Inventory & Evaluation of Environmental and Biological Response Data for Fish Habitat Assessment

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PRESENTED TO

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Acronyms/Abbreviations	Definition
CBF	Chesapeake Bay Foundation
CBL	Chesapeake Biological Laboratory
CBP	Chesapeake Bay Program
DNREC	Department of Natural Resources & Environmental Conservation (Delaware)
DOEE	Department of Energy & Environment (District of Columbia)
DO	Dissolved Oxygen
FHEP	Fisheries Habitat and Ecosystem Program
ICPRB	Interstate Commission for the Potomac River Basin
MD DNR	Maryland Department of Natural Resources
NEFSC	Northeast Fisheries Science Center
NFHP	National Fish Habitat Partnership
NOAA	National Oceanographic and Atmospheric Administration
ODU	Old Dominion University
ORP	Oyster Recovery Partnership
PEARL	Patuxent Environmental & Aquatic Research Laboratory
STAC	Scientific and Technical Advisory Committee
SERC	Smithsonian Environmental Research Center
SAV	Submerged Aquatic Vegetation
UMCES	University of Maryland Center for Environmental Sciences
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
VECOS	Virginia Estuarine and Coastal Observing System
VIMS	Virginia Institute of Marine Science
VOSARA	Virginia Oyster Stock Assessment and Replenishment Archive

EXECUTIVE SUMMARY

The 2014 Chesapeake Bay Watershed Agreement identified a broad series of goals that, when implemented, would further the restoration and protection of the Chesapeake Bay watershed and its resources. One of the themes, Abundant Life, addressed the threats of over-exploitation of species, fragmentation and loss of habitat, and the loss of a balanced ecosystem. To address these challenges, the Agreement developed outcomes that were directly aimed at several species or groups of species, including blue crabs, oysters, Eastern Brook Trout, and Forage Fish. A related outcome that addressed multiple fish and shellfish species was to further assess habitat within the Bay watershed. Specifically, the Agreement stated: “Identifying and improving our understanding about important fish habitat will help target our conservation and restoration efforts.” To this end, the Sustainable Fisheries and Vital Habitat Goal Implementation Teams held a workshop in 2018 to identify factors influencing habitat function throughout the Chesapeake Bay Watershed. Prior to the workshop a team of USGS and NOAA scientists compiled and inventoried relevant fish habitat stressor metadata for participants to consider. A recommendation from the workshop was to conduct a data mining exercise to fill data gaps in the inventory. USGS continued to inventory datasets from nontidal waters, and Tetra Tech began to inventory and acquire relevant biological fish habitat data from tidal waters in 2019.

Key findings from the tidal fish habitat inventory:

- Datasets identified and described with metadata records: 108
- Data collection spans over 50 years, with the majority collected in the past 15 years
- Number of datasets acquired: 51
- Number of agencies with identified datasets: 30
- Data types identified: Fin-fish (72 datasets), water quality (43), oyster (13), habitat (8), crab (7) and others (SAV, wetland, benthic, shoreline)

From the review of data and metadata, several recommendations emerged:

1. **Scale**: A single Bay-wide fish habitat assessment, as such, is challenging, but attainable, given the enormous diversity in populations and variability in habitat, which is reflected in the available data. It is preferable, and more useful, to conduct habitat assessments at reduced scales which are quantitatively more defensible, while also being relevant at local (segment to tributary level) hierarchies.
2. **Pilot effort**: With the recommendation of scale in mind, the next step should be a pilot fish habitat assessment for a sub-estuary within the Bay. Here, we suggest using the Choptank River (MD) as there is a wealth of data already available for the river and previous work has laid the groundwork for a full assessment.
3. **Quantitative approach**: There are several quantitative options to consider using for a fish habitat assessment. Considering the success of other regional assessments, two modeling approaches can be considered, given the highly variable data structure. Both hierarchical models and General Additive Models (GAMs) would be the appropriate tools to apply to the existing data. There are also opportunities to design surveys to confirm the predictive models.
4. **Collaboration**: Thirty different organizations were identified as data owners. This suggests a wealth of institutional knowledge on fish population trends, habitat trends and stressors, and knowledge of local conditions that might otherwise be missed. We recommend inclusion of expert institutions and individuals most familiar with data to provide recommendations to the framework and datasets incorporated in a fish habitat

assessment in order to incorporate the best science required to develop and refine the analyses