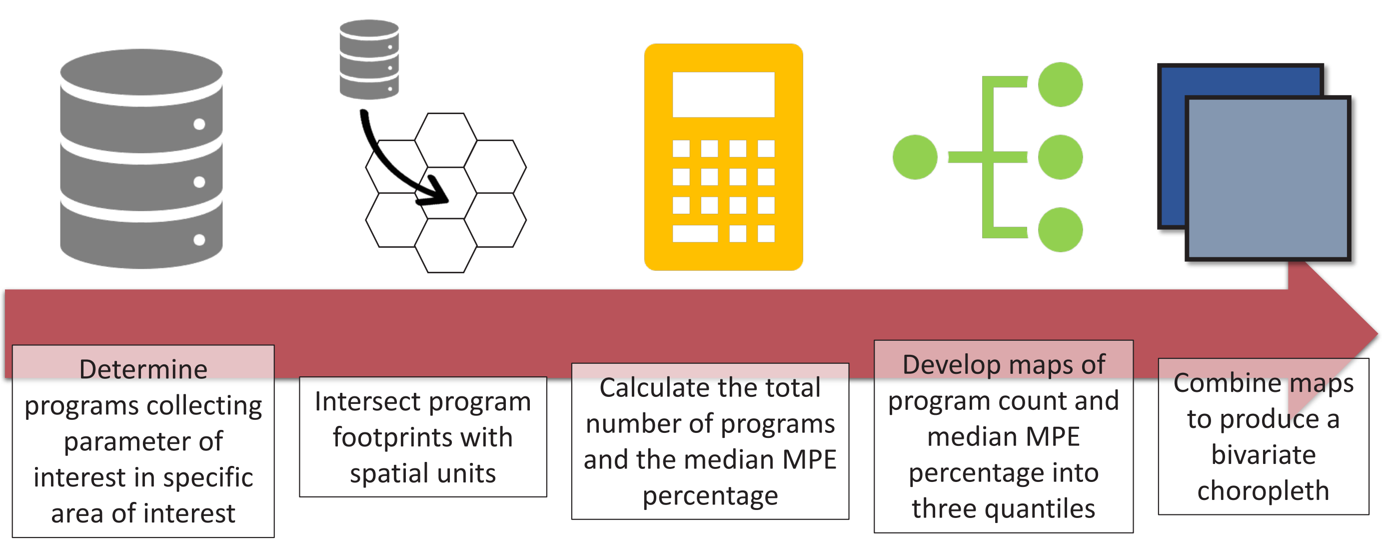
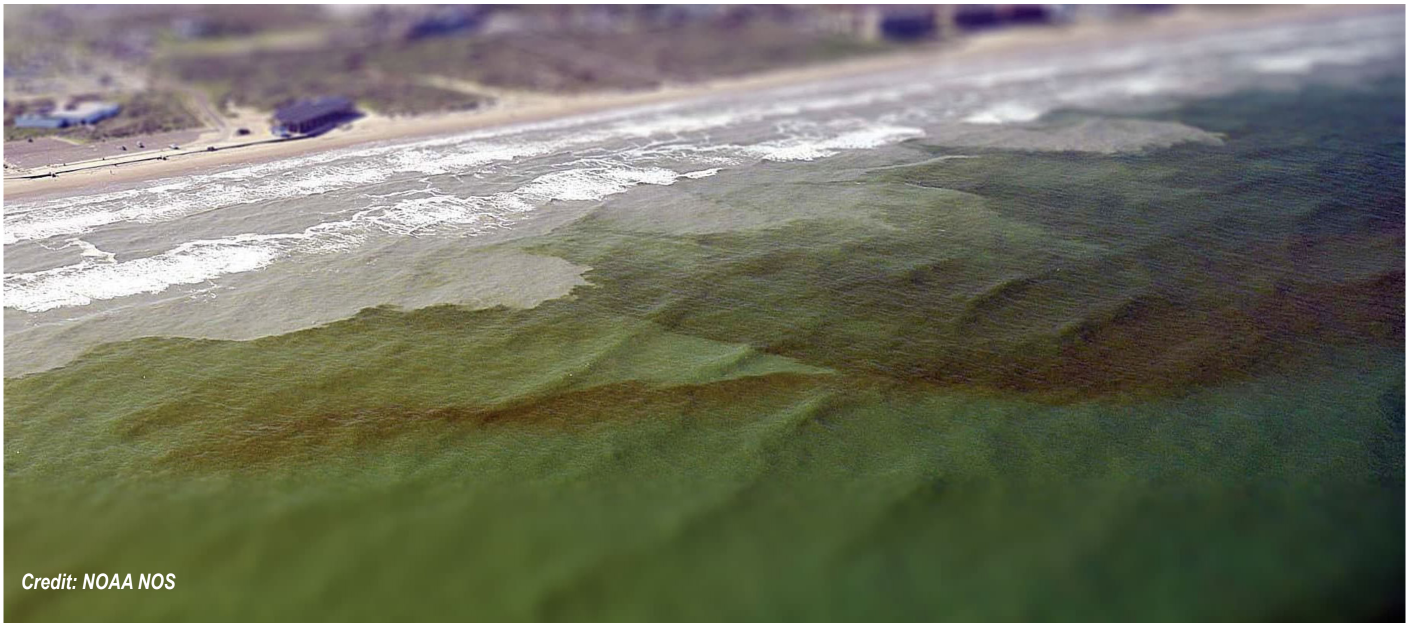


Figure 5. Gap assessment process followed to generate maps of spatial gaps.



Credit: NOAA NOS

Pilot Watershed-level Gap Assessments

Overall, CMAP conducted a pilot watershed-level gap assessment within each of the five Gulf of Mexico states. These pilot watershed-level gap assessments, including the Perdido River basin assessment described here, were developed using questions proposed by state representatives in the CMAWG, an advisory group for the CMAP project (NOAA and USGS, 2019a).

Each CMAWG state representative identified a focal watershed and specific management question(s) that would be used to target parameters within the Inventory. Rather than directly answering these questions, the watershed-level gap assessments were intended to demonstrate the framework at a more local level and show how questions could be addressed using inventoried information. The boundaries for these gap assessments were developed by combining various USGS HUC boundaries to align with estuarine drainage areas developed by Greene et al. (2014). The analysis was similar to what is presented in this report with a few exceptions: (1) bivariate choropleth maps were not developed; (2) data were aggregated and analyzed using multiple units of analysis (i.e., HUC-12s and 1-km^2 hexagons); and (3) site and transect locations were displayed in addition to the choropleth maps.

The gap assessments for Texas (Salt Bayou), Louisiana (Calcasieu–Sabine–Neches), and Alabama (Perdido River basin) were highlighted in breakout sessions at the Monitoring Community of Practice (MCoP) workshop at the Gulf of Mexico Alliance (GOMA) Mid-year Meeting in January 2020. Gap assessment results for Florida (Suwannee River) and Mississippi (St. Louis Bay) were presented at a later date to state colleagues. The materials from these pilot gap assessments are included in Chapter 3 and Appendix 1.

Credit: NOAA NCCOS

Credit: Anna Windle and Sarah Poulin

3 Summary of Results

Gulf of Mexico-wide Assessment of the Water Column Habitat

Temporal and Informational Gaps

The study area for the Gulf of Mexico-wide Water column habitat gap assessment extends across the entire CMAP area of interest and focuses on water quality monitoring (Figure 2). Within this study area, a total of 358 programs in the Inventory monitored within the Water Column habitat. The parameter monitored by the greatest number of these programs was water temperature (n = 313), followed by conductance (includes both conductivity and salinity; n = 304), total phosphorus (TP; n = 132), and total nitrogen (TN; n = 128). Figure 6 displays the dates of activity and levels of documentation for programs that monitored each of these parameters.

Similar trends were observed for all four parameters. Most programs were actively collecting monitoring data post-2010; however, only a small percentage of those programs had complete documentation or were highly accessible. While the total number of completely documented programs increased over time, the proportion of those programs within each time period stayed consistently low (25–39%). Of the 358 programs that operated in the Water Column, all of them had an accessible POC and a significant number (n = 312; 87%) had data accessible via the web or available upon request. Yet, only about half of these programs had accessible metadata (n = 166; 46%), documented quality assurance (QA) protocols (n = 209; 58%), and documented analytical procedures (n = 212; 59%). This pattern is consistent across all time periods for all programs that monitored these parameters within the Water Column habitat.

Most of the 313 programs that monitored water temperature were active post-2010 (n = 278; 89%). However, only 76 (27%) of those had complete documentation. Only 61 (19%) programs that monitored water temperature were active prior to 1990 and only 15 (25%) of those had complete documentation.

The temporal and informational gaps observed for conductance monitoring was similar to the results seen for water temperature. This is not surprising since there was a significant overlap between programs that monitored both of these parameters. Most of the programs monitoring conductance were actively monitoring since 2010 (n = 271; 89%), but only 75 (28%) of those had complete documentation.

As observed with the monitoring of water temperature and conductance, TP and TN are often monitored in conjunction with one another. Most of the programs that monitored these two parameters collected data post-2010. Nearly half of these programs (43–51%), across all time periods, were moderately documented.

Programs measured water quality parameters, including the four detailed above, at varying frequencies. The 357 water quality monitoring programs that operated in the Water Column habitat (out of 358 total programs) most commonly measured water quality parameters on a monthly basis (n = 120; 34%). Some programs also conducted sampling annually (n = 62; 17%) or more frequently than hourly (n = 60; 17%).

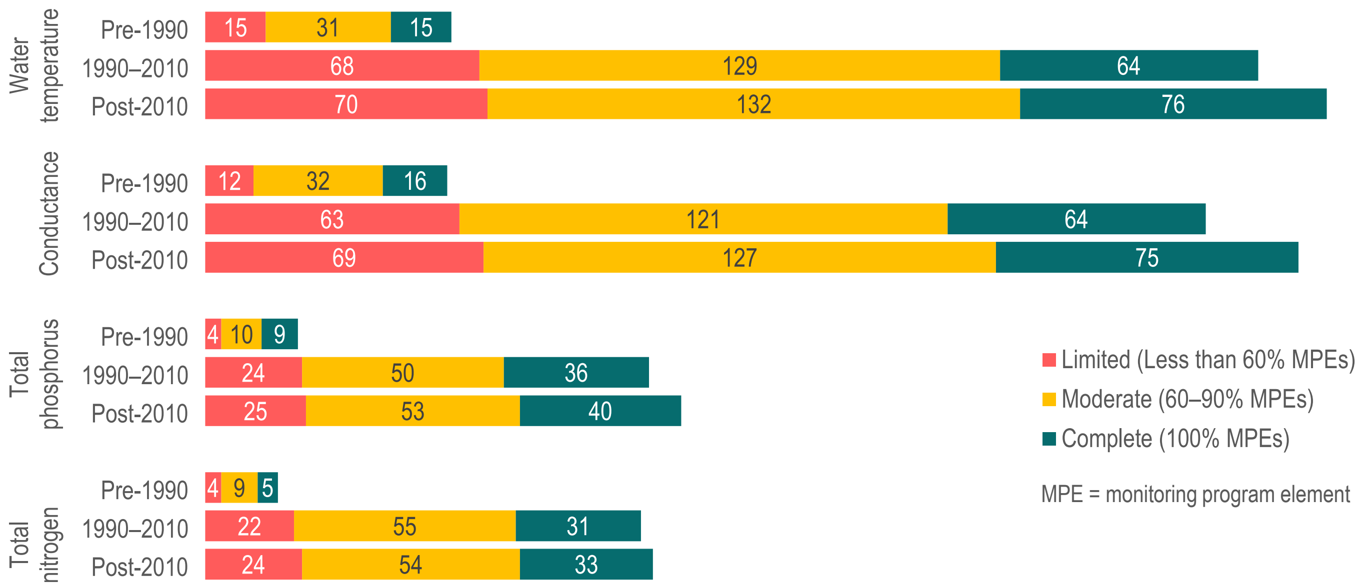


Figure 6. Program activity and documentation levels of programs that monitored water temperature (n = 313), conductance (n = 304), total phosphorus (n = 132), and total nitrogen (n = 128) within the Water Column habitat. Documentation levels are summarized by monitoring program elements (MPEs), which indicate the level of efficacy, comparability, and accessibility of a program or project.

Spatial and Informational Gaps

As with the previously discussed temporal and informational gap results, programs monitoring water temperature and conductance follow similar spatial distribution patterns (Figures 7 and 8). These programs are widely distributed across the entire Gulf of Mexico region. This coarse scale view of spatial distribution shows a general pattern of a high incidence of monitoring of these parameters occurring along the coastlines of each state and in the northwestern marine zone of the Gulf of Mexico (Figure 7A, Figure 8A). Median MPE percentages were generally higher for programs operating in the terrestrial or estuarine zone compared to those operating in the deeper marine waters (Figure 7B, Figure 8B). However, higher median MPE percentages were seen throughout the West Florida Shelf and around the Flower Garden Banks off the coasts of Louisiana and Texas (Figure 2). For a geographical reference to key locations across the Gulf of Mexico, refer to Figure 2.

Figures 7C, 8C, 9C, 10C depict bivariate choropleth maps, which examine the intersection between the two variables of interest: count of programs and median MPE percentage. Black hexagons represent areas in which there is a high frequency of programs with high median MPE percentages. For water temperature and conductance, high frequency areas are seen along the eastern Texas and West Louisiana coasts, around the birdsfoot delta of the Mississippi River, and distributed along inland areas of South Alabama and the Florida Panhandle. Alternatively, bright yellow hexagons represent areas where many programs were operating, yet documentation and accessibility levels were low. South Florida, Florida's Big Bend, the Mississippi Sound, the Texas coastline, and areas along the Texas and Louisiana continental shelf all appeared to have a high number of programs which monitor water temperature and conductance, yet have low median MPE percentages. This highlights potential gaps in data and information availability in areas where there is a wealth of monitoring.

The spatial distribution of programs monitoring TP and TN was concentrated along the coastal and inland areas of the CMAP study area with higher MPE percentages well distributed across those areas. Lower median MPE percentages were observed for both TP and TN throughout the marine zone. With the exception of an area south of Tampa Bay (Figure 10C), there were no areas in which a high count of programs and low median MPE percentages overlap (bright yellow hexagons). However, areas throughout the Florida Peninsula and along the Mississippi coast, highlighted in brown, had high levels of monitoring for both TP and TN, but informational gaps existed in these areas. A key area to note in the marine zone is the Desoto Canyon off the coast of the Florida Panhandle. This is an area in which some monitoring of TP and TN was prevalent, yet median MPE percentages were low (Figures 9C and 10C).

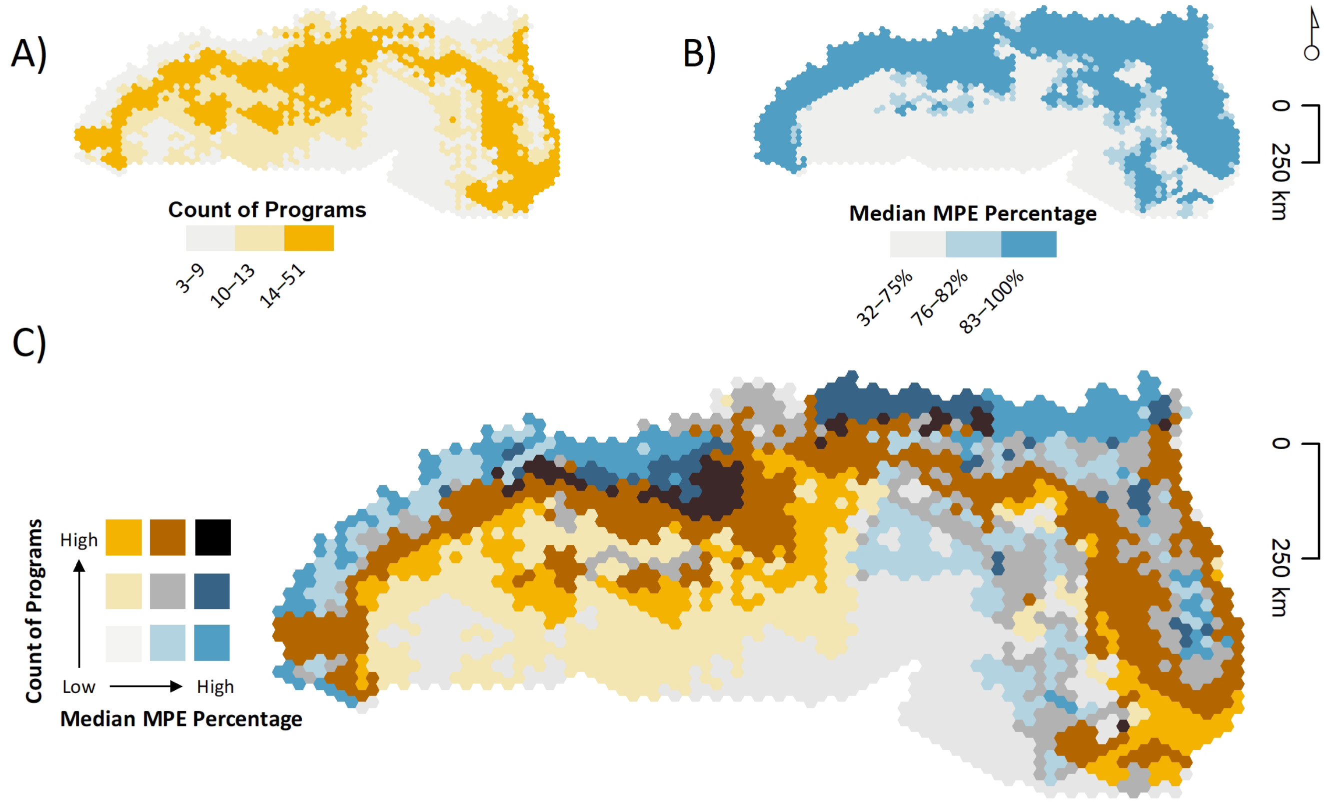


Figure 7. Spatial distribution of programs that monitored water temperature within the Water Column habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

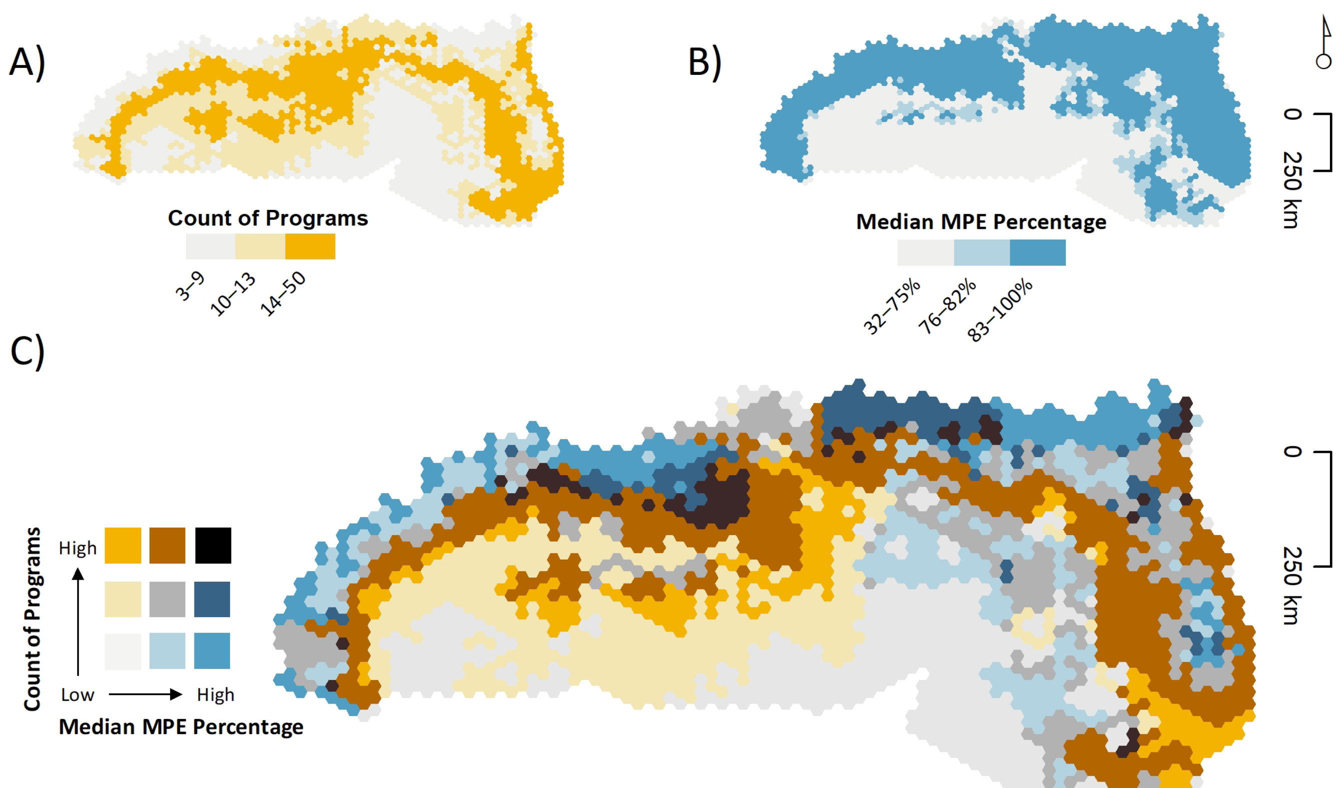


Figure 8. Spatial distribution of programs that monitored conductance within the Water Column habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

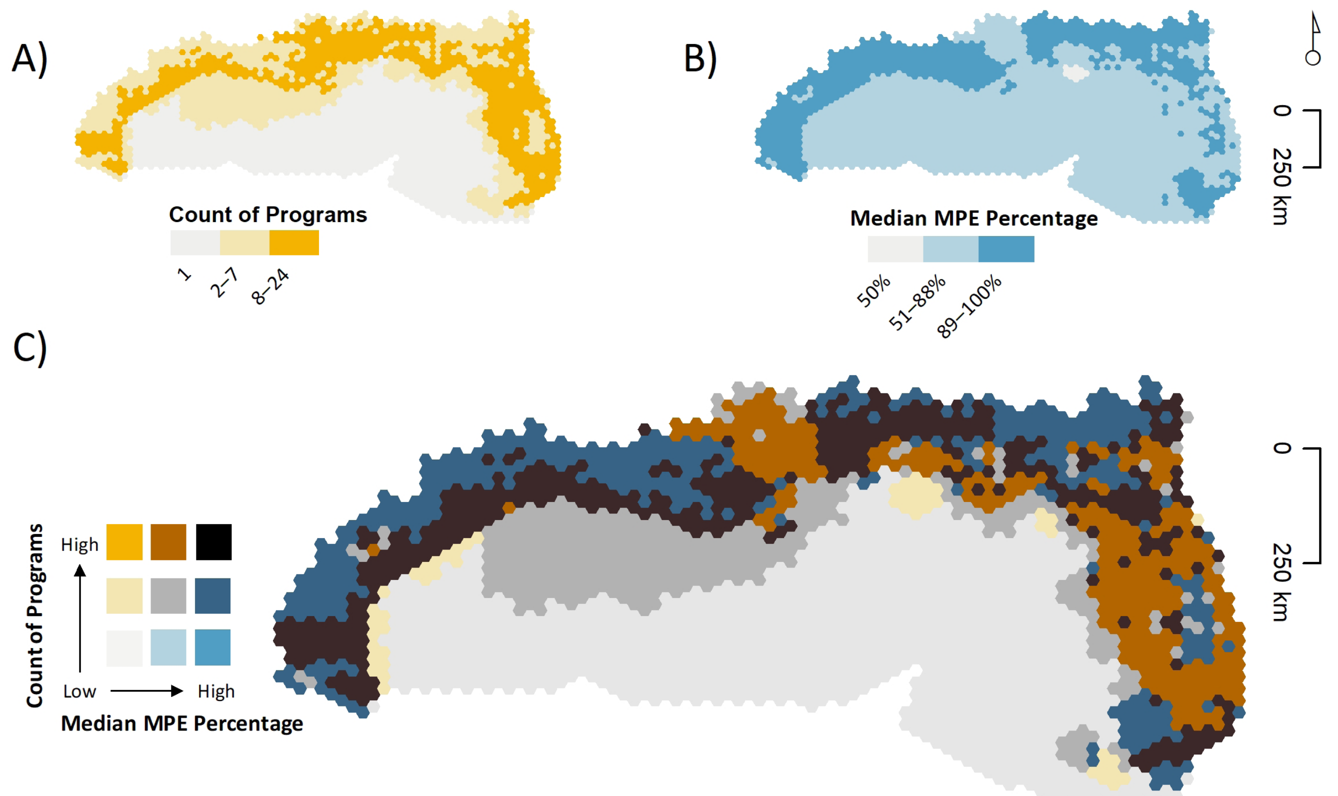


Figure 9. Spatial distribution of programs that monitored total phosphorus within the Water Column habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

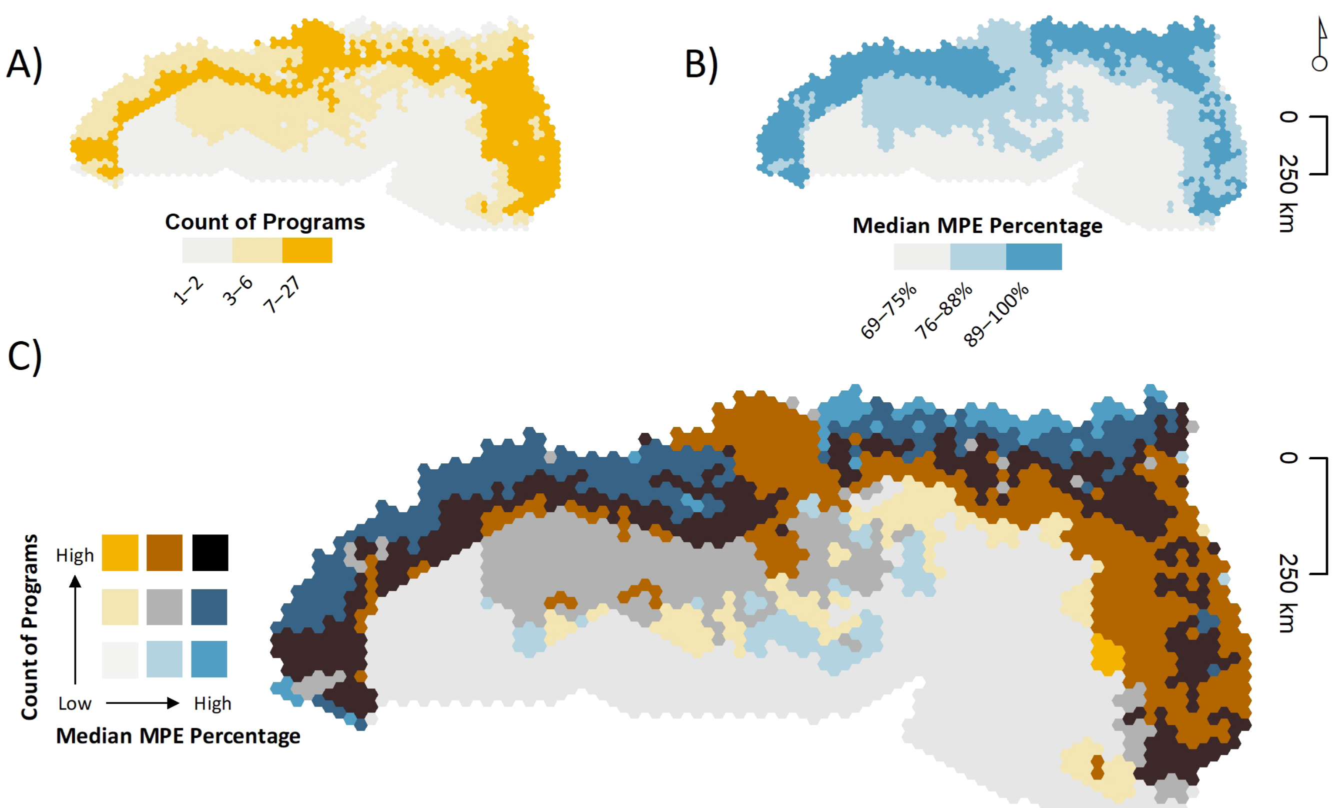


Figure 10. Spatial distribution of programs that monitored total nitrogen within the Water Column habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

While monitoring of TP and TN in the marine zone does occur, especially in relation to benthic habitats such as deep-sea corals, these parameters are more commonly monitored within the terrestrial and estuarine zones. A caveat in most spatial analyses, and especially in relation to using a quantile data classification, is that results are relative to and dependent on the scale of the study area. Thus, monitoring of TP and TN in the Water Column could be further examined by assessing the terrestrial, estuarine, and marine zones separately. This could potentially present additional insight and highlight new areas of interest specific to these zones. For example, this approach could provide a higher level of specificity of areas in the marine zone in which monitoring gaps exist. Therefore, it is important to verify that the study area chosen closely aligns with the analysis question.

Gulf of Mexico-wide Assessment of the Oyster Habitat

Temporal and Informational Gaps

A total of 70 programs in the Inventory monitored within the Oyster habitat. The parameters monitored by the greatest number of these programs were area of habitat types (AOHT; n = 31) and conductance (n = 31), followed by dissolved oxygen (DO; n = 22), and SHBA density (n = 18). Figure 11 displays the dates of activity and levels of documentation for programs that monitored each of these parameters.

As observed in the assessment of Water Column parameters, most programs that monitored in the Oyster habitat were active post-2010 and the number of programs with complete documentation increased over time. The proportion of completely documented programs within each time period remained low with a slight increase observed over time. Nearly all (n = 69; 99%) of the programs that operated in the Oyster habitat had an accessible POC and a significant number (n = 60; 86%) had data accessible via the web or a send upon request. Fewer programs had accessible metadata (n = 37; 53%), documented QA protocols (n = 39; 56%), or documented analytical procedures (n = 42; 60%).

Out of the 31 programs that mapped AOHT, 29 (94%) were active since 2010. Of these programs, only nine (29%) had complete documentation. Prior to 1990, only seven (23%) programs were creating maps of habitat types and only one was completely documented. While increases in monitoring and documentation levels over time were observed for each parameter, the majority of programs were moderately documented, indicating that informational gaps exist.

Of the parameters presented within this report, density was the least frequently monitored parameter in the Oyster habitat, with only 18 programs collecting these data over time. Only three (17%) programs monitored density prior to 1990 and none had complete documentation. Since 2010, 17 programs were actively monitoring density, but only three (18%) had complete documentation. Similar to AOHT, most of the programs which monitored density in the Oyster habitat were moderately documented.

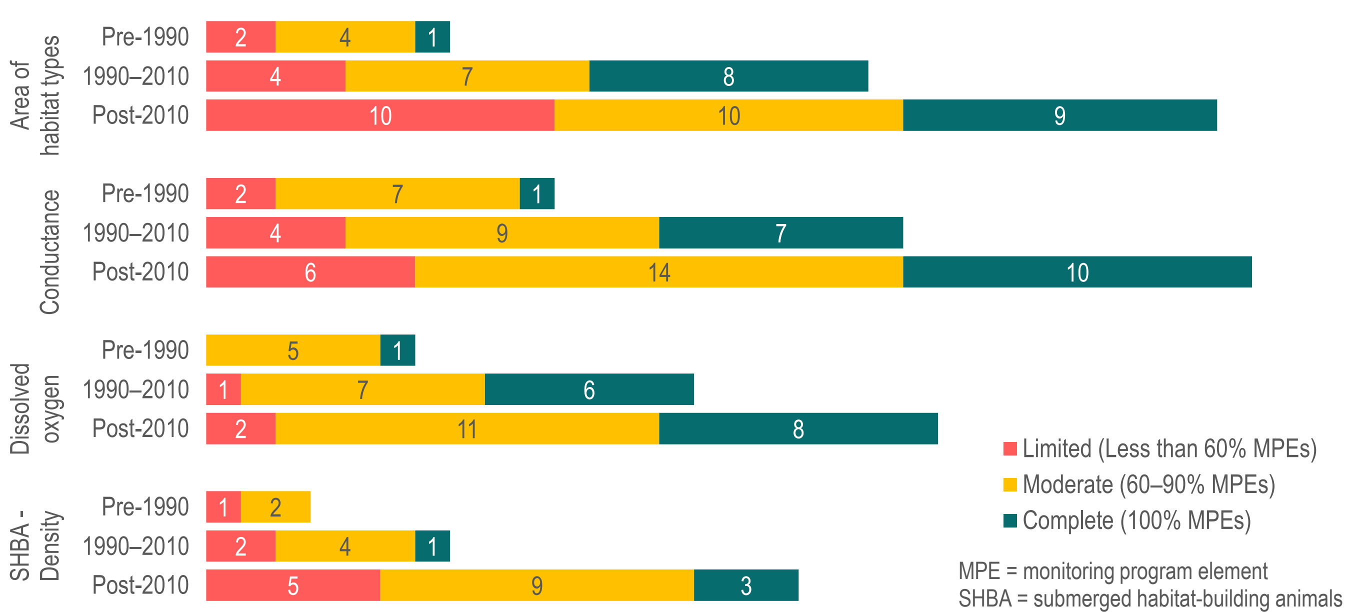


Figure 11. Program activity and documentation levels of programs that mapped and monitored area of habitat types (n = 31), conductance (n = 31), dissolved oxygen (n = 22), and submerged habitat-building animal (SHBA; n = 18) density within the Oyster habitat. Documentation levels are summarized by monitoring program elements (MPEs), which indicate the level of efficacy, comparability, and accessibility of a program or project.

Water quality monitoring programs (n = 47) that operated in the Oyster habitat most commonly monitored water quality parameters, including conductance and DO, on a monthly (n = 22; 47%), annual (n = 11; 23%), more frequently than hourly (n = 7; 15%), or quarterly (n = 7; 15%) basis. For habitat parameters such as SHBA density, the most commonly reported measurement frequencies by habitat monitoring programs (n = 45) were annual (n = 21; 47%), monthly (n = 13; 29%), and biannual (n = 7; 16%). Mapping parameters such as AOHT were most commonly collected by mapping programs (n = 40) only one time or at a variable frequency (n = 4; 10% for both). Mapping programs operated at a lower frequency than water quality monitoring or habitat monitoring programs, with three (8%) programs creating maps every 5–6 years and another three creating them every 10 years. Mapping frequency was captured in the "temporal resolution" field in the Inventory, and additional information was collected after a detailed review of each mapping program's methodology. Since measurement frequencies varied significantly, the information was also binned into broader categories (NOAA and USGS, 2020).

Spatial and Informational Gaps

Figures 12–15 show the spatial distribution of programs that monitored or mapped within the Oyster habitat. Programs that mapped AOHT were distributed across the entire study area, but most of those programs were operating around Sabine Lake, the Mississippi Sound, Mobile Bay, Pensacola Bay, and throughout Florida's Big Bend and western coastline (Figure 12A). However, the highest median MPE percentages for these mapping programs were seen only in Florida. Figure 12C displays the bivariate choropleth, or the intersection between count of programs and median MPE percentage, for programs that mapped AOHT. A high count of programs and high median MPE percentages overlap throughout Florida's coast. These areas, symbolized as black hexagons, include: Choctawhatchee Bay, Apalachee Bay, Clearwater, Saint Petersburg, Sarasota, and Ten Thousand Islands. Symbolized by bright yellow hexagons, Lake Borgne, the Mississippi Sound, Mobile Bay, Pensacola Bay, St. Andrew Bay, and St. George Sound were all areas with a relatively higher number of habitat mapping programs, yet the median MPE percentages were low. These areas are identified as having informational gaps in mapping of AOHT.

Monitoring of conductance in the Oyster habitat was most prevalent in Galveston Bay, Sabine Lake, Bay Boudreau, St. Louis Bay, the Mississippi Sound, Mobile Bay, Choctawhatchee Bay, Apalachicola Bay, and Charlotte Harbor (Figure 13A). Throughout the estuarine zone, there were some areas without any conductance monitoring in the Oyster habitat (white hexagons). The highest MPE percentages were seen throughout the entire Florida coast, a few areas in Texas, and along the western edge of the Alabama coast (Figure 13B). There were no areas in which a high count of programs and high median MPE percentages overlap for conductance monitoring. However, throughout the state of Florida there were areas with low or mid-level counts of programs overlapping with high median MPE percentages (Figure 13C). Key areas of informational gaps, highlighted in bright yellow, were observed in Galveston Bay, Sabine Lake, Bay Boudreau, St. Louis Bay, the Mississippi Sound, Mobile Bay, and Choctawhatchee Bay. Comparing these results (Figure 13C) with the results for the water column (Figure 8C) help show the role of spatial extent and habitat type in a gap assessment.

DO monitoring in the Oyster habitat was most prevalent across the Texas and Florida coasts (Figure 14A). These areas include: Aransas Bay, Galveston Bay, Sabine Lake, the Florida Panhandle, the Suwannee Sound, Waccasassa Bay, Tampa Bay, Sarasota, Charlotte Harbor, and Ten Thousand Islands. The highest MPE percentages for programs monitoring DO were primarily seen throughout the Florida coast (Figure 14B). Figure 14C shows that potential informational gaps in monitoring exist in Texas, Louisiana, and in parts of Florida. In general, DO monitoring was lacking in the estuarine zones of southern Texas, Louisiana, Mississippi, and Alabama.

Of the four parameters assessed with the Oyster habitat, density appeared to have the most significant spatial and informational gaps in monitoring. Most of the programs monitoring density operated across the Louisiana coast, part of the Mississippi coast, Mobile Bay, and Apalachicola Bay (Figure 15A). The highest median MPE scores were seen in Aransas Bay, across the Louisiana coast, and in few areas along the Florida coast (Figure 15B). The Louisiana coast was one of the most well documented areas with a higher number of programs monitoring density within the Oyster habitat (Figure 15C). Mobile Bay and Apalachicola Bay had a higher number of programs monitoring density, but those programs collectively had lower median MPE percentages.

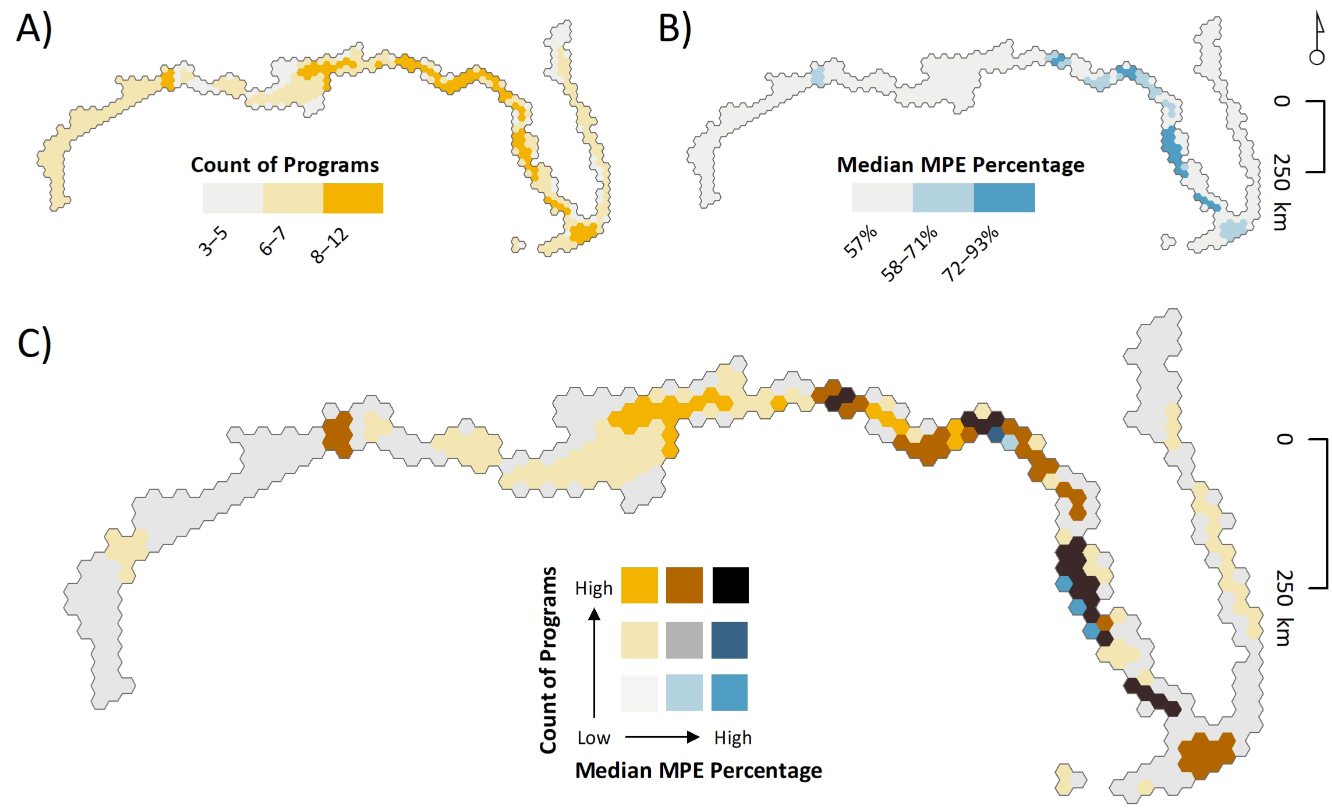


Figure 12. Spatial distribution of programs that mapped area of habitat types within the Oyster habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

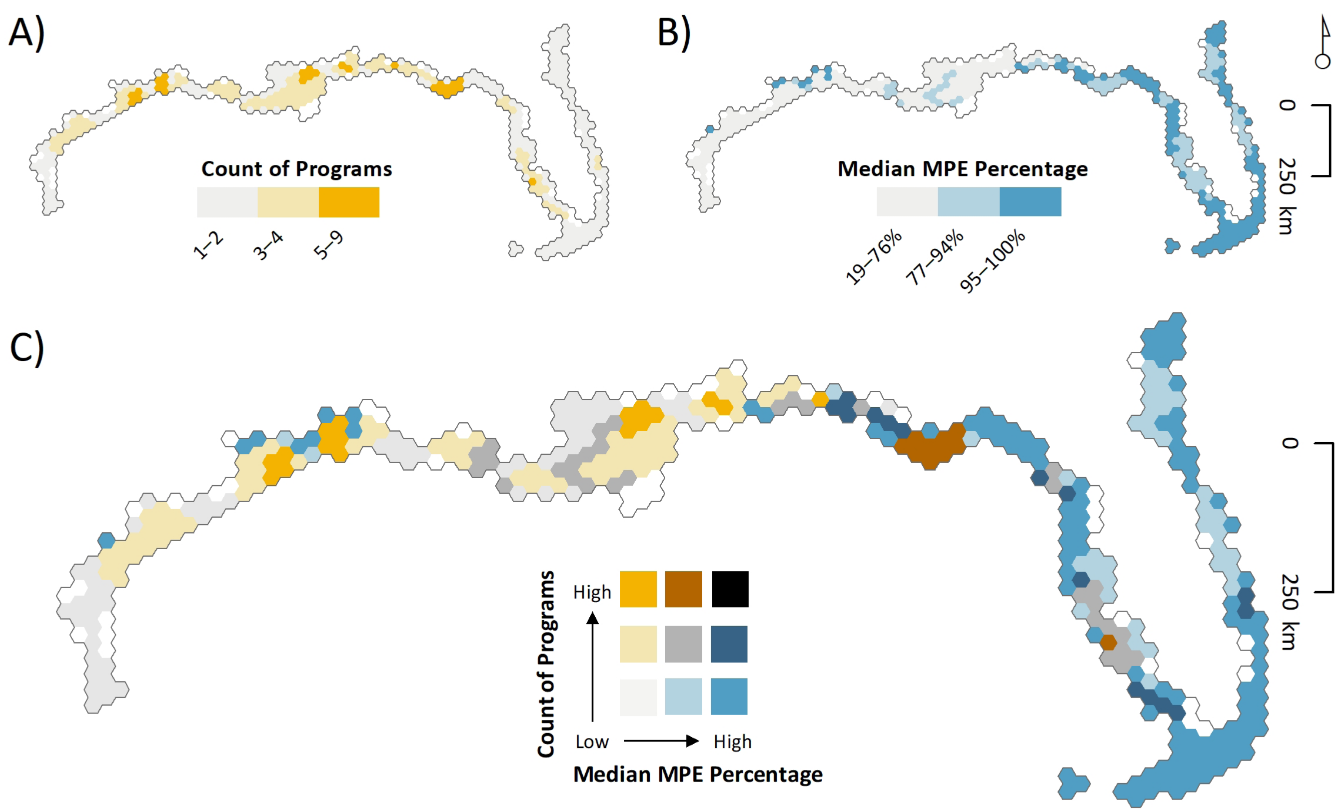


Figure 13. Spatial distribution of programs that monitored conductance within the Oyster habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

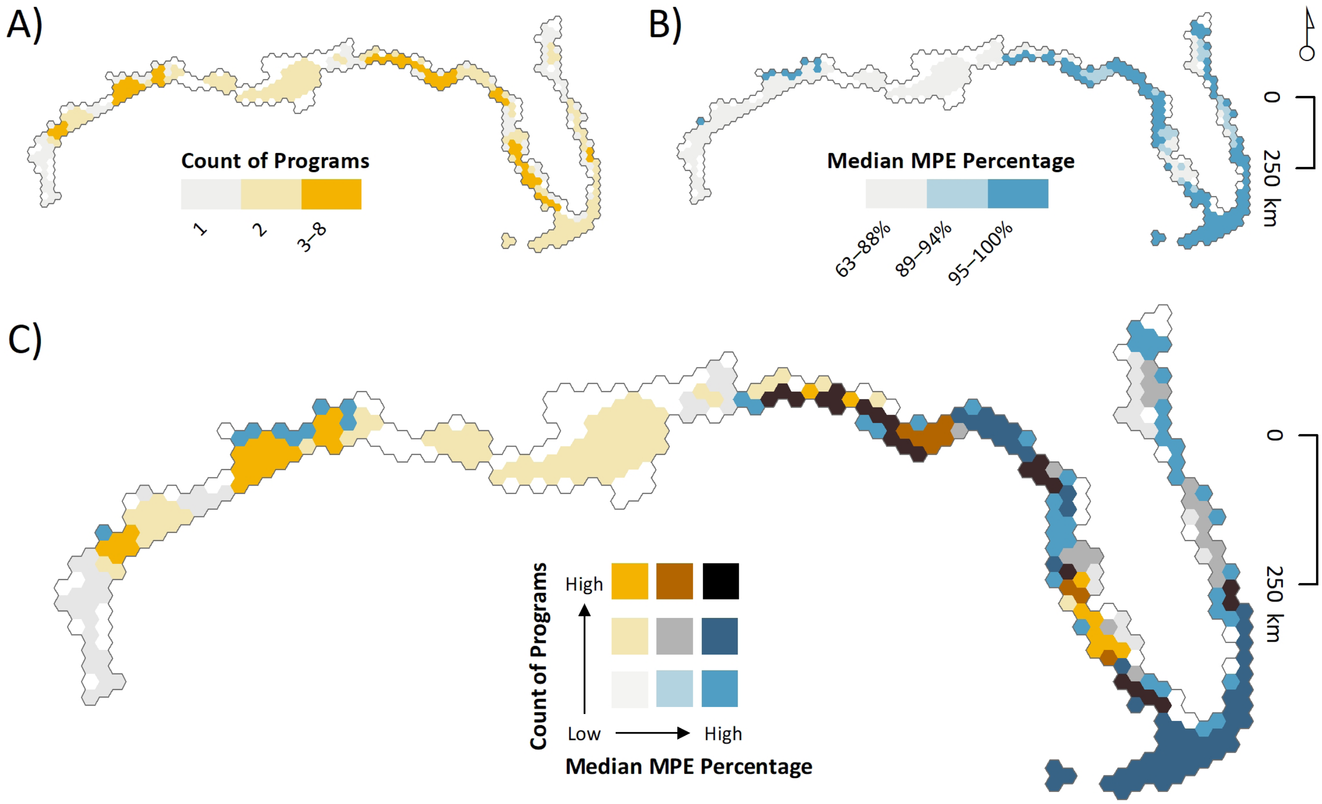


Figure 14. Spatial distribution of programs that monitored dissolved oxygen within the Oyster habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

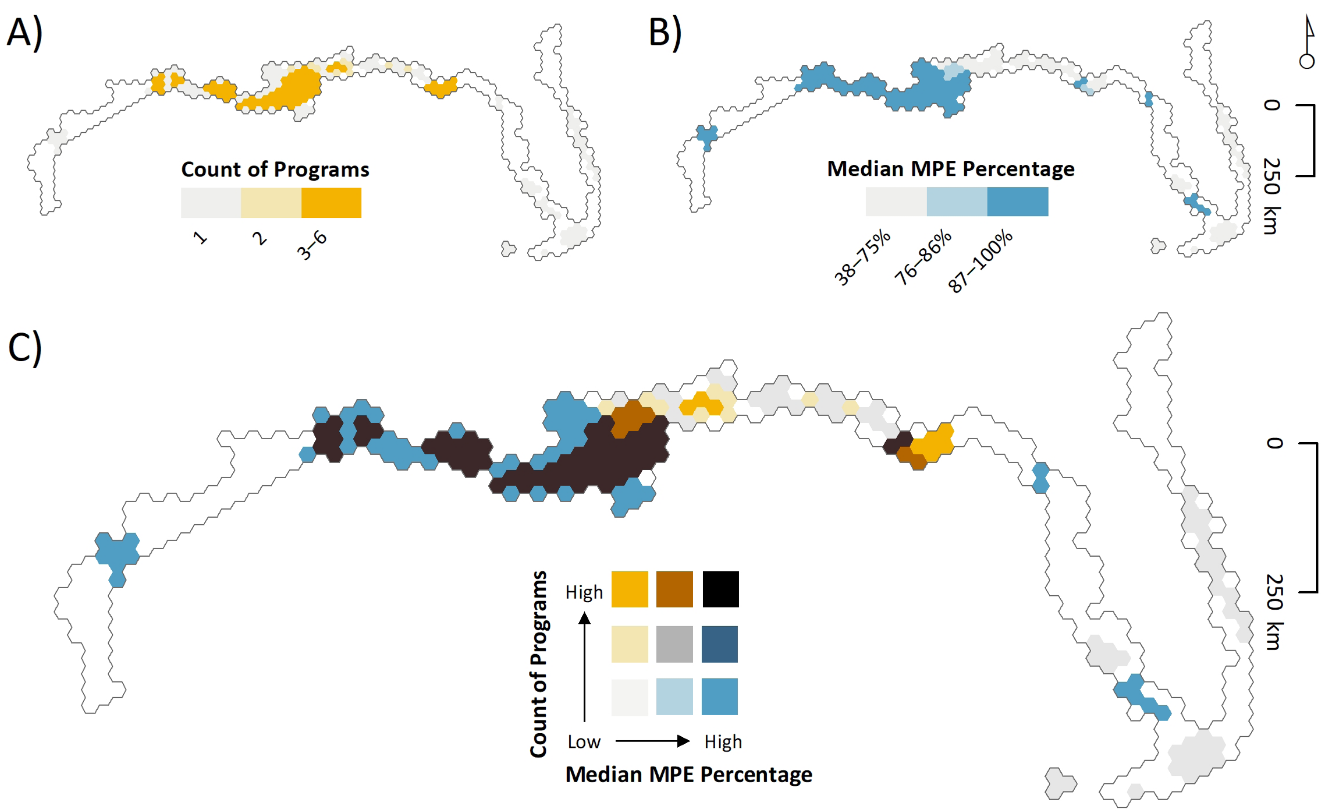


Figure 15. Spatial distribution of programs that monitored SHBA density within the Oyster habitat. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 2 for geographic reference.

Watershed-level Assessment of the Perdido River Basin

The gap assessment process was also applied and refined through a pilot study of the Perdido River basin (Figure 3) focusing on pertinent questions of interest posed by Alabama state representatives within the CMAWG. In particular, natural resource managers in Alabama were interested in understanding how CMAP products could be used to answer the following questions:

Where in the Perdido River basin would nutrient reduction, agriculture and silviculture best management practices (BMPs), and/or riparian buffers be most effective and potentially measurable?

Where is water quality monitoring for parameters such as total suspended solids (TSS), total nitrogen, and total phosphorus already taking place?

Where are agriculture and silviculture activities concentrated?

What physical conditions could be exacerbating runoff (e.g., areas of higher relief and/or erodible soils)?

Additionally, state representatives identified several monitoring and mapping parameters relevant to the questions listed above. Eight parameters were assessed within the Perdido River basin and presented to the Alabama CMAWG representatives and the MCoP (Appendix 1). This assessment is not necessarily meant to directly answer the questions listed above, but rather provides a demonstration of how the Inventory can be used to find the information and data needed to answer those questions. The information presented within this report focuses on the assessment of four of those parameters: TP, TSS, TN, and AOHT.

Temporal and Informational Gaps

A spatial query of the Inventory uncovered a total of 115 programs that operated within the Perdido River basin. Of the parameters examined within this report, the parameter monitored by the greatest number of these programs was TP (n = 25; 22%) followed by TSS (n = 21; 18%), TN (n = 20; 17%), and AOHT (n = 18; 16%). Figure 16 displays the dates of activity and levels of documentation for programs that monitored each parameter.

Compared to what was observed for the Gulf of Mexico-wide Water Column habitat, programs that monitored TP, TSS, and TN in the Perdido River basin had a higher level of complete documentation; between 40–85% of programs within each time period were completely documented. The

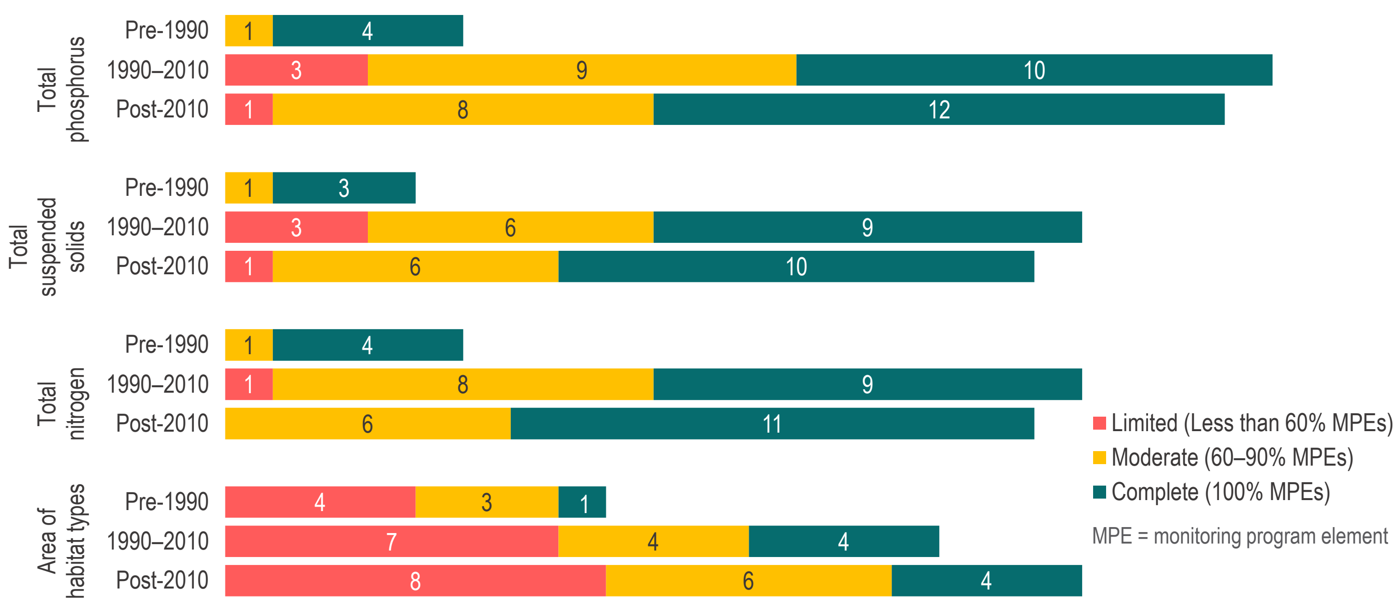


Figure 16. Program activity and documentation levels of programs that monitored total phosphorus (n = 25), total suspended solids (n = 21), total nitrogen (n = 20), and area of habitat types (n = 18) in the Perdido River basin. Documentation levels are summarized by monitoring program elements (MPEs), which indicate the level of efficacy, comparability, and accessibility of a program or project.

majority of these programs were actively monitoring between 1990 and 2010. Conversely, most of the programs mapping AOHT were active post-2010 and had limited documentation. However, from 1990 to 2010, the proportion of programs that mapped AOHT with complete documentation nearly doubled. Alternatively, the proportion of complete programs monitoring TP, TSS, and TN decreased over time; this indicates a lack of progress with regard to monitoring data and information accessibility. Nearly all programs in the Perdido River basin had an accessible POC (n = 112; 97%) and 104 (90%) of the 115 programs had data accessible via the web or upon request. However, fewer programs had accessible metadata (n = 71; 62%), documented analytical procedures (n = 67; 58%), and documented QA protocols (n = 70; 61%).

Out of the 115 total programs that operated in the Perdido River basin, water quality monitoring programs (n = 57) most commonly collected water quality parameters (e.g., TP, TSS, TN) on a monthly (n = 16; 28%), annual (n = 10; 18%), or variable (n = 10; 18%) basis. Mapping parameters such as AOHT were collected by mapping programs (n = 61) at various frequencies: seven (11%) programs measured them on a variable basis, while two (3%) programs each measured them annually, biennially, decennially, and every 5–6 years. Beyond the Inventory, in-depth programmatic information, including additional information on mapping frequencies, was gathered after a detailed review of each mapping program's methodology (NOAA and USGS, 2020).

Spatial and Informational Gaps

Figures 17–20 display the spatial distribution of programs across HUC-12 watersheds, which monitored TP, TSS, TN, and AOHT within the Perdido River basin. Water quality programs monitoring TP, TSS, and TN show similar spatial patterns along the Perdido River and within Perdido Bay, Big Lagoon, and Little Lagoon. Very little variation was seen with regard to median MPE percentages for water quality monitoring programs; these values are high across the entire study area, which indicates that monitoring data and information were highly accessible.

Programs that mapped AOHT in the Perdido River basin were mostly located in the southern, coastal areas of the watershed including the lower reaches of the Perdido River, Perdido Bay, Little Lagoon, and Big Lagoon (Figure 20). These coastal regions of the watershed also had higher median MPE scores; however, the highest value in the range was 0.78, which indicates that documentation was not as complete as observed for the water quality programs.

The bivariate choropleth maps each show areas where there is an overlap between a high number of programs and high median MPE percentages (Figures 17C, 18C, 19C, 20C). With the exception of AOHT, there were no HUC-12 watersheds that appeared to have notable information gaps (i.e., bright yellow areas; high count of programs and low median MPE scores). However, if a smaller spatial unit of analysis was used, results could possibly uncover finer scale informational gaps.

Credit: NOAA Gulf Spill Restoration

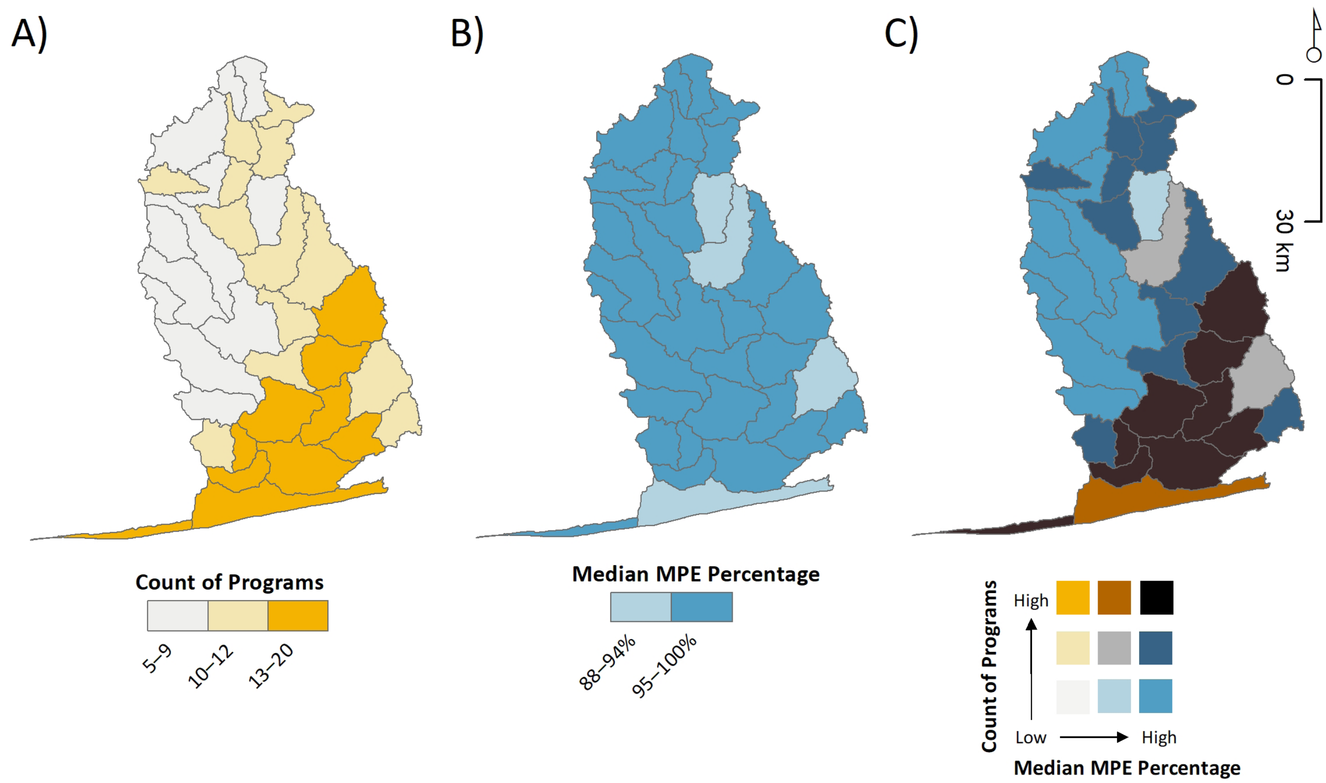


Figure 17. Spatial distribution of programs that monitored total phosphorus in the Perdido River basin. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 3 for geographic reference.

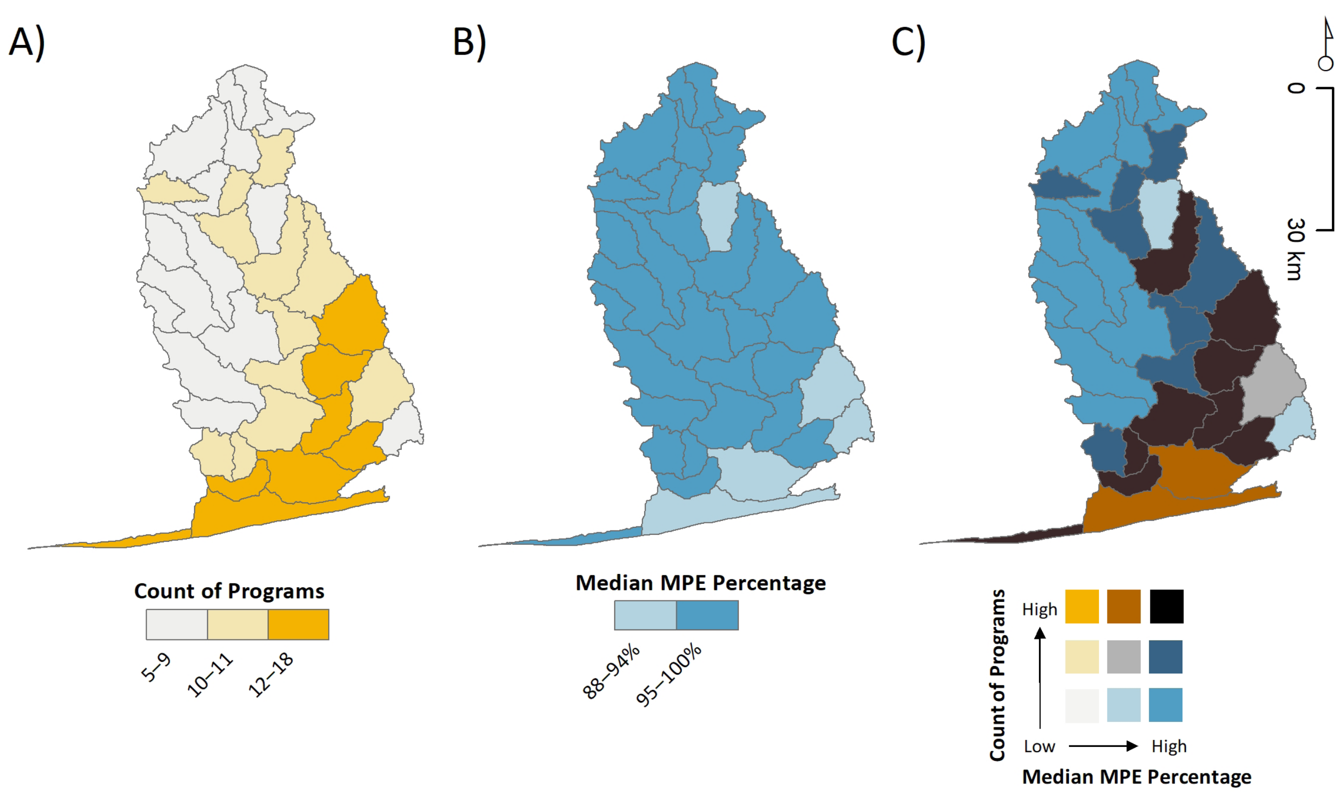


Figure 18. Spatial distribution of programs that monitored total suspended solids in the Perdido River basin. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 3 for geographic reference.

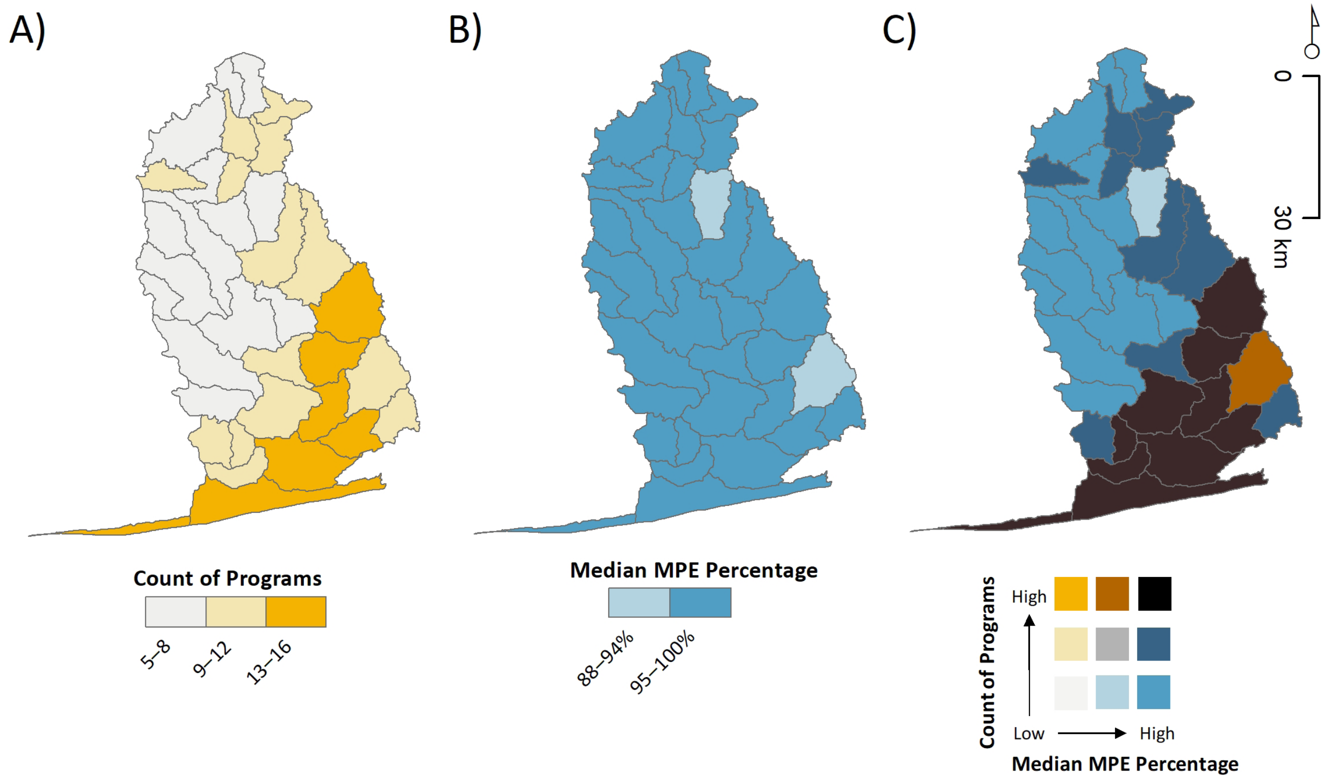


Figure 19. Spatial distribution of programs that monitored total nitrogen in the Perdido River basin. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 3 for geographic reference.

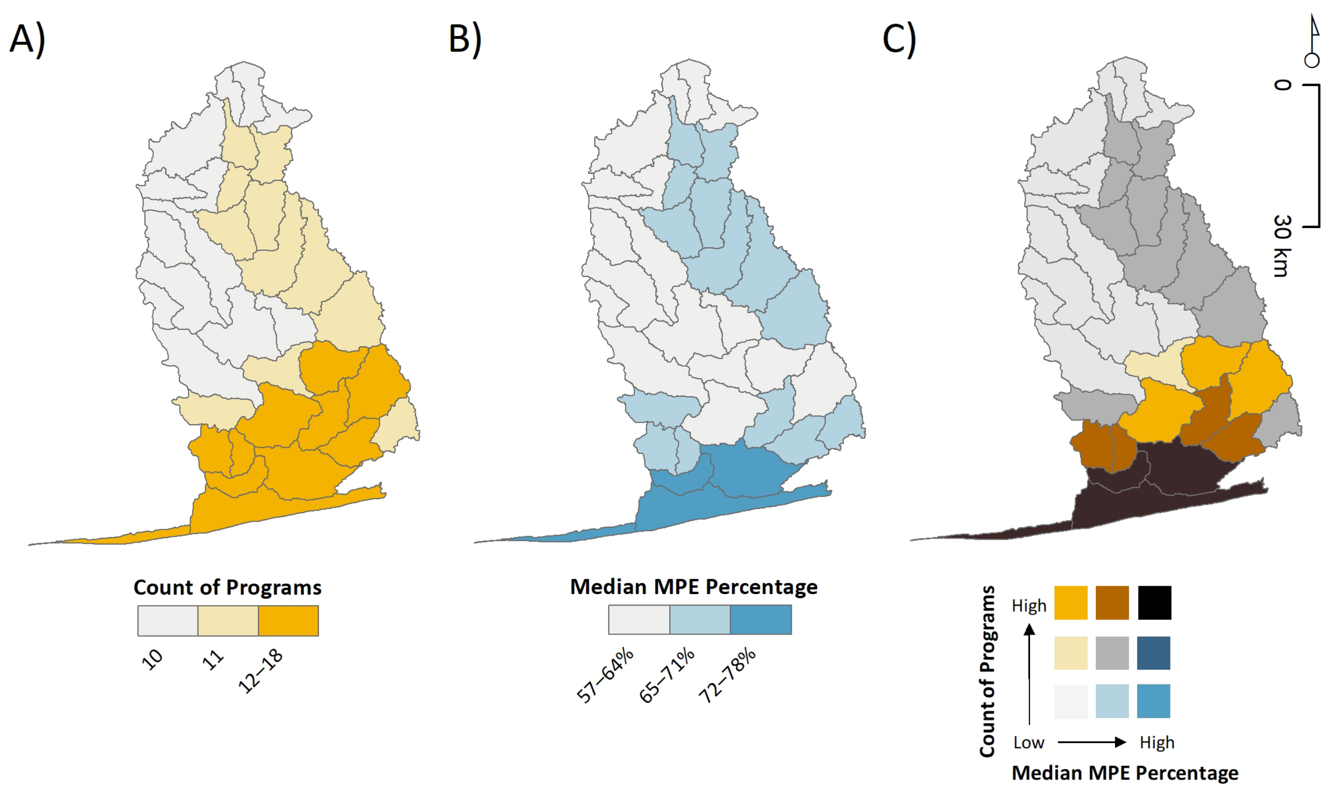


Figure 20. Spatial distribution of programs that mapped area of habitat types in the Perdido River basin. A) Count of programs per spatial unit. B) Median percentage of monitoring program elements (MPEs) per spatial unit. C) Bivariate choropleth showing the intersection between A and B. See Figure 3 for geographic reference.

MCoP Workshop Feedback of Watershed-level Assessments

Three watershed gap assessments (Salt Bayou, Texas; Calcasieu/Sabine/Neches, Louisiana; Perdido, Alabama) were presented at the GOMA MCoP workshop in January 2020. This workshop included breakout sessions for each watershed with numerous attendees including representatives from each state and other monitoring practitioners. In these breakout sessions, the audience members were presented the gap assessment information and asked pre-determined questions to assess how they would use the inventory database and associated webtool to conduct a gap assessment. The questions included:

What are current or future drivers for an information search?

What process is used to assess data availability/ gaps in a geographic area of interest?

What information is most important to query from existing monitoring programs?

What scale of information is necessary?

Who else besides your agency might use this information?

How would you use the Inventory to inform a restoration monitoring plan?

How does CMAP evolve into the future?

A summary of responses are listed below, as well as a compilation of comments that were common across the three breakout groups.

Question 1. What reasons are you searching for information?

Resource managers are often searching for project-specific information within an area of interest. They are generally looking for information external to their respective agency, but could also be searching internally. The information is commonly needed for assessing data comparability as well as looking for targeted informational and temporal gaps.

Question 2. What process is used to assess data availability/gaps in a geographic area of interest?

All groups commented that evaluating data availability was conducted by coordinated meetings with experts. The experts would be able to comment on data caveats, how to apply their information, and how it would be most useful in any scenario.

Question 3. What information is most important to query from existing monitoring programs?

The most common response was metadata for project or program information. Availability of and access to monitoring data and protocols were also rated as important. The groups identified that the most difficult information to obtain from a query were methods and units, undocumented changes in units, spatial queries, datum, and data status (accessibility and format). The Inventory provides this information if it is available and confirmed by program POCs.

Question 4. What scale of information is necessary?

The CMAP team presented information to each breakout group in two scales. The broadest resolution assessment was conducted using HUC-12 watersheds, whereas the highest resolution assessment was conducted using 1-km^2 hexagonal grids. The groups noted pros and cons for each. The 1-km^2 grid was considered useful for small-scale monitoring. The higher resolution reveals visualization of actual sites, if they are present. HUC level of information was considered to be adequate for large geographic areas where the user is conducting an initial inquiry of available programs. Some noted that their agencies have a pre-defined grid system that does not conform to the CMAP structure. In these cases, the Inventory can be downloaded and the users can overlay their grid system with CMAP information for their own analyses.

In offshore waters, there are no HUCs and some participants noted that a 1-km^2 grid is too fine. Participants suggested developing an offshore grid system such as Bureau of Ocean Energy Management (BOEM) lease blocks (finer resolution) or the Ocean Conservancy approximately 3,600-km^2 hexagonal grid (coarser resolution; Love et al., 2015).

Question 5. Who else besides your agency might use this information?

Other identified users included:

- **State and federal agencies**
- **Planners**
- **Counties**
- **Engineers**
- **Private industry**

Question 6. How would you use the Inventory to inform a restoration monitoring plan?

- **Discover long term data for model calibration/ evaluation**
- **Determine the robustness of parameter(s) at different scales**
- **Evaluate whether monitoring is sufficient to measure goals**
- **Evaluate existing monitoring and maximize efficiency; is new monitoring needed?**
- **Evaluate consistency in methods at various scales**
- **Discover historical data; archive**
- **Identify programs from other states**
- **Improve integration among existing monitoring programs**
- **Utilize as an overlay with other services (stressor layers)**

Question 7. What features/parameters/attributes would you like to see in a query?

- **Site-level data (e.g., where is the program monitoring?)**
- **Parameter measurement frequency (e.g., various measurement frequencies of discrete and continuous data)**
- **All information on available programs within a specific date range**

Credit: Michael Lee (USGS)

The final question was not posed by CMAP staff, but by the MCoP participants. All were interested in the future for the Inventory. In the summer and fall of 2020, National Oceanic and Atmospheric Administration (NOAA), USGS, and GOMA staff will conduct in-person or virtual demonstrations of the webtool to RESTORE Steering Committee members and pertinent collaborators. Additional feedback on tool function and utility will be evaluated and incorporated as appropriate and feasible.

In order to be an effective tool for the Council and the broader monitoring community, the Inventory will need routine maintenance. The NOAA and USGS team are working on a process for this to occur. Additional functionality may be added to the Inventory at the discretion of the CMAWG/Steering Committee. The Inventory could be built upon with additional water quality, habitat, and mapping programs. Roughly 40% of the POCs did not provide feedback on the accuracy of the Inventory. There could be substantial additions to protocols, metadata, or site locations. Additionally, natural resource monitoring for birds, mammals, sea turtles, and more could also be added.

These activities would require various levels of funding to achieve desired results. Participants commented that perhaps a shared approach could be established where state representatives would take care of updates/maintenance within their respective state or perhaps this could be achieved through some of the GOMA Priority Issue Teams (PITs), specifically the Data and Monitoring PIT. Regardless of the mechanism, the MCoP strongly advocated for continued collaboration to stay updated on the state of coastal monitoring in the Gulf of Mexico.

4 Uses, Benefits, Limitations, and Future Recommendations

Credit: Nichoias Enwright (USGS)

The gap assessment approaches highlighted in this report demonstrate how practitioners could use the Inventory to identify and explore spatial, temporal, and informational gaps in monitoring and mapping across the Gulf of Mexico at varying scales. These examples were refined and adapted based on discussions and feedback from the CMAWG and MCoP. This feedback highlighted the need to demonstrate how varying spatial extents and spatial units can be chosen and how those variations can impact the resulting query and analysis of the Inventory.

A Gulf of Mexico-wide assessment of monitoring and mapping gaps uncovered similar spatial trends as those observed by Love et al. (2015). Since 1980, monitoring and mapping efforts have been more centrally focused along the terrestrial and estuarine zones of the Gulf of Mexico, leaving major gaps in the depths of the offshore marine zone. In both the Water Column and Oyster habitats across the Gulf of Mexico, most inventoried programs were active post-2010 and surprisingly only a small percentage of those programs were found to have complete documentation. While there have been increases in the numbers of monitoring and mapping programs over time, very little change has been observed with regard to the proportion of programs with readily accessible data, metadata, and protocols or procedures. A more focalized study of the Inventory, however, reveals that within different study areas or habitats varying patterns of spatial and informational gaps for unique parameters exist. For instance, significant informational, temporal, and spatial gaps were found to exist in the monitoring of oyster density. Very few programs monitored density prior to 1990 and even fewer had accessible documentation, but a spatial assessment revealed that well documented and highly accessible oyster density data may be found along the Louisiana coast. These gap assessments also revealed that, in general, the State of Florida is often highlighted as having a wealth of accessible monitoring and mapping data with complete documentation. By narrowing the study area, as was demonstrated for the Perdido River basin, local management questions can be examined more closely and reveal both gaps and strengths in particular regions. While the Inventory is limited with regard to monitoring parameter and site specifics, it can reveal previously unknown data sources, enable an assessment of data quality, enable broader scale assessments of resource status and trends, and foster potential future cross-jurisdictional partnerships in monitoring, mapping, and restoration.

Uses and Benefits

As previously mentioned, the approaches highlighted in this report can serve as a screening tool to understand the "who," "what," "when," "where," and "how" of monitoring programs. This process should effectively direct the user to the monitoring programs with the data and data quality characteristics that are of interest. To assist with a deeper dive into programs, common parameters, methods, and units were analyzed and highlighted in a companion CMAP report (NOAA and USGS, 2020). Collectively, the gap assessment and the details on common parameters, methods, and units will help the user to identify which datasets may be foundational to their needs and questions. The gap assessment essentially describes "where we are now," (circa 2019) which is an important step in understanding the state of monitoring in the

Gulf of Mexico. A next step would be to identify and fill data gaps. To do this, users need to address further questions including: (1) identifying “where you want to be;” (2) what questions need to be addressed; and/or (3) what outcome(s) need to be detected in relation to conservation, restoration, or management objectives.

The CMAP project has developed a set of products and tools to assist in the analytical exercises needed to conduct a data gap analysis, which included: (1) inventory database; (2) spreadsheets; (3) GIS and mapping tools; (4) web services; (5) web visualization tools; and (6) monitoring program data links. Monitoring practitioners can use these products and tools to assess the patterns and trends in the data availability and data quality from programmatic metadata, and use that exploration to pinpoint datasets within programs that they want to investigate further to address their objectives.

Once datasets are identified by a user, data links from the Inventory would facilitate access to the data and POCs who could assist in addressing any questions regarding the data. The user would compile the identified data that meet data quality and management objectives, and then investigate those data using preferred statistical packages or languages (e.g., SAS, R). Various statistical approaches could be used to investigate the current baseline of available data and then measure the gap against the desired data.

By understanding which programs are collecting the data that meet user requirements, significant cost efficiencies and leveraging opportunities can occur by: (1) not initiating redundant data collection efforts; (2) adding resources to existing programs to fill data gaps; (3) coordinating on new data collections that can meet multiple program needs; and (4) facilitating compatibility between new and existing data collections.

Some additional applications of CMAP products include:

Development of custom data visualizations.

Evaluation of information to determine whether existing monitoring is sufficient to inform collective restoration/management efforts within a geographic area.

Informing future restoration monitoring plan development (i.e., potential monitoring programs to build upon, consistency in methods and units, and/or selection of possible reference locations).

Limitations and Recommendations

The Inventory is a static database, which was finalized in 2019. Ideally, the content captured within it (e.g., POCs, website links, parameters, measurement frequencies, protocols, etc.) should be maintained over time. Throughout the CMAP project, numerous participants of the MCoP have acknowledged that the Inventory fills an important need, and ensuring that the database remains current is imperative. Thus, we recommend annual database maintenance, which would include online database hosting and basic updates as described above, and suggest a thorough update of habitat and water quality monitoring and mapping programs approximately every three years.

Due to the extensive nature of the development of the Inventory, we leveraged existing criteria from Love et al. (2015) to develop filters necessary to highlight long-term monitoring programs. As a result, short-term (less than five years of data collection) monitoring initiatives may not be included in the Inventory unless they were identified as a principal source of rare data for a particular region or monitoring objective. It is a challenge to fully grasp what constitutes a “rare” source of data prior to performing a targeted gap assessment, such as the examples provided within this report. Acknowledging that, it is important to emphasize the steadfast role of the monitoring community in the development and maintenance of an inventory of this sort. For future updates, the monitoring community could be engaged to explore known gaps and decide if exceptions should be made for specific types of programs in order to avoid inadvertently excluding important monitoring efforts.

Furthermore, the Inventory currently does not include information regarding the monitoring of key ecosystem components (e.g., living marine resources), which could potentially be incorporated into the Inventory in the future. The approach for these updates could occur following the original survey process with the monitoring program POCs (NOAA and USGS, 2019) or establishing a portal where POCs can directly provide updates that would be quality controlled and ingested into the database and displayed through the webtool. The states could also take ownership over the Inventory and maintain and update their monitoring program information. Maintaining and updating the database will allow for repeated gap analyses over time as new data become available, allowing for re-evaluations of the monitoring network to see if data gaps are closing (or growing).

In addition to being static, the Inventory contains programmatic-level descriptive metadata. This means that information, such as monitoring frequency, start date, and documentation level, is applicable to the overall program rather than specific parameters. As an example, if a program recently began monitoring a new parameter, users would need to investigate the data to determine where and when this change occurred. As outlined earlier, the Inventory is a starting point for identifying site and/or parameter-specific information. If feasible, future updates could potentially add site-level metadata.

Scale is an important factor in any geospatial analysis. In this effort, two types of grids were used to summarize the spatial distribution and the documentation level of programmatic metadata within monitoring programs. However, there are many ways in which these data could be aggregated and visualized. For example, the spatial units may vary depending on the question being asked, the analysis to be performed, the desired scale of the analysis, and the availability of existing custom grids or preferred planning units.

While programmatic footprints were used as the source layer for the gap assessments, future assessments could be developed using monitoring site locations. In addition to CMAP-identified site locations, users could supplement their analyses with databases such as the USGS National Water Information System (NWIS) and the EPA's STORET (storage and retrieval for water quality data), which would provide a much more substantial coverage at the site level (Appendix 1). It is important to note that spatial data and information for some CMAP programs were discovered through these databases; however, potential duplications in the data could be investigated and handled by users in future gap assessments.

Two key advantages of using site locations as the data input are that they provide an exact location of monitoring activity and allow the potential for site-level metadata to be utilized, if available. The latter point is something that can be currently extracted from NWIS and STORET using EPA's Water Quality Portal (https://www.waterqualitydata.us/), and something that could be incorporated into future CMAP updates. Finally, the robust spatial information that could be provided by a gap assessment built from site locations would allow for more complex spatial statistical analyses to be performed, such as a hotspot analysis.

Future efforts could expand on the temporal and informational gap assessment by distinguishing between new and existing programs in each temporal period. In addition to providing details on how new monitoring efforts have changed over time, this would also provide a more nuanced understanding of how methodological gaps have changed over time.


Credit: Michael J. Osland (USGS)

Beyond water quality monitoring, habitat monitoring, and mapping programs, it is often critical for restoration planners to also factor in faunal monitoring. The current Inventory does not include faunal monitoring unless the monitoring program explicitly collected habitat or water quality data. Where appropriate, restoration planners can combine the Inventory with monitoring inventories and gap assessments that are developed by faunal specialty groups, such as the Gulf of Mexico Avian Monitoring Network.

While CMAP has taken an initial step in the investigation of methodologies for core parameters (NOAA and USGS, 2020), the incorporation of methodological gaps was beyond the scope of this effort. In the future, a more in-depth investigation needs to be conducted to categorize methodologies used to measure parameters into groups based on the information/measurement compatibility. This will be a difficult task that will require a wide range of expertise as the interpretation will vary based on habitat types, parameter(s), scale of monitoring, and location. A starting point for this type of effort may involve working at local scales for specific questions similar to the Perdido River basin example. Once completed, these assessments could be collated and scaled up to provide important information needed to factor in methodology in future gap assessments. Collectively, the tools and products developed by CMAP should provide resources to the Gulf of Mexico monitoring community to help initiate these discussions.

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Appendix A: Watershed Case Studies

Appendix A provides materials and gap assessment watershed case study results for the Perdido River basin (Alabama), Suwannee River (Florida), Calcasieu/Sabine-Neches (Louisiana), St. Louis Bay (Mississippi), and Salt Bayou (Texas).

The following page provides a guide to the contents presented for each of the five watershed case studies. This information was presented to a group of representatives for each state via a webinar. Additionally, results for the Perdido River basin, Salt Bayou, and Calcasieu/Sabine-Neches were presented and discussed during group sessions at the 2020 Gulf of Mexico Alliance (GOMA) Mid-Year Meeting. These case studies are initial demonstrations of the gap assessment framework. The results of these assessments were not detailed to the same degree as the assessments found in the body of the report.

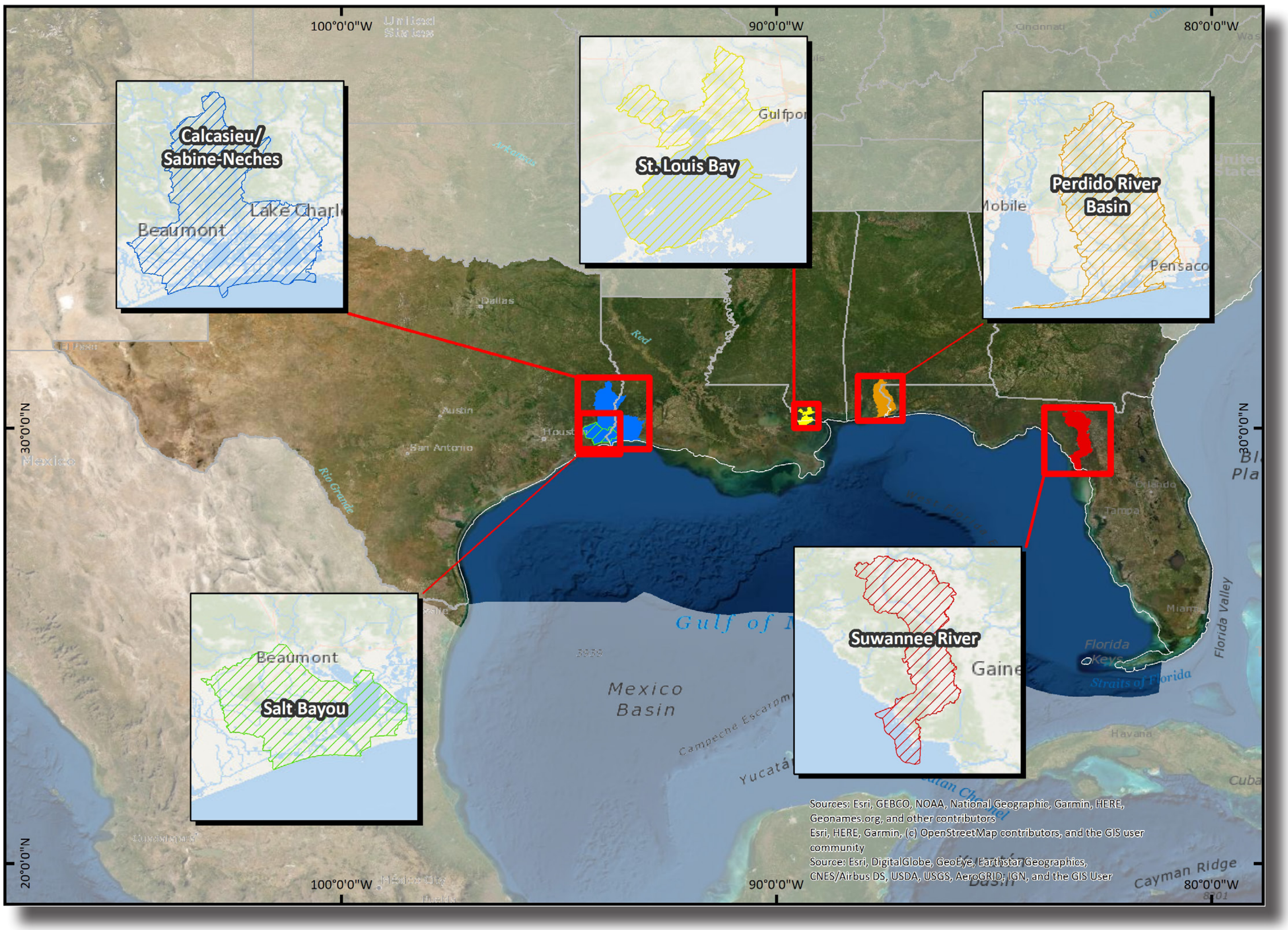
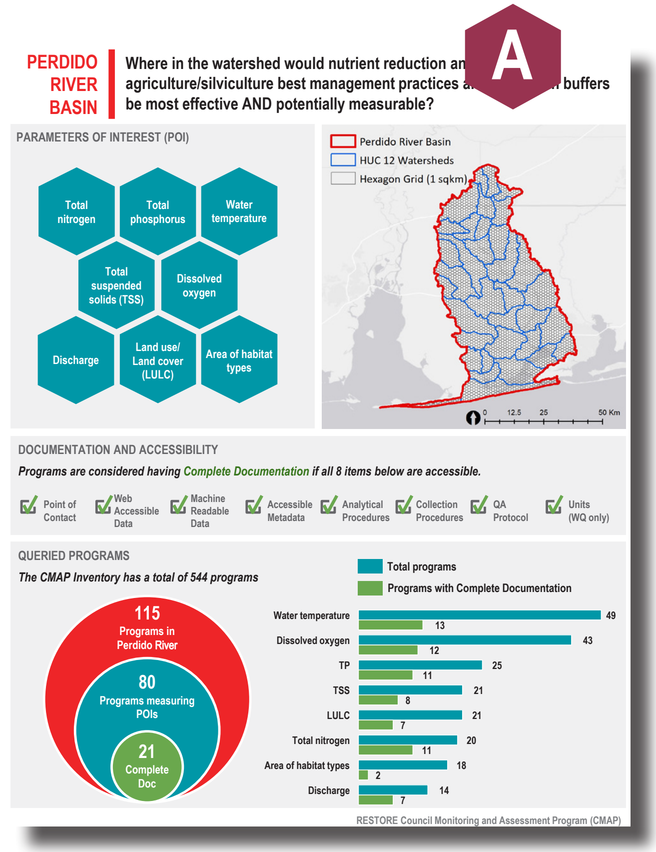


Figure A1. Geographic reference of all watershed study areas presented in this Appendix.

Each section of this appendix will include:

A

One-page descriptions of each case study, which includes: the study question(s), parameters of interest, study area (see Figure A1 for geographic reference of all watershed study areas), and statistics describing the Inventory query results.



B

Headings describing the watershed of interest and the specific query (e.g., "All intersecting programs") presented. Additionally, three maps are included that depict the number of:

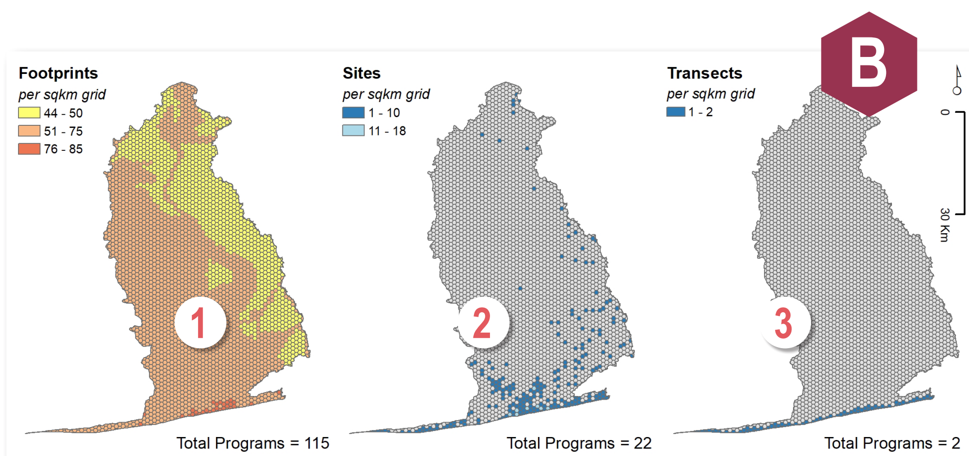
1. Intersecting program footprints per spatial unit,
2. Monitoring sites* per spatial unit; and
3. Monitoring transects* per spatial unit.

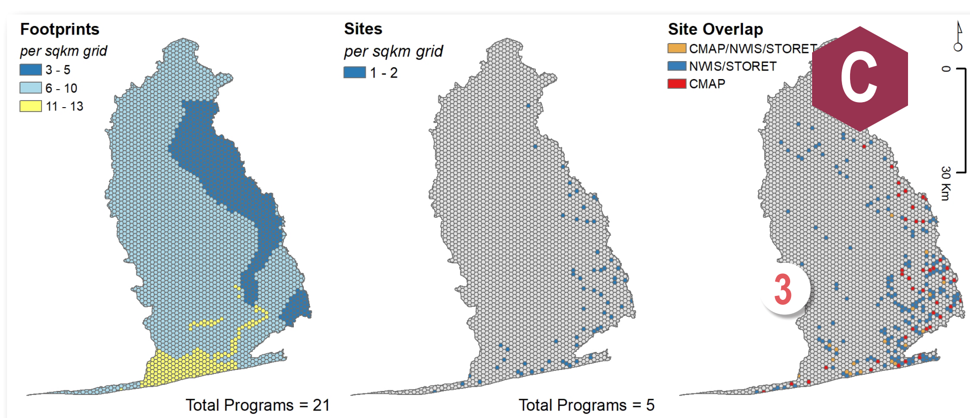
** Monitoring sites and transects were not available for all inventoried programs. See "Total Programs" counts at the bottom of each map for clarity on the number of programs with available monitoring location data.*

C

For each case study, the same set of three maps are presented for each parameter of interest. Rather than the count of transects per spatial unit, map 3 for some parameters presents the general locations of monitoring sites discovered by CMAP and sites discoverable via the USGS NWIS and EPA STORET databases.

Locations of monitoring sites from the NWIS and STORET databases are highlighted in blue. These additional data sources may potentially be used to supplement known monitoring datasets identified by CMAP. Spatial units highlighted in red represent areas where only sites discovered via CMAP are known. Orange areas represent potential overlap in monitoring sites known via CMAP and the USGS and EPA databases.

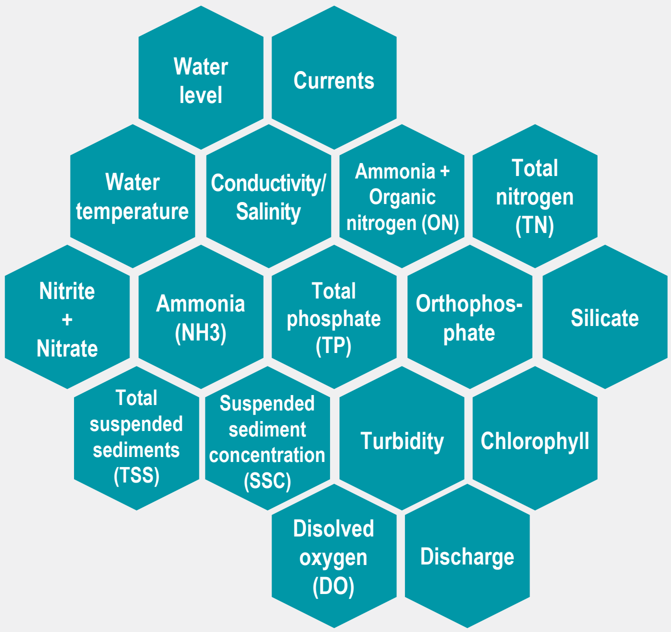


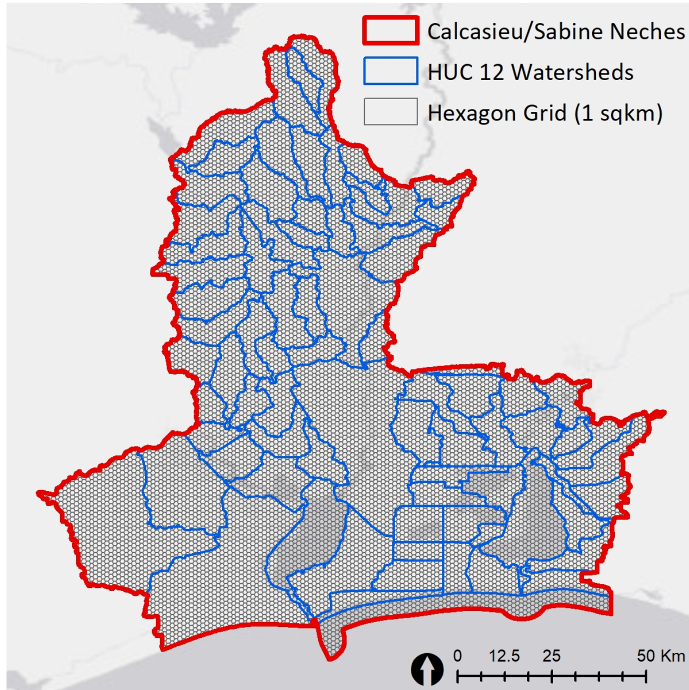


CALCASIEU SABINE NECHES

What is the influence of the Toledo Bend Reservoir on water flow?
How does water move through the canal system?
What additional data are needed for a water quality baseline?

PARAMETERS OF INTEREST (POI)





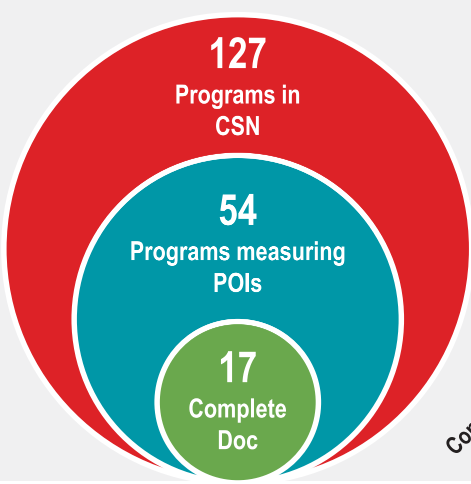
DOCUMENTATION AND ACCESSIBILITY

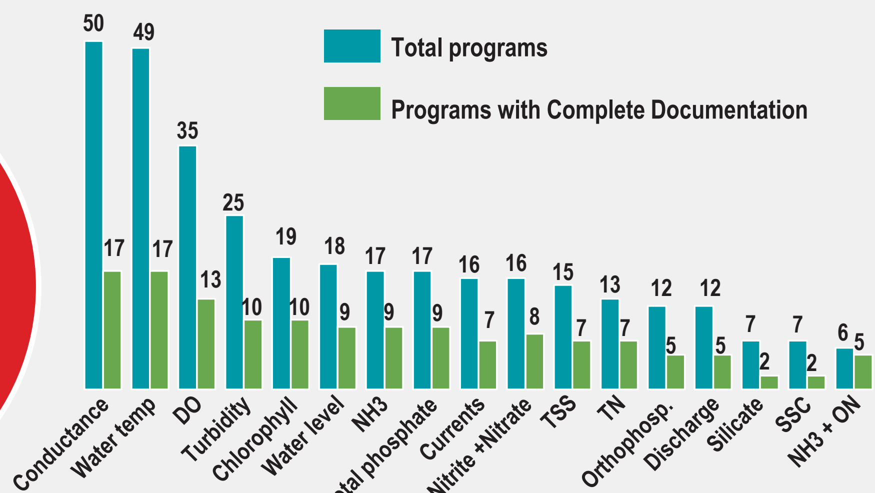
Programs are considered having Complete Documentation if all 8 items below are accessible.

- ☑ Point of Contact
- ☑ Web Accessible Data
- ☑ Machine Readable Data
- ☑ Accessible Metadata
- ☑ Analytical Procedures
- ☑ Collection Procedures
- ☑ QA Protocol
- ☑ Units (WQ only)

QUERIED PROGRAMS

The CMAP Inventory has a total of 544 programs

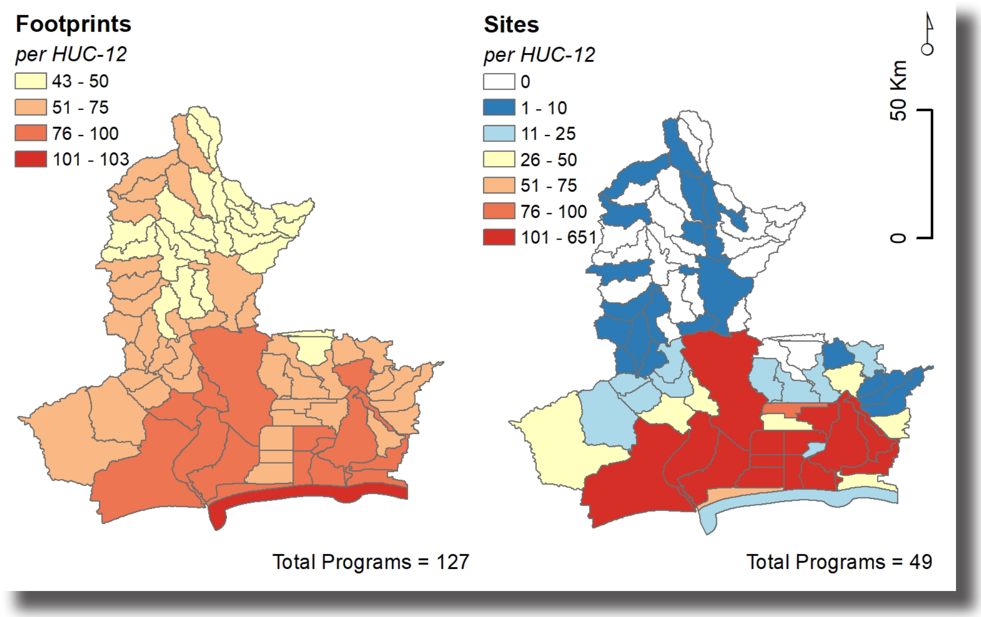




RESTORE Council Monitoring and Assessment Program (CMAP)

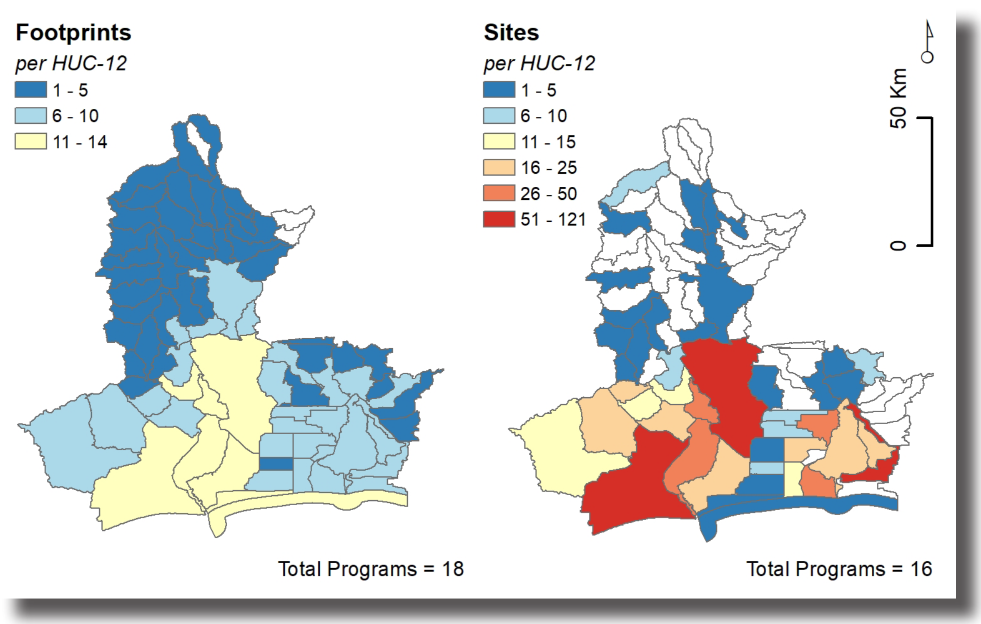
Calcasieu/Sabine-Neches

All intersecting programs per HUC-12 watershed



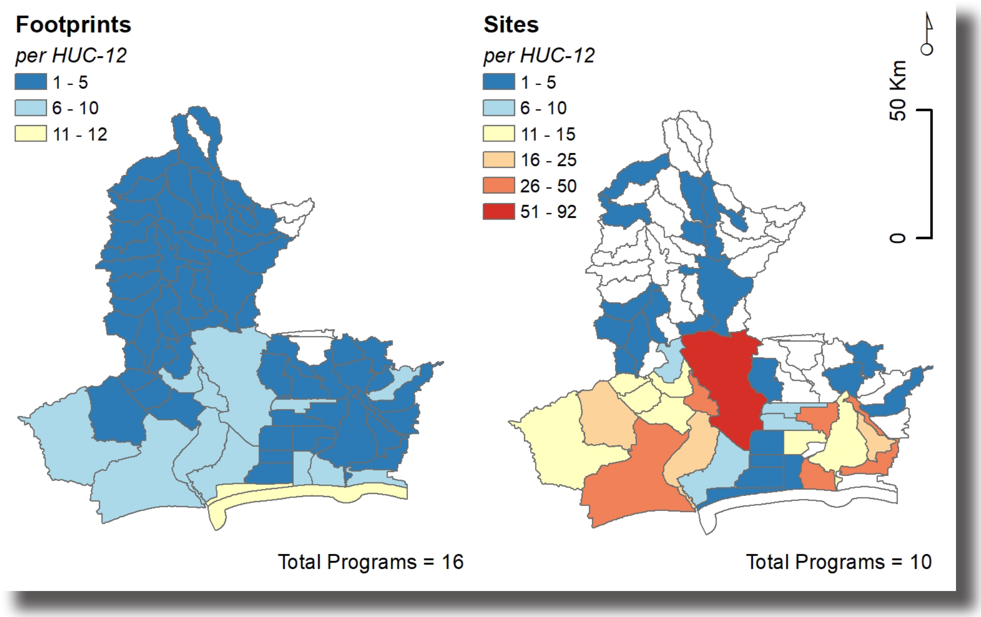
Calcasieu/Sabine-Neches

All intersecting programs that monitored water level



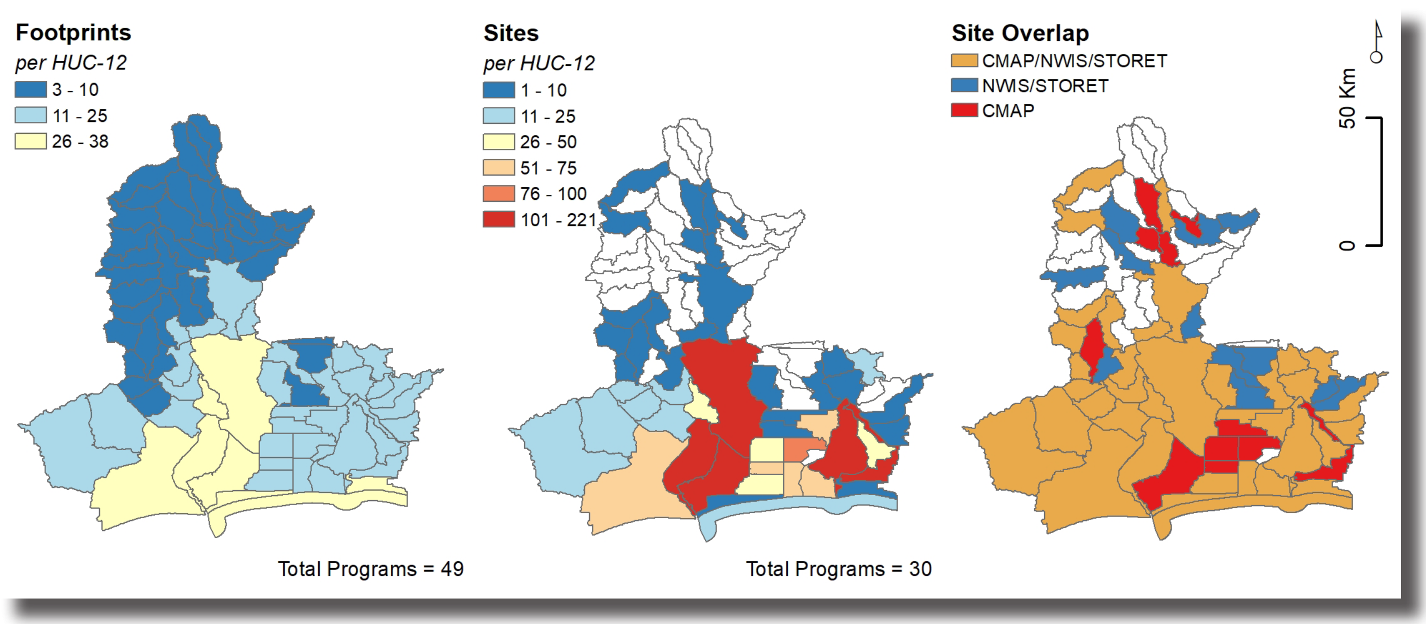
Calcasieu/Sabine-Neches

All intersecting programs that monitored currents



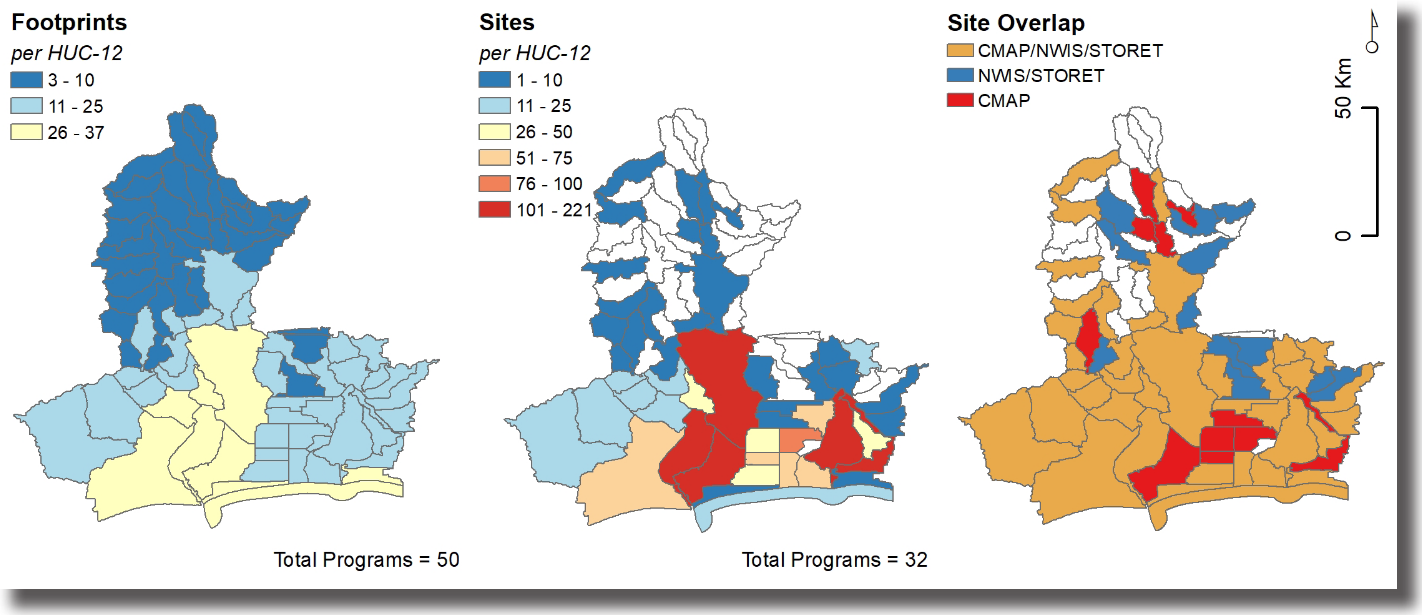
Calcasieu/Sabine-Neches

All intersecting programs that monitored water temperature



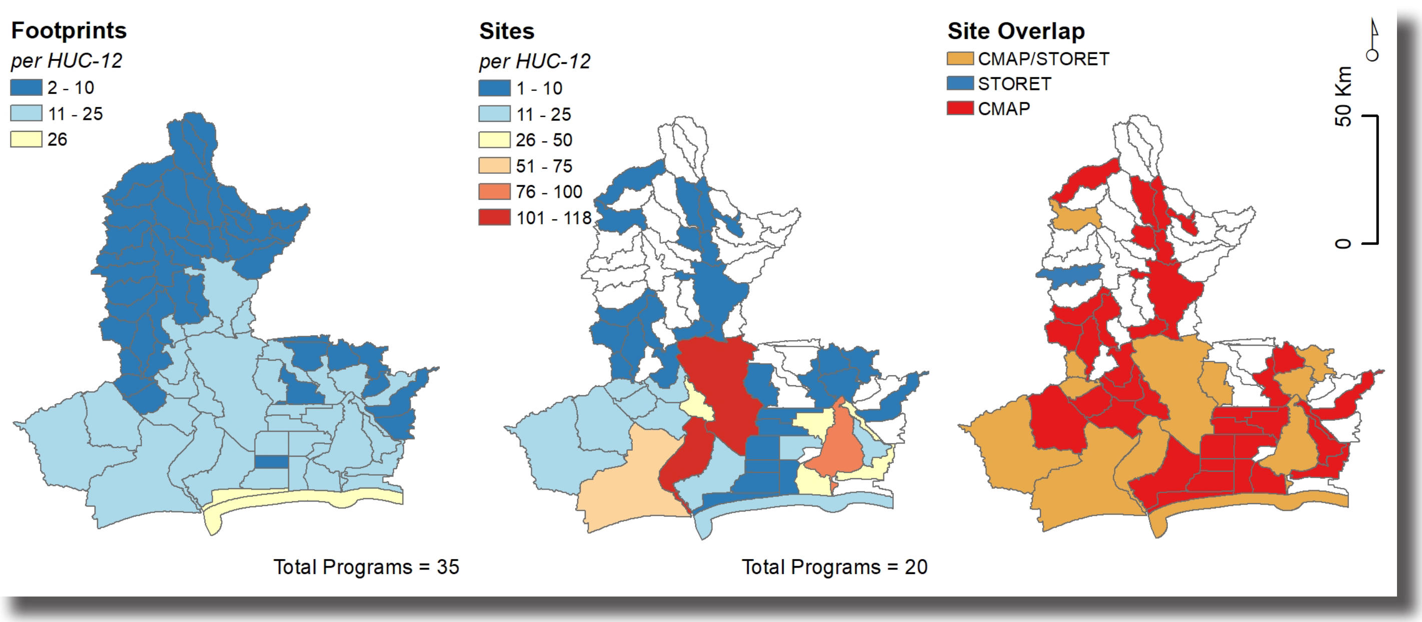
Calcasieu/Sabine-Neches

All intersecting programs that monitored conductance



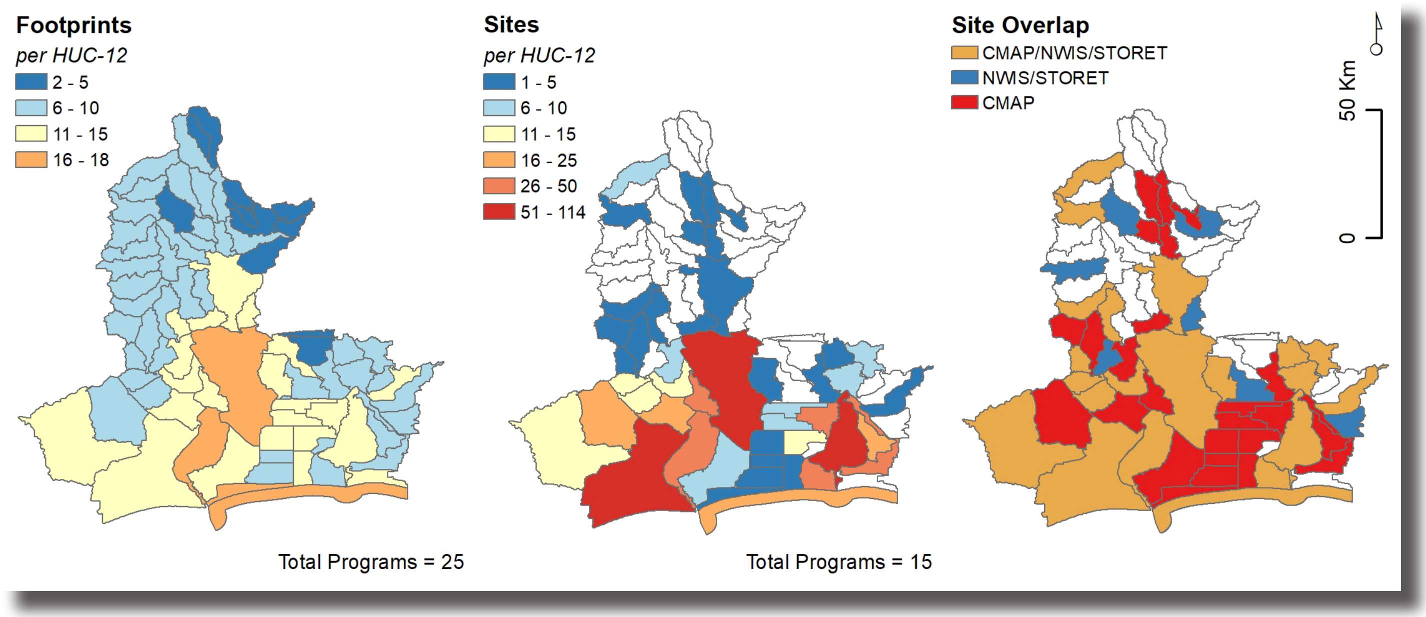
Calcasieu/Sabine-Neches

All intersecting programs that monitored dissolved oxygen



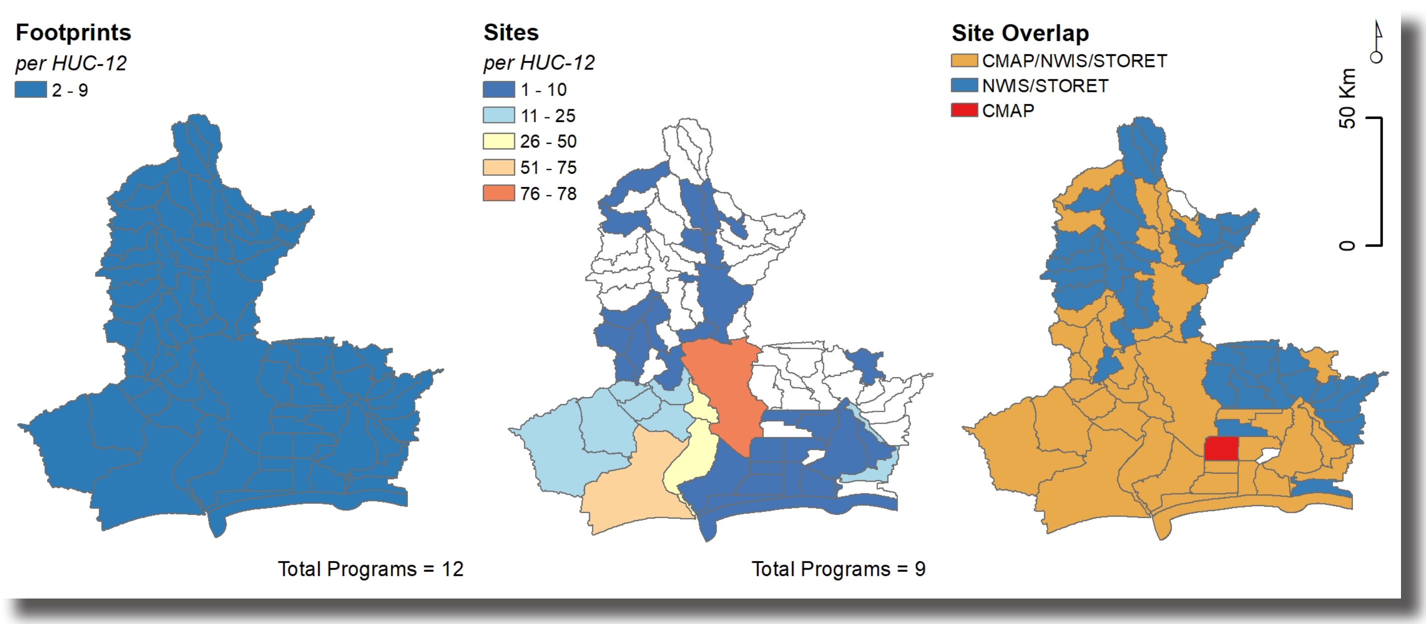
Calcasieu/Sabine-Neches

All intersecting programs that monitored turbidity



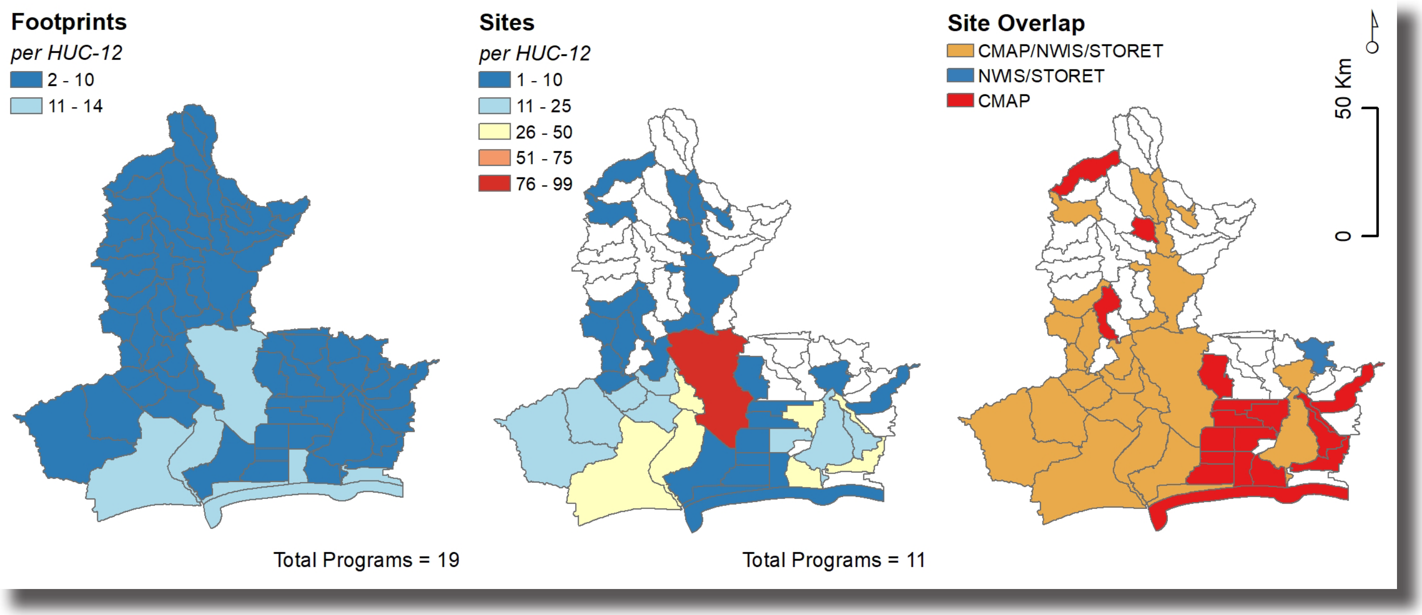
Calcasieu/Sabine-Neches

All intersecting programs that monitored discharge



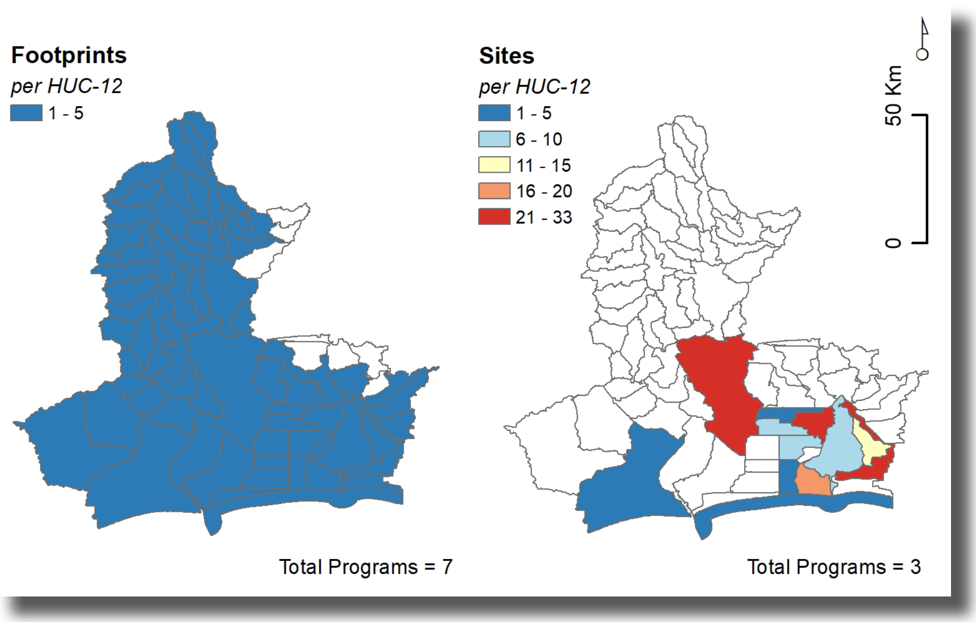
Calcasieu/Sabine-Neches

All intersecting programs that monitored chlorophyll



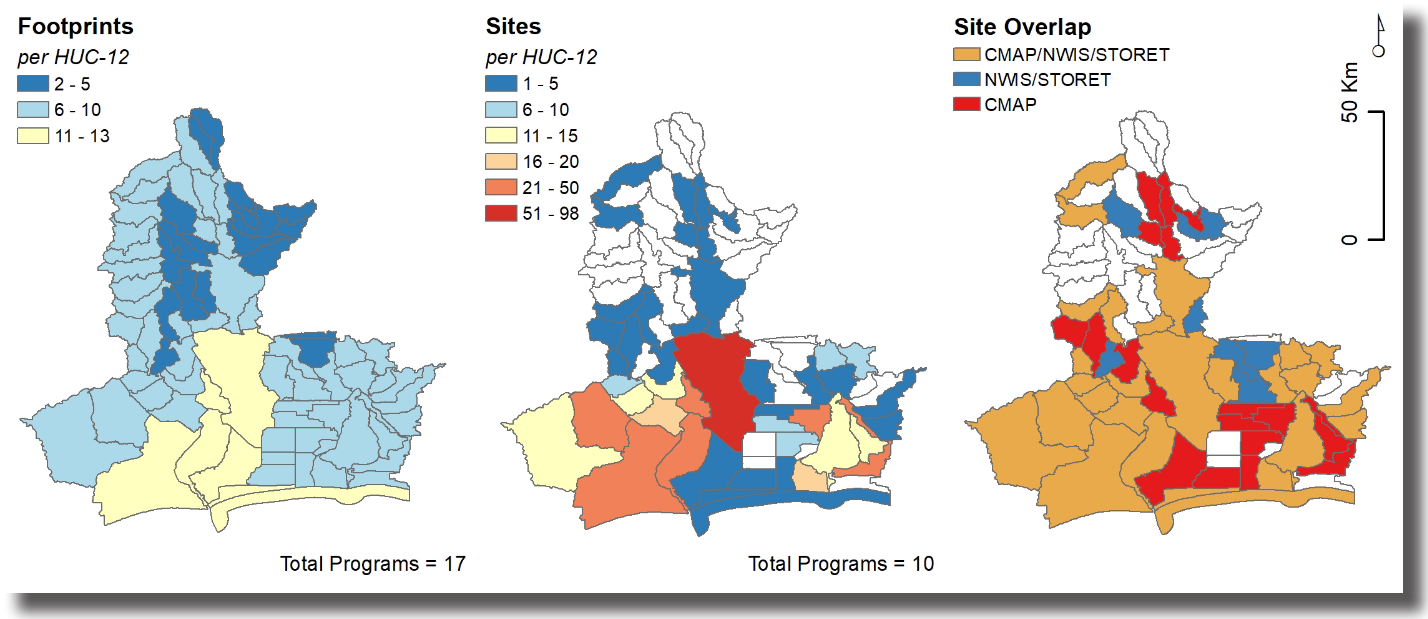
Calcasieu/Sabine-Neches

All intersecting programs that monitored silicate



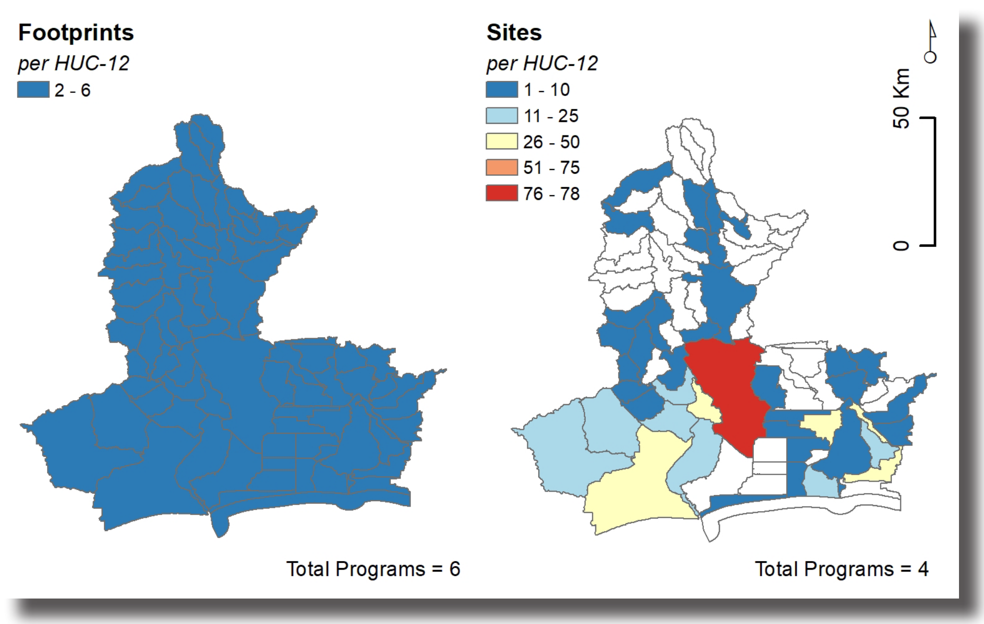
Calcasieu/Sabine-Neches

All intersecting programs that monitored ammonia



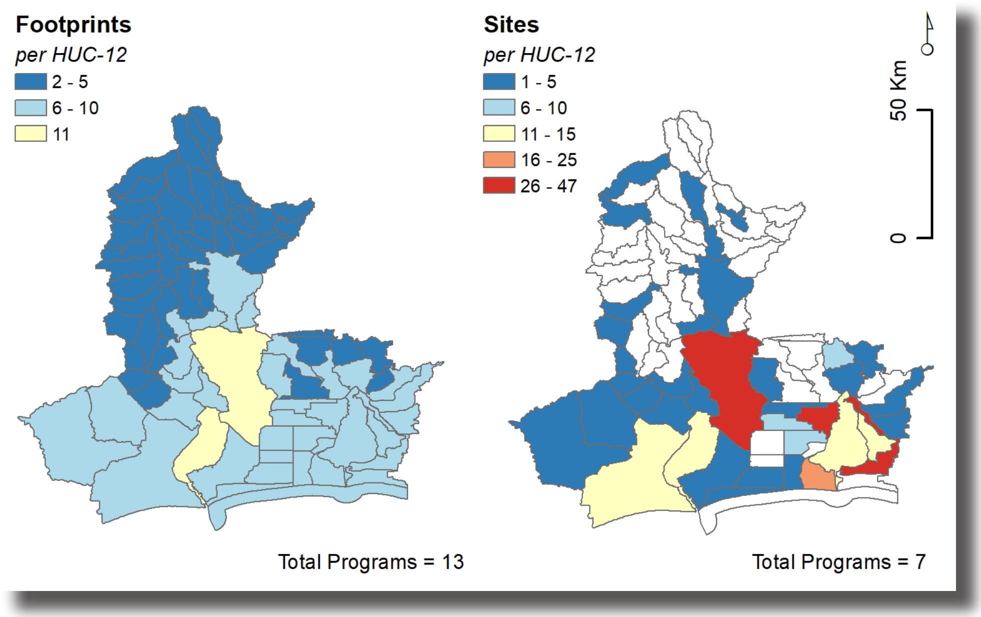
Calcasieu/Sabine-Neches

All intersecting programs that monitored ammonia + organic nitrogen



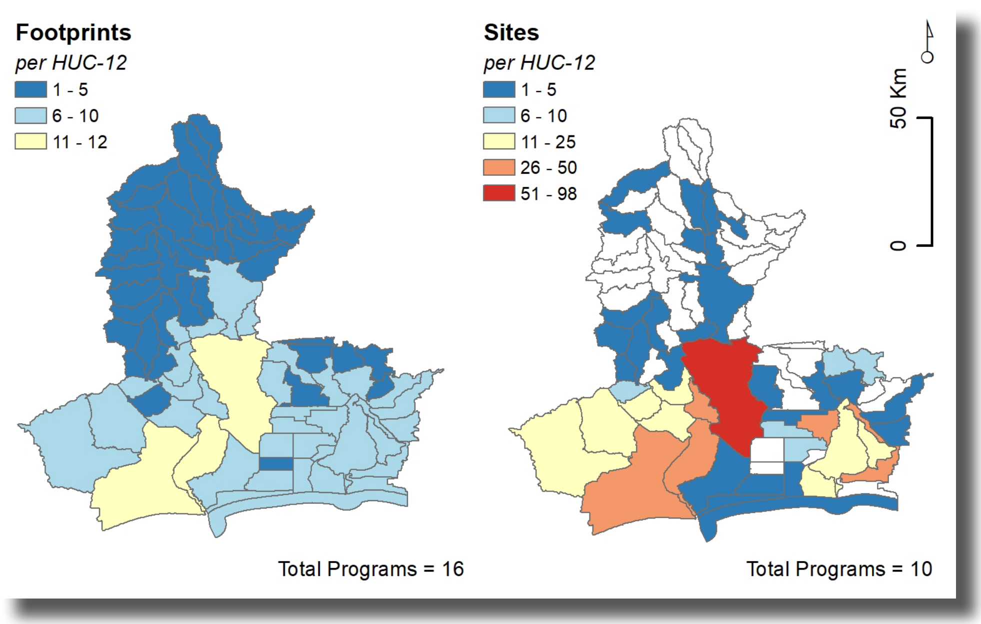
Calcasieu/Sabine-Neches

All intersecting programs that monitored total nitrogen



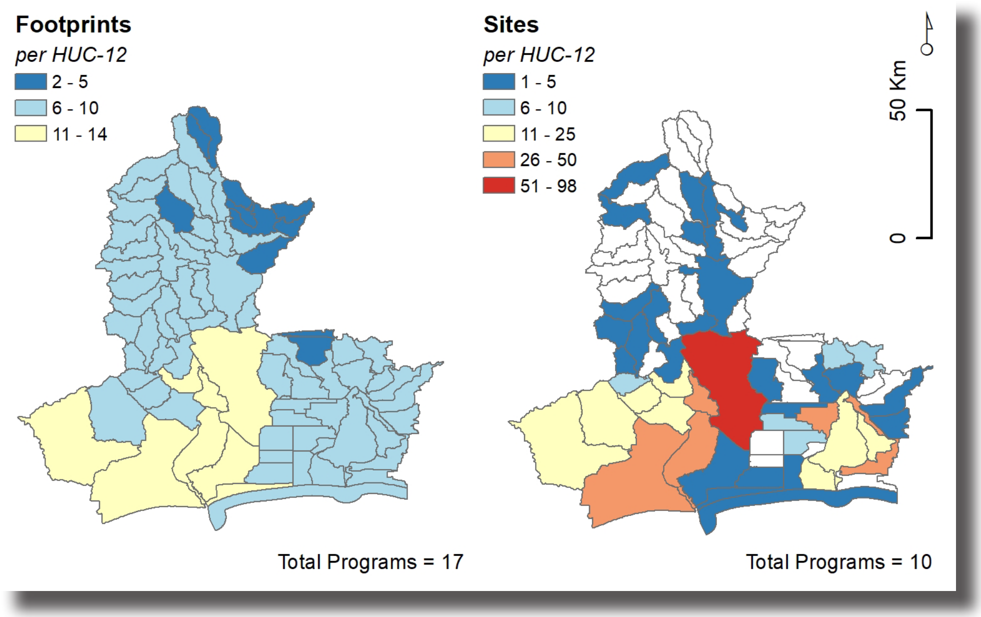
Calcasieu/Sabine-Neches

All intersecting programs that monitored nitrite + nitrate



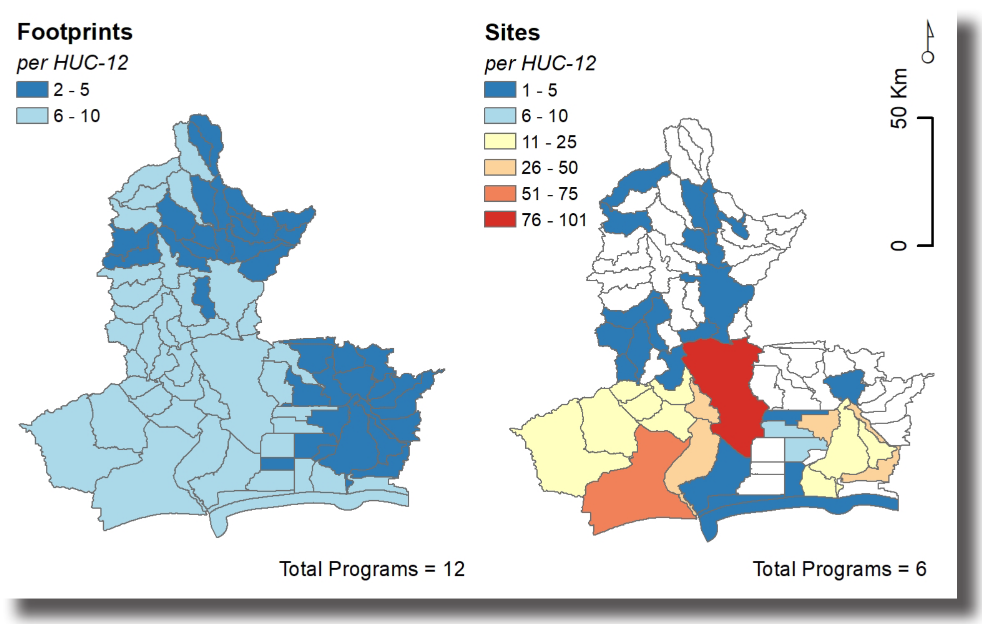
Calcasieu/Sabine-Neches

All intersecting programs that monitored total phosphorus



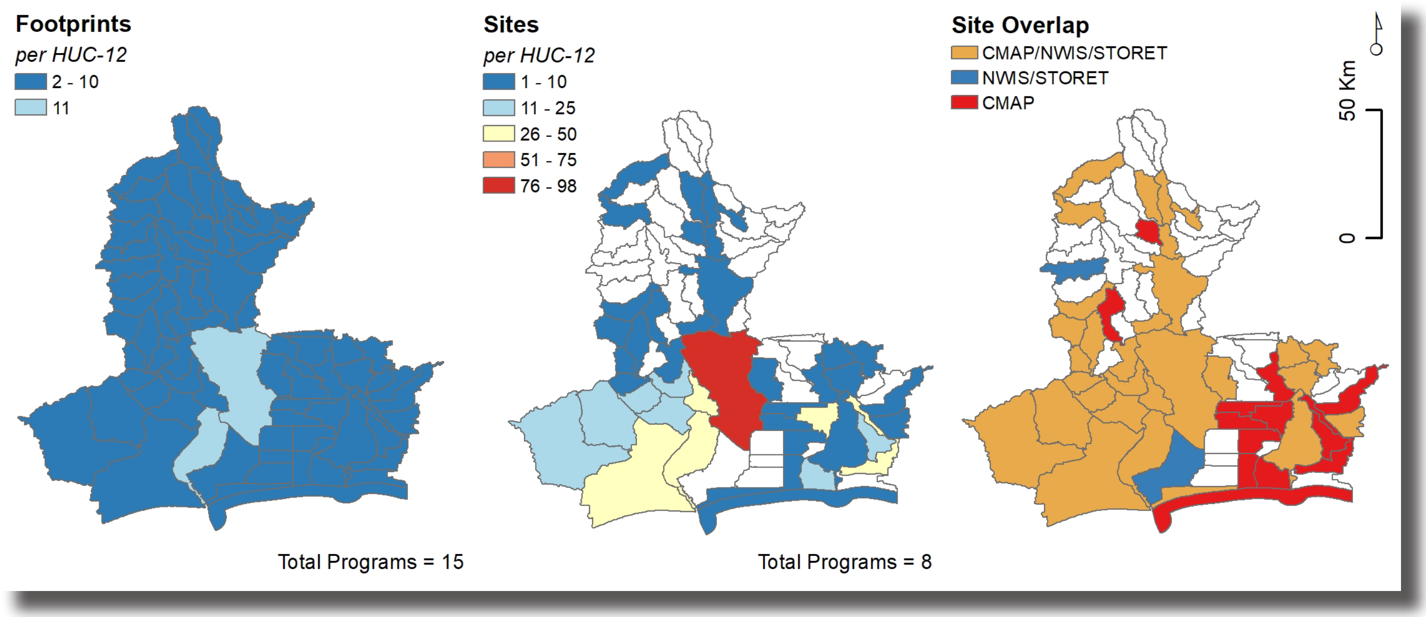
Calcasieu/Sabine-Neches

All intersecting programs that monitored orthophosphate



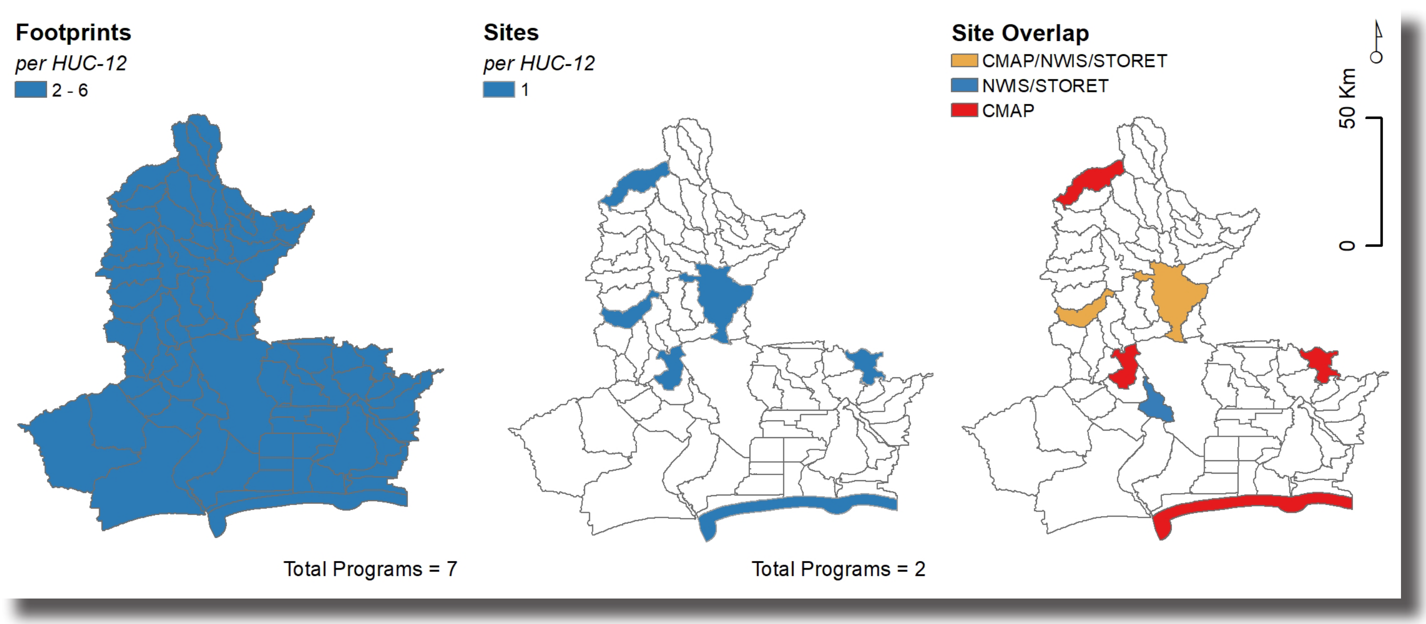
Calcasieu/Sabine-Neches

All intersecting programs that monitored total suspended solids



Calcasieu/Sabine-Neches

All intersecting programs that monitored suspended sediment concentration

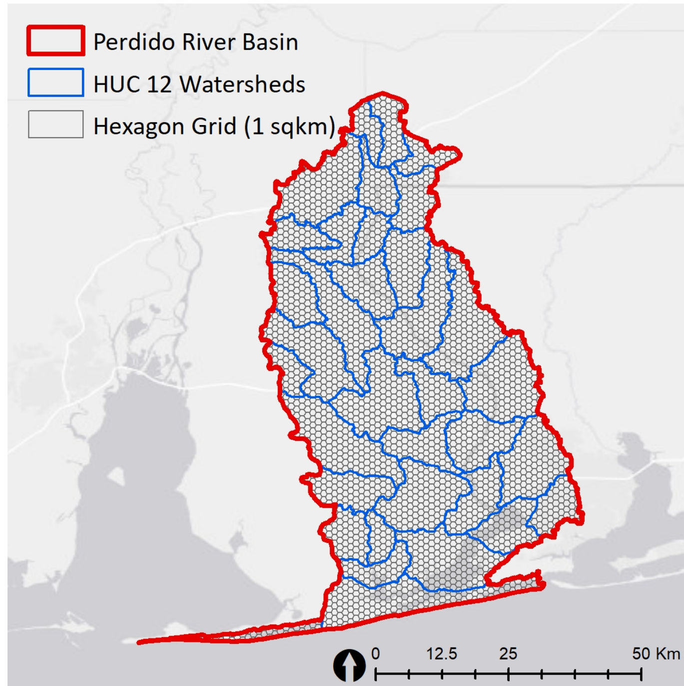


PERDIDO RIVER BASIN

Where in the watershed would nutrient reduction and agriculture/silviculture best management practices and or riparian buffers be most effective AND potentially measurable?

PARAMETERS OF INTEREST (POI)

- Total nitrogen
- Total phosphorus
- Water temperature
- Total suspended solids (TSS)
- Dissolved oxygen
- Discharge
- Land use/ Land cover (LULC)
- Area of habitat types



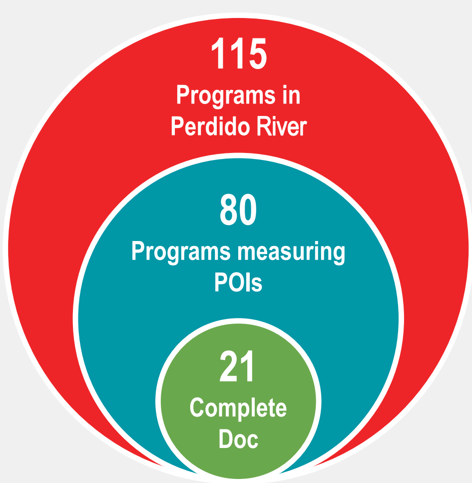
DOCUMENTATION AND ACCESSIBILITY

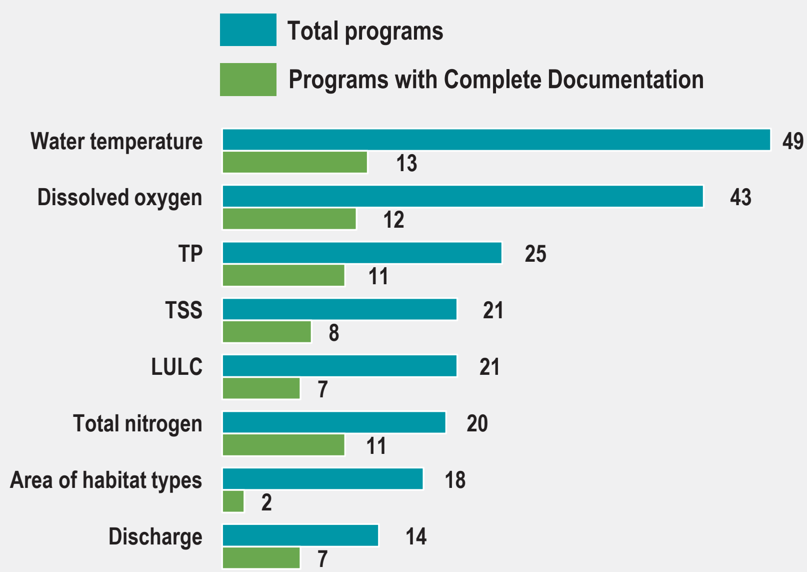
Programs are considered having Complete Documentation if all 8 items below are accessible.

- ☑ Point of Contact
- ☑ Web Accessible Data
- ☑ Machine Readable Data
- ☑ Accessible Metadata
- ☑ Analytical Procedures
- ☑ Collection Procedures
- ☑ QA Protocol
- ☑ Units (WQ only)

QUERIED PROGRAMS

The CMAP Inventory has a total of 544 programs

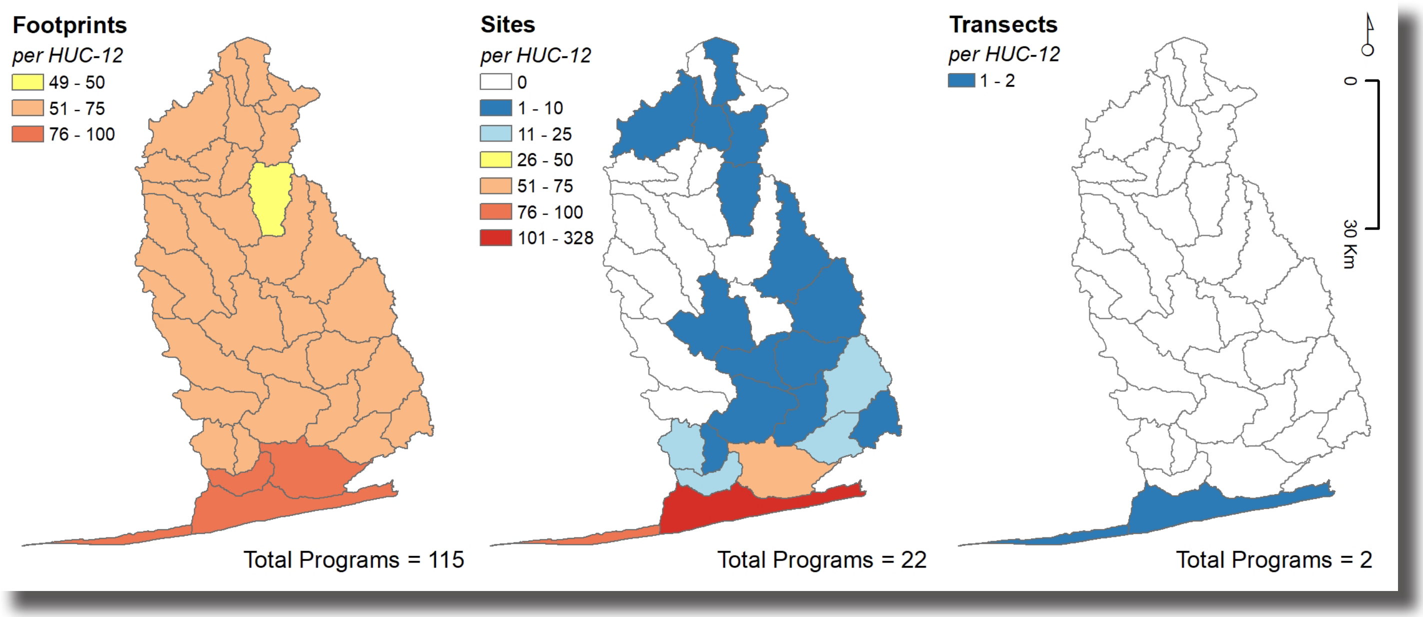




RESTORE Council Monitoring and Assessment Program (CMAP)

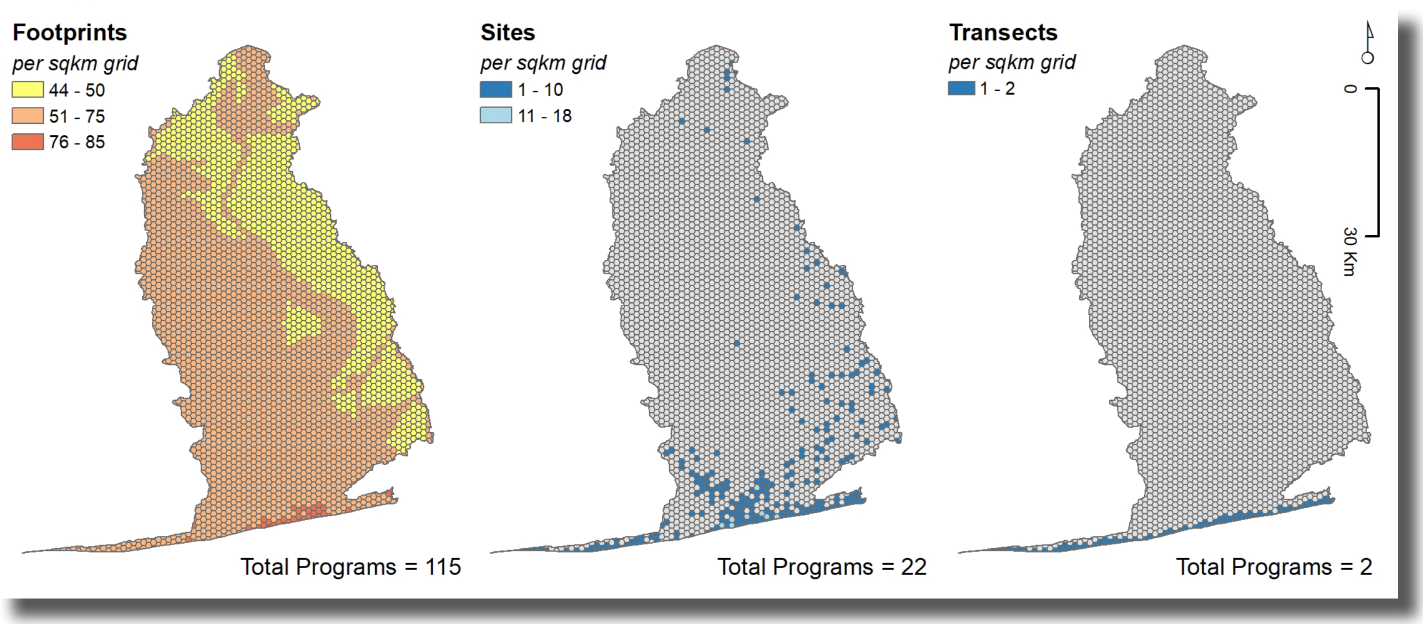
Perdido River Basin

All intersecting programs per HUC-12 watershed



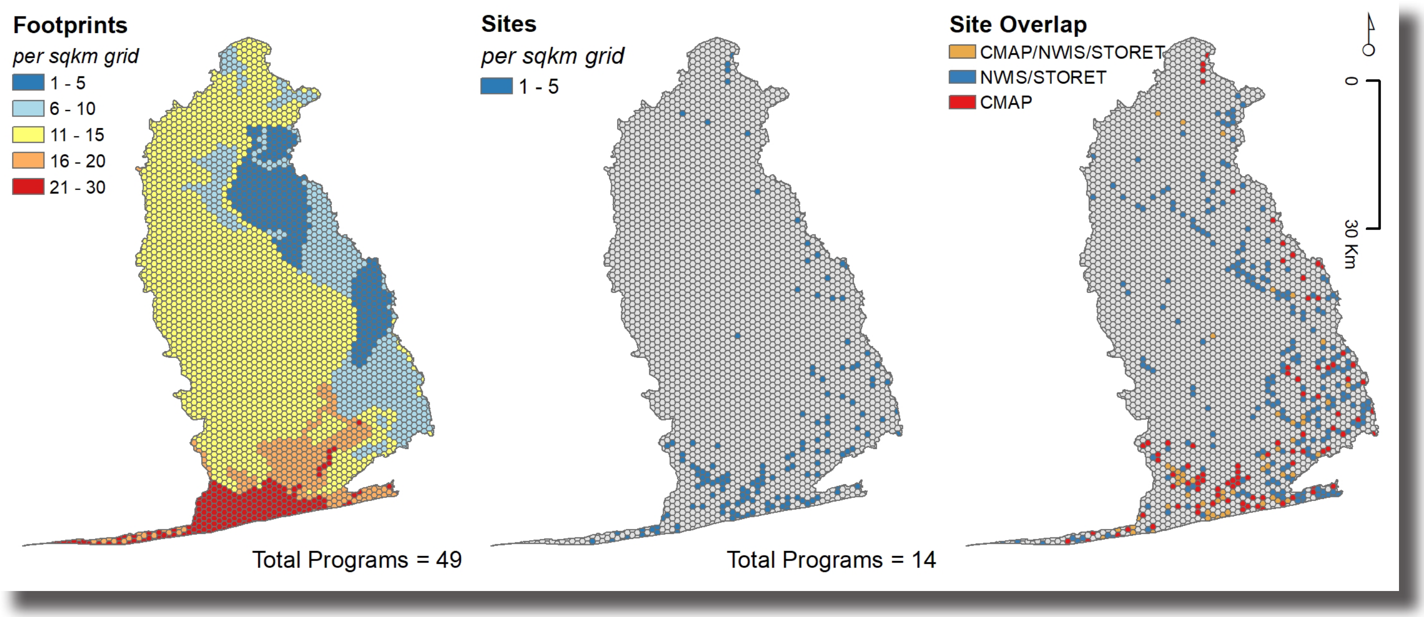
Perdido River Basin

All intersecting programs per 1-km² hexagon grid



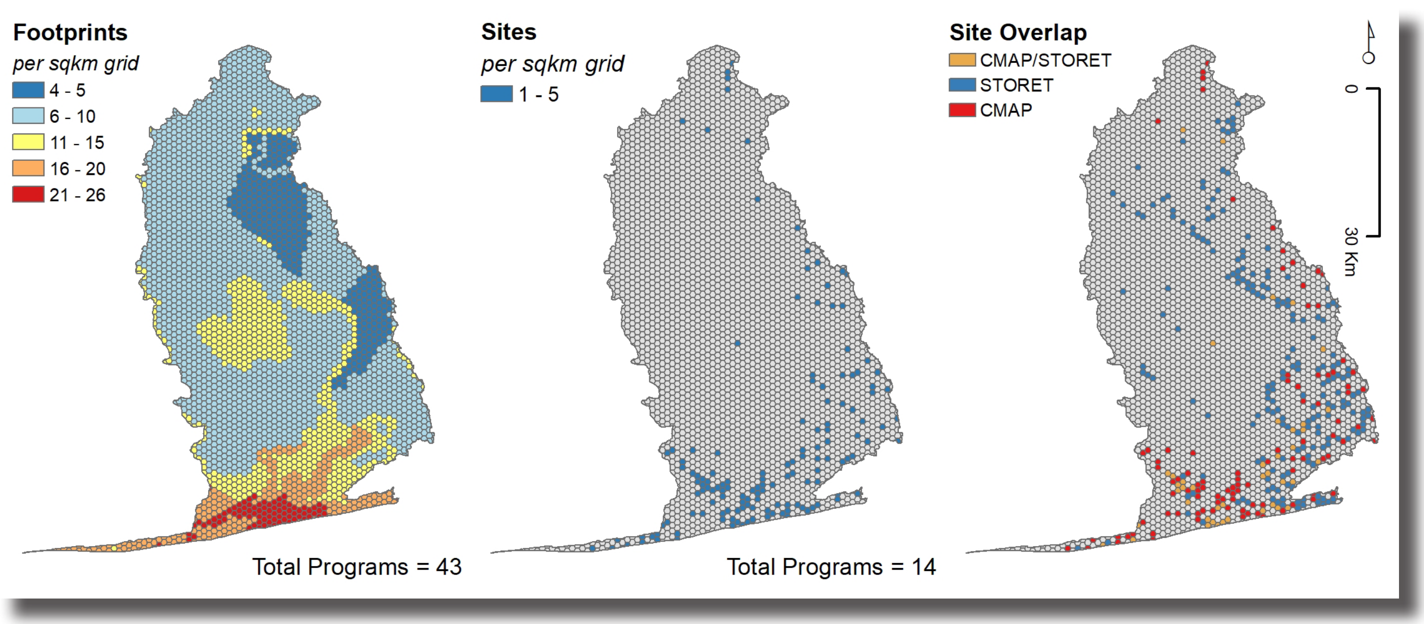
Perido River Basin

All intersecting programs that monitored water temperature



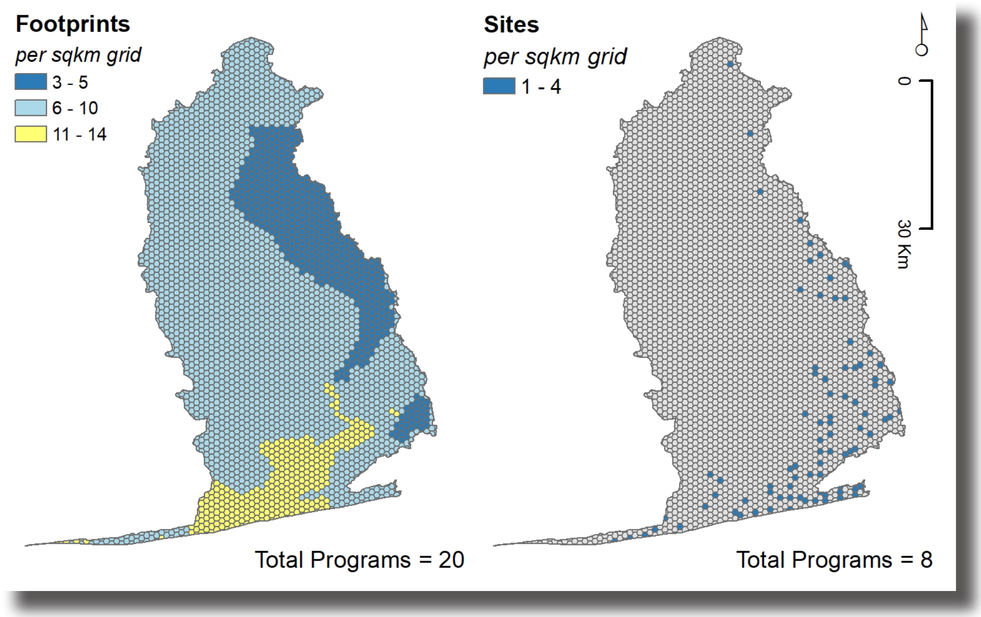
Perdido River Basin

All intersecting programs that monitored dissolved oxygen



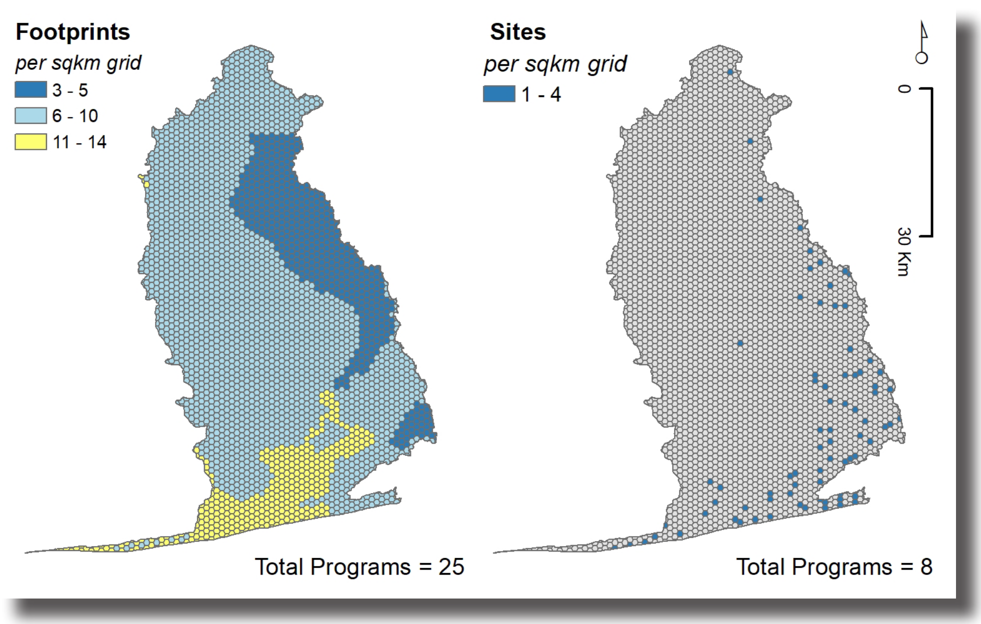
Perdido River Basin

All intersecting programs that monitored total nitrogen



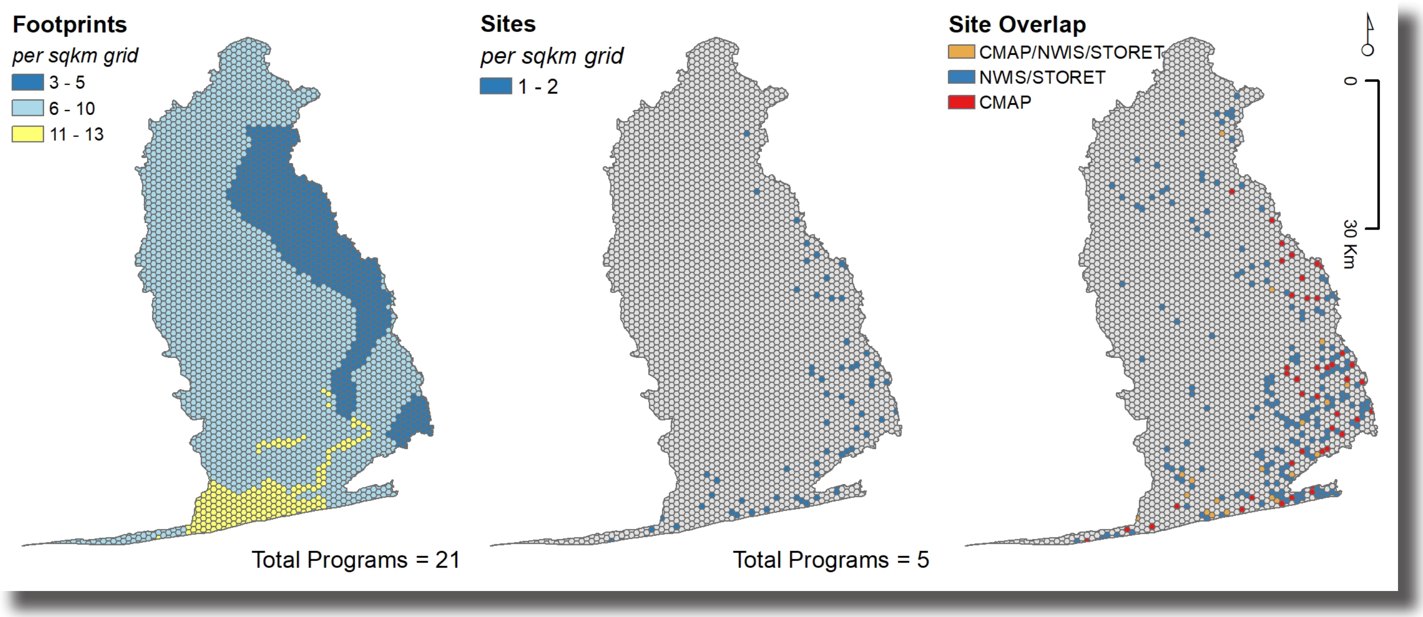
Perdido River Basin

All intersecting programs that monitored total phosphorus



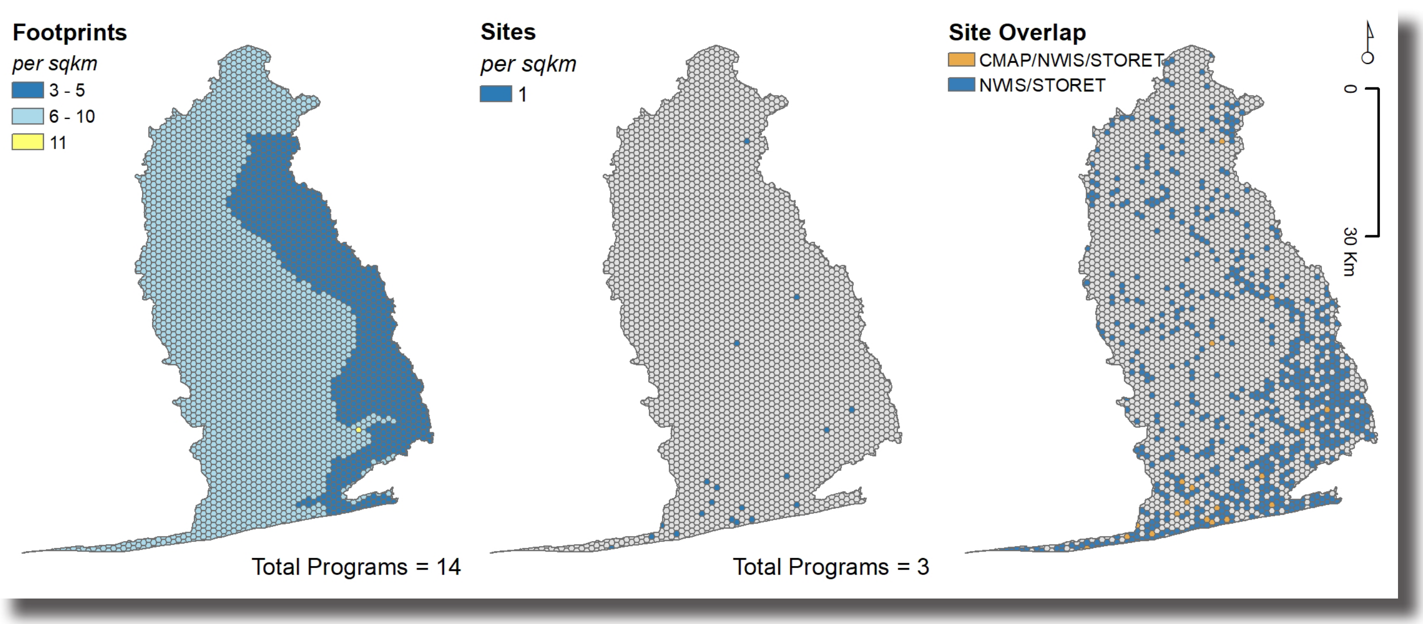
Perdido River Basin

All intersecting programs that monitored total suspended solids



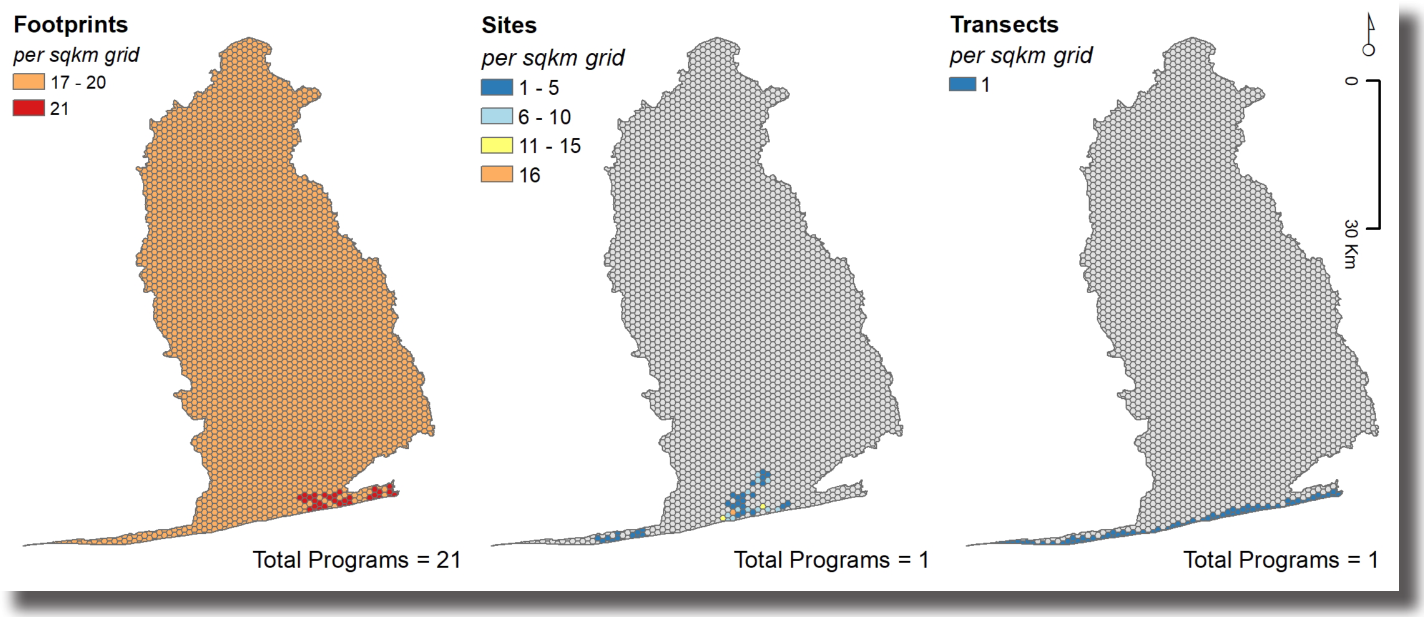
Perdido River Basin

All intersecting programs that monitored discharge



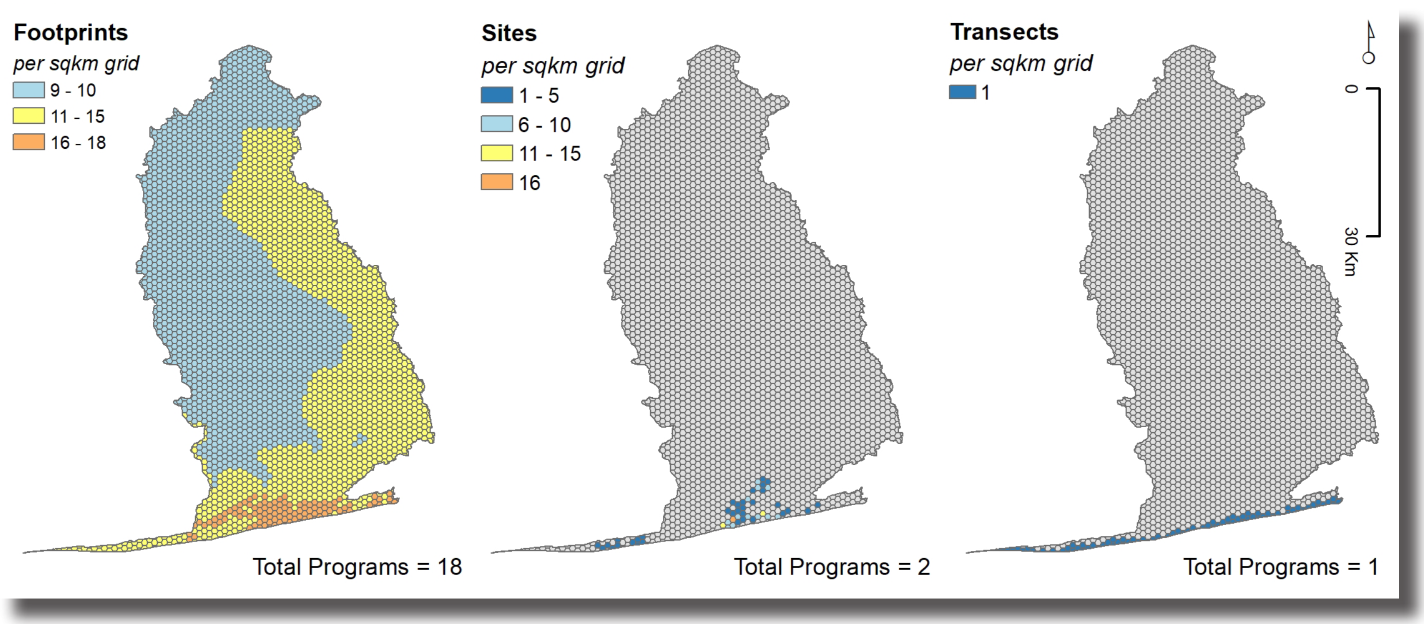
Perdido River Basin

All intersecting programs that mapped land use/land cover



Perdido River Basin

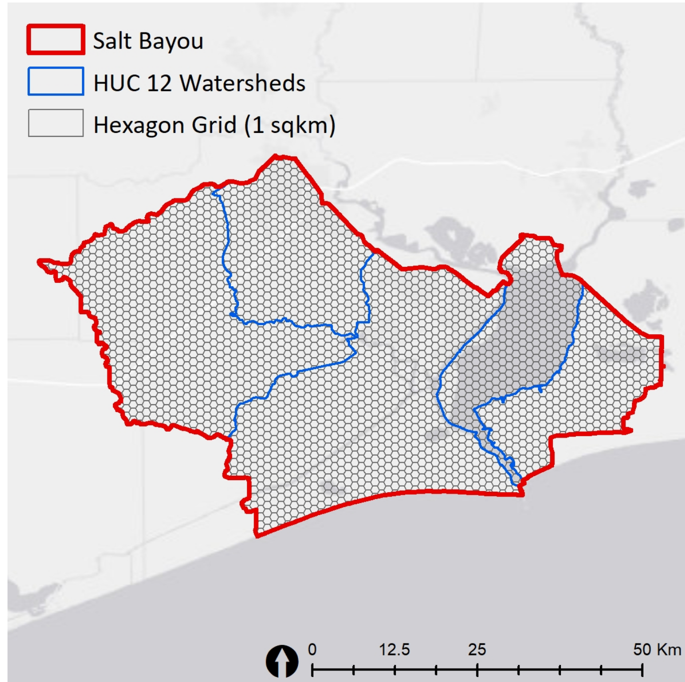
All intersecting programs that mapped of habitat types



SALT BAYOU

Identify the data availability for strong drivers of wetland loss and change in the watershed.

PARAMETERS OF INTEREST (POI)



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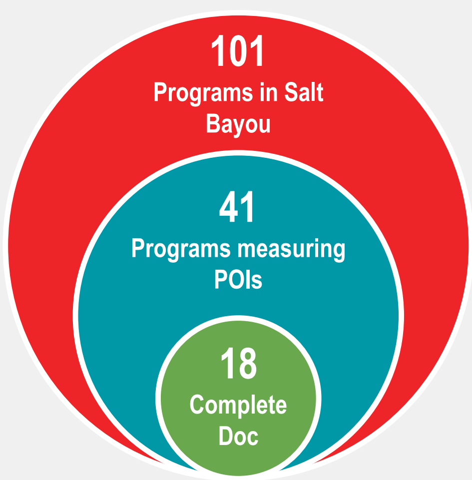
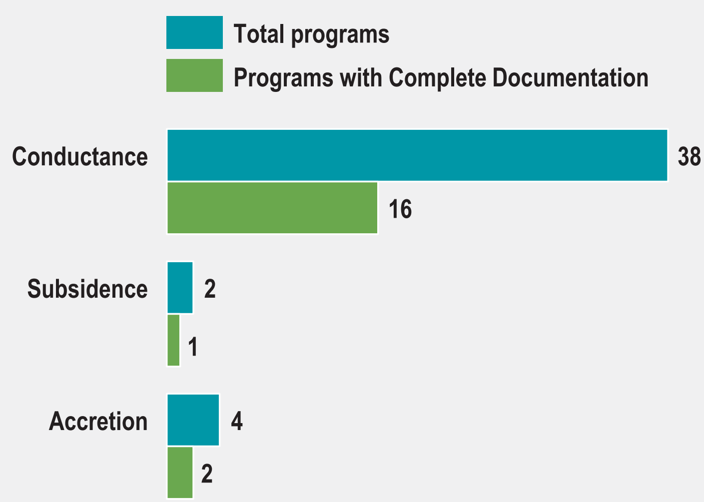
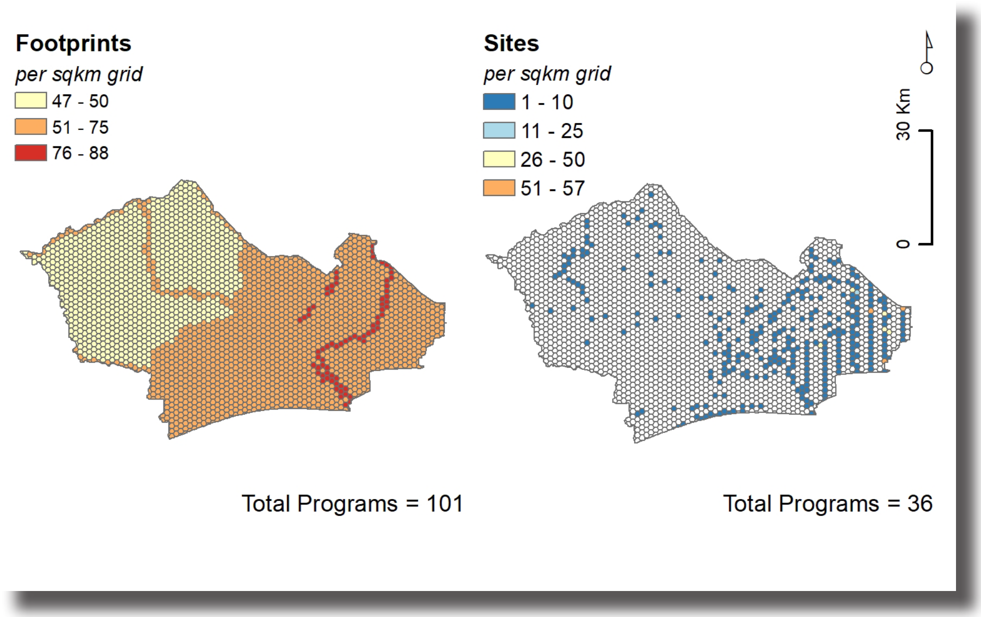




RESTORE Council Monitoring and Assessment Program (CMAP)

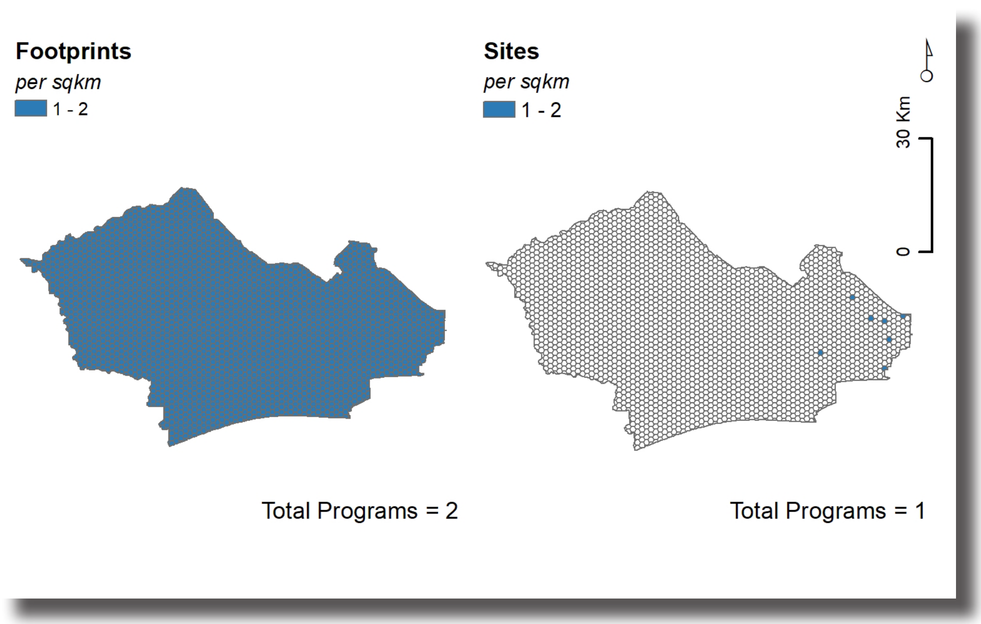
Salt Bayou

All intersecting programs per 1-km² hexagon grid



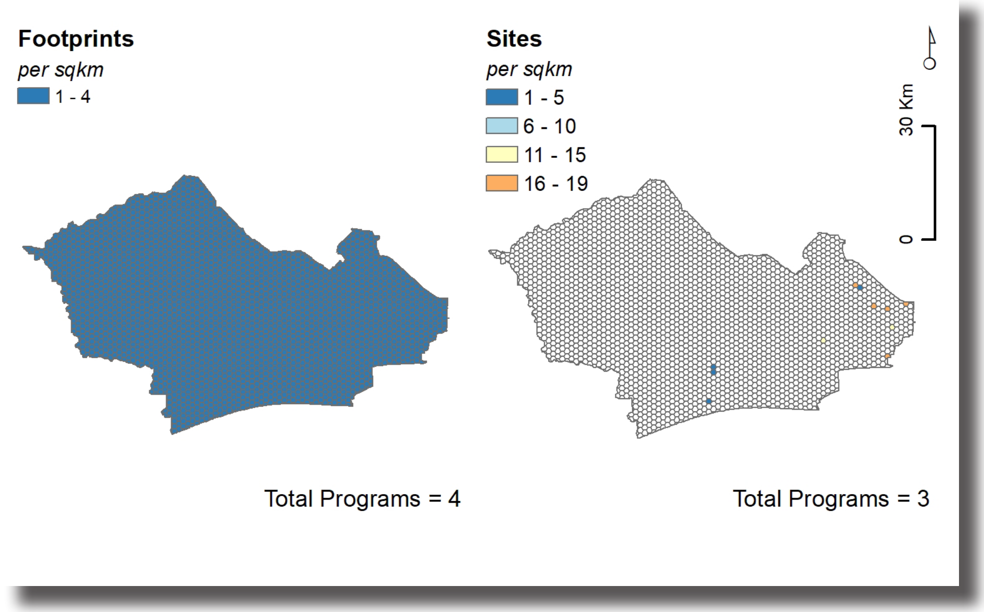
Salt Bayou

All intersecting programs monitored subsidence



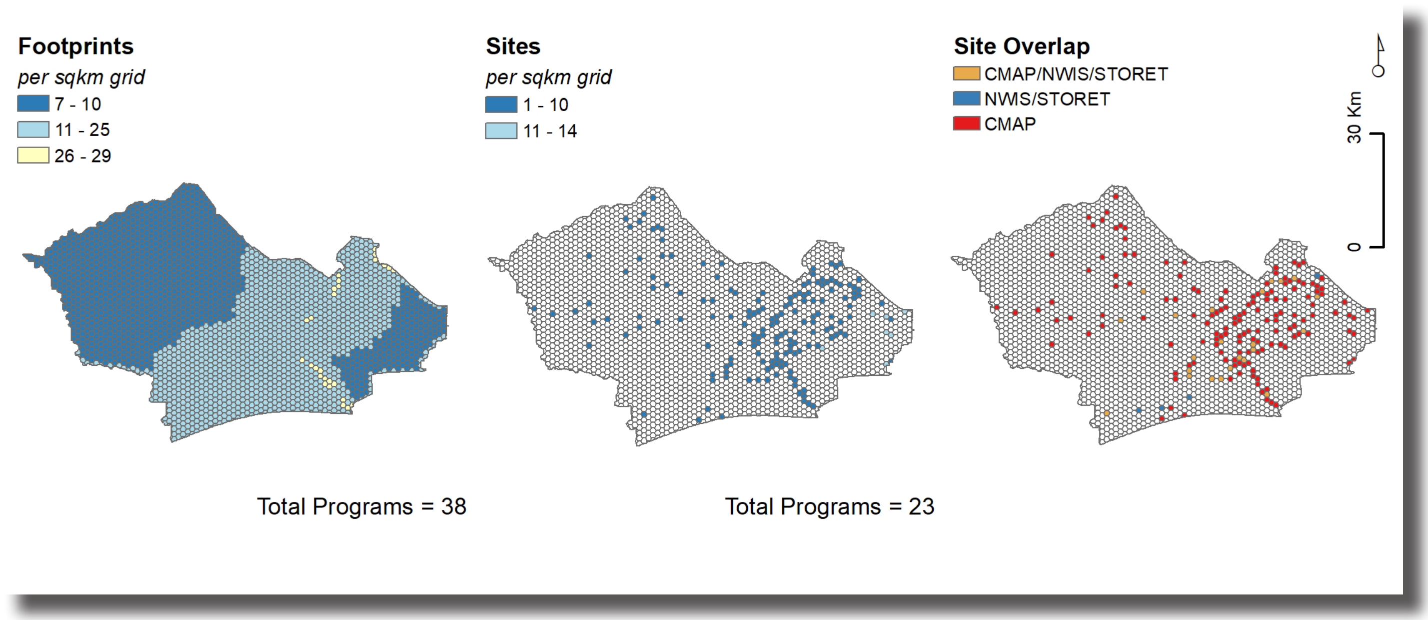
Salt Bayou

All intersecting programs that monitored accretion



Salt Bayou

All intersecting programs monitored conductance

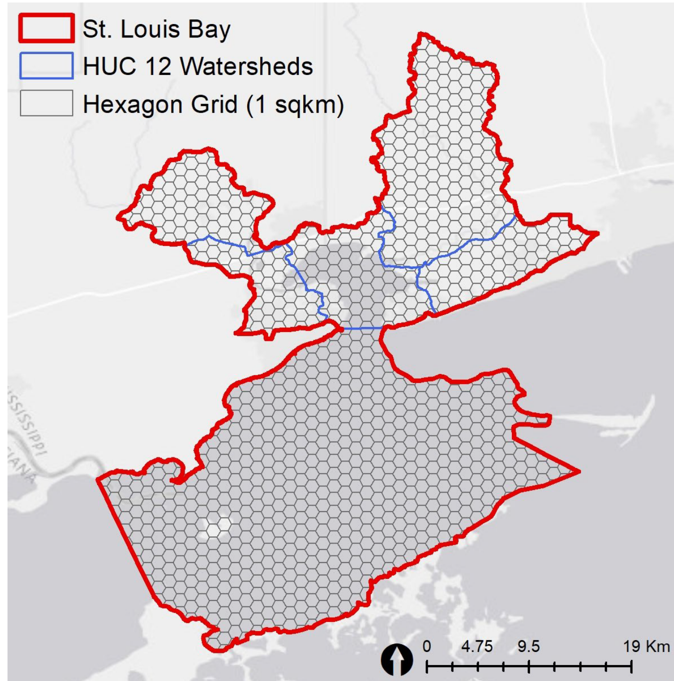


ST. LOUIS BAY

Identify gaps in the availability of data used to evaluate changes in salinity in St Louis Bay over time.

PARAMETERS OF INTEREST (POI)

- Conductance/ Salinity
- Water Temperature



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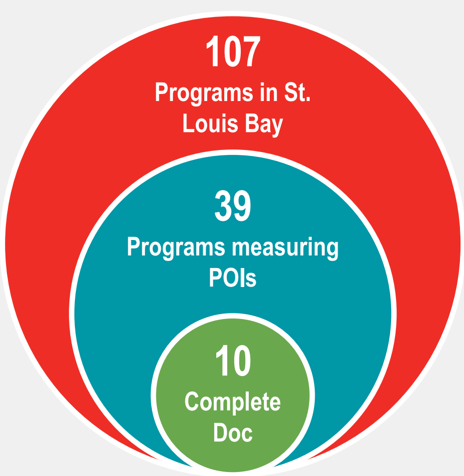
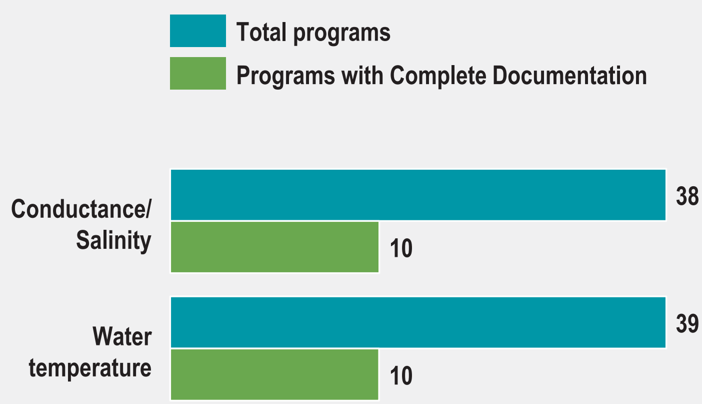
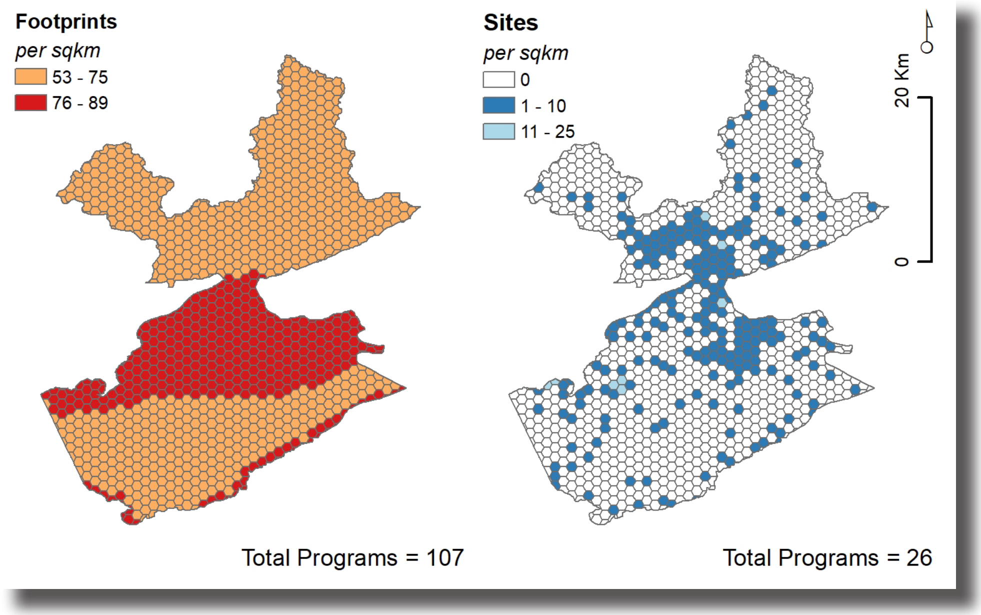




RESTORE Council Monitoring and Assessment Program (CMAP)

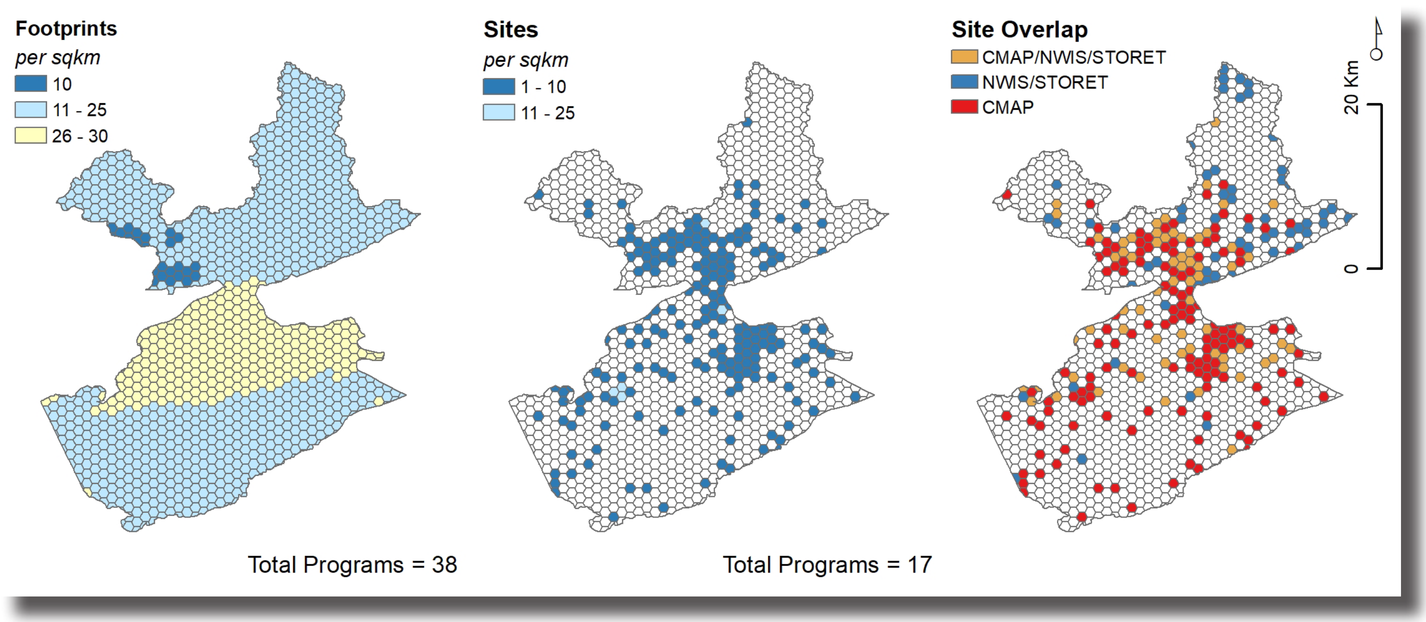
St. Louis Bay

All intersecting programs per 1-km² hexagon grid



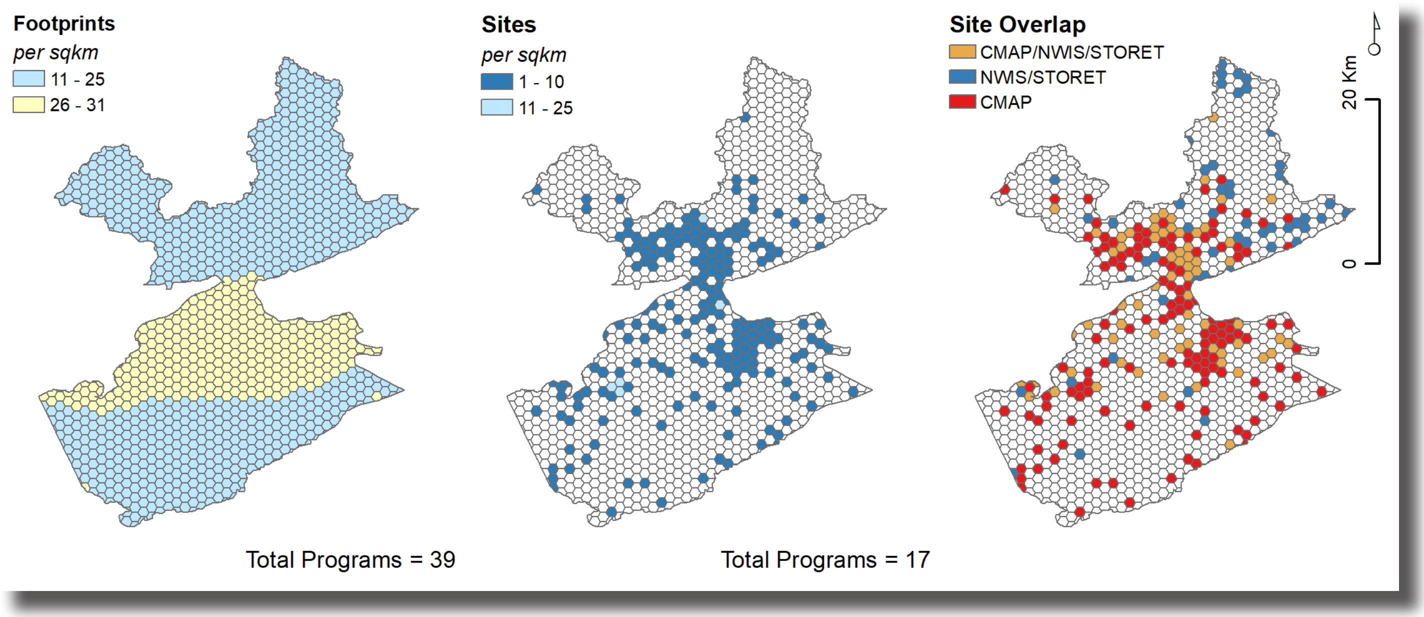
St. Louis Bay

All intersecting programs monitored conductance



St. Louis Bay

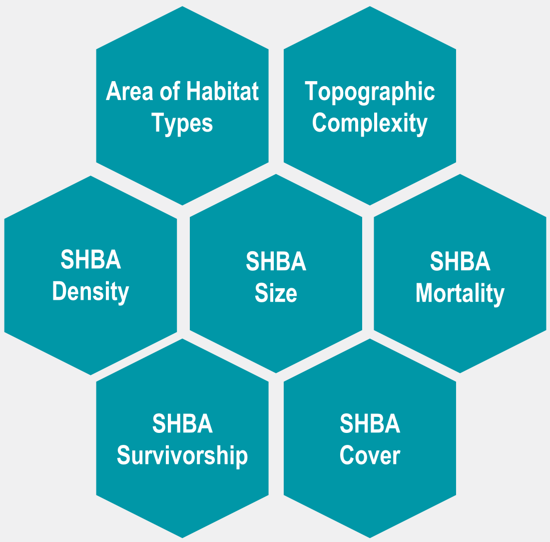
All intersecting programs monitored water temperature



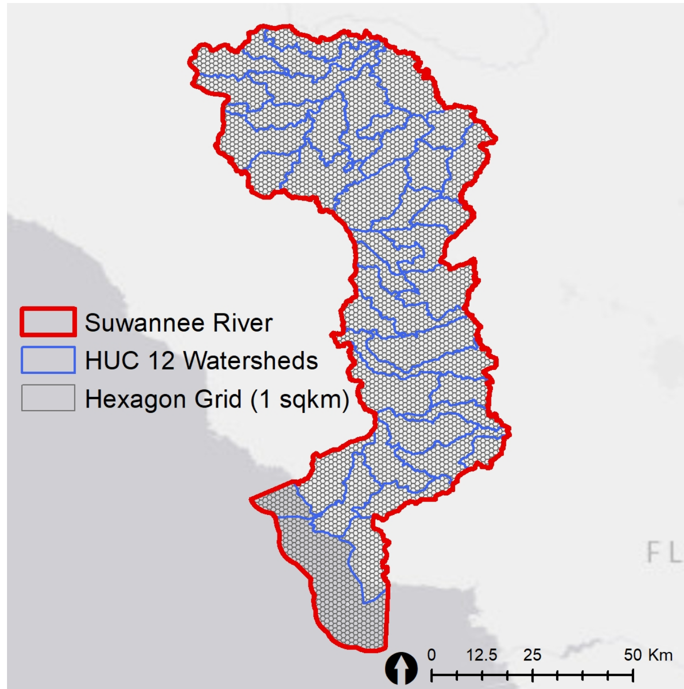
SUWANNEE RIVER

What is the availability of core parameters used to evaluate oyster restoration in the Suwannee Watershed?

PARAMETERS OF INTEREST (POI)



SHBA (Submerged Habitat Building Animals)



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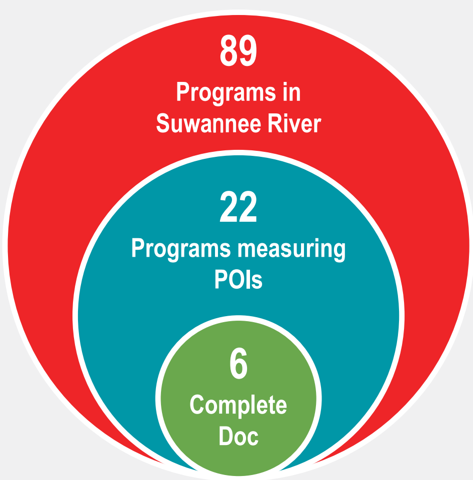
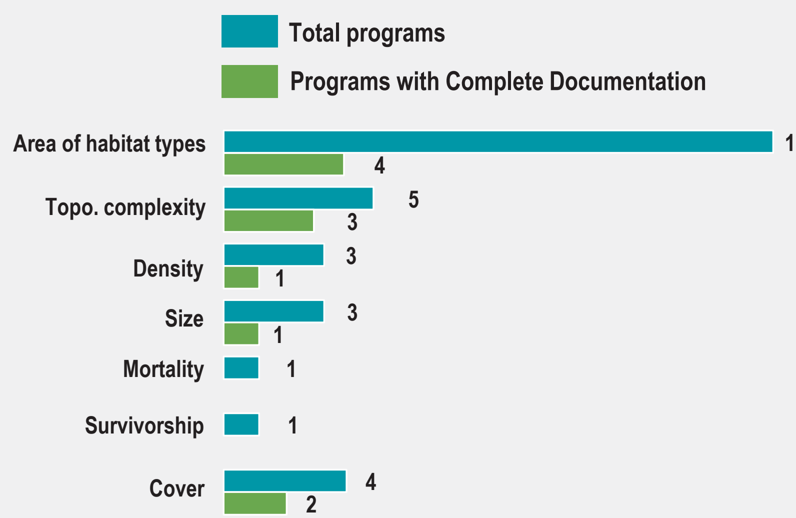
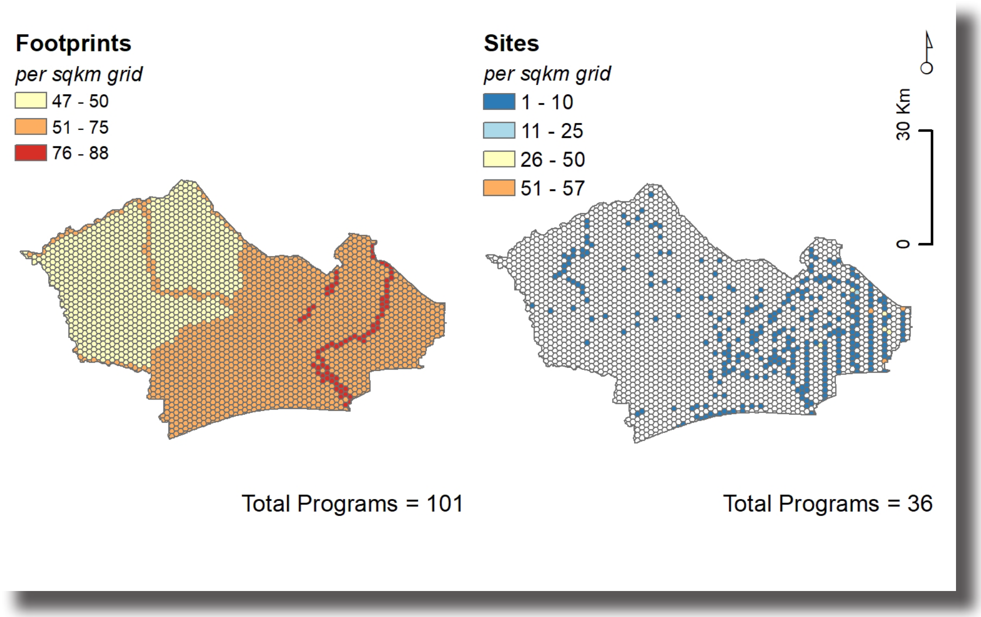




RESTORE Council Monitoring and Assessment Program (CMAP)

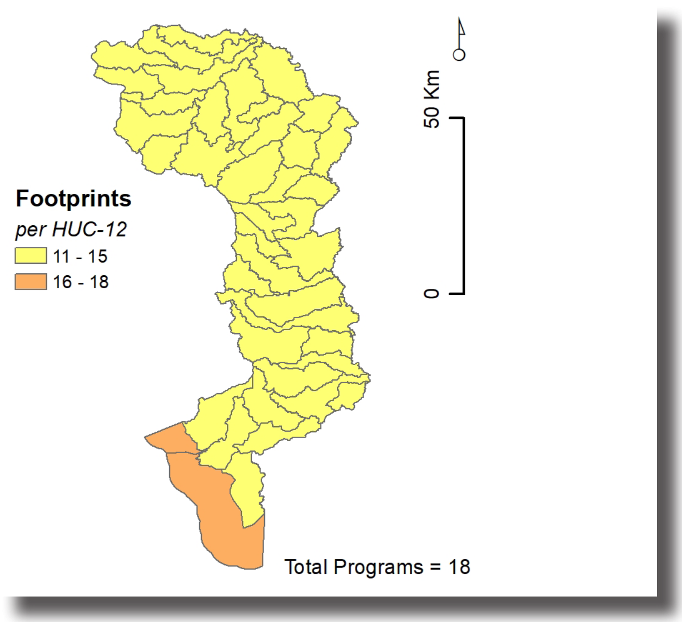
Suwannee River

All intersecting programs per HUC-12 watershed



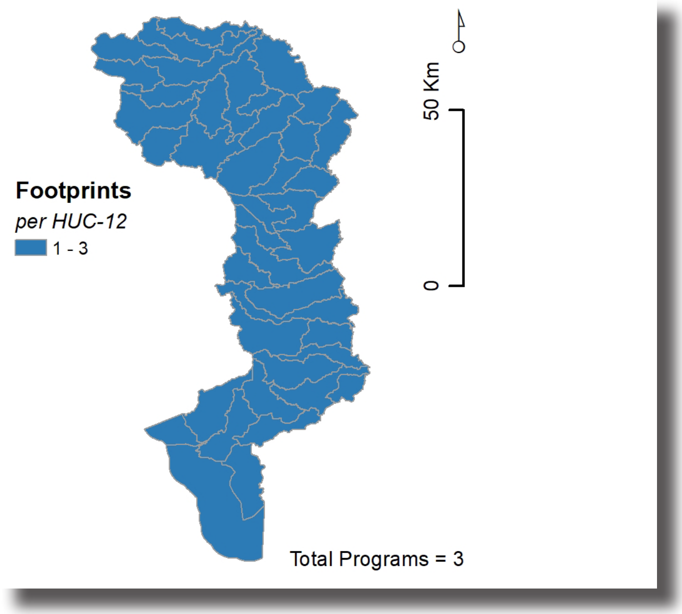
Suwannee River

All intersecting programs that mapped area of habitat types



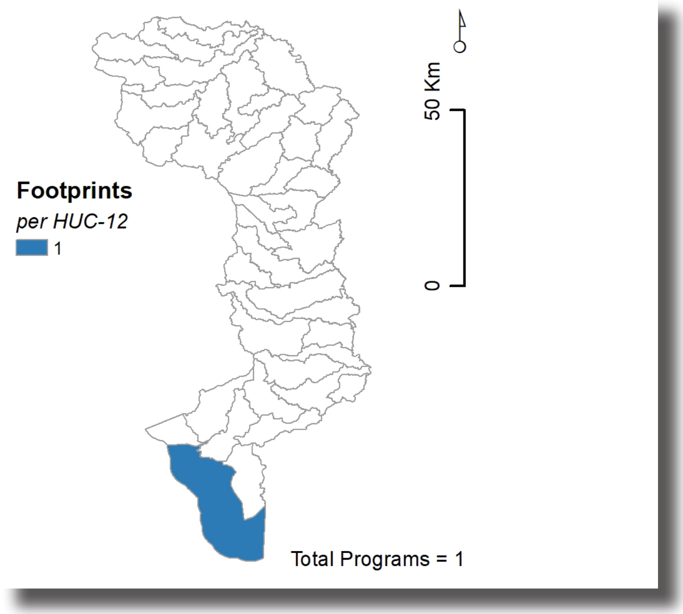
Suwannee River

All intersecting programs that monitored submerged habitat-building animal (SHBA) size



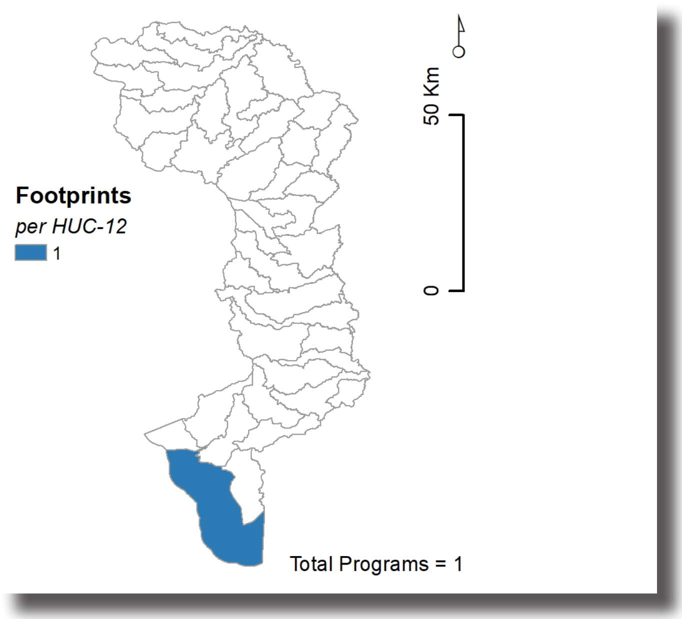
Suwannee River

All intersecting programs that monitored SHBA survivorship



Suwannee River

All intersecting programs that monitored SHBA mortality



Suwannee River

All intersecting programs that monitored SHBA cover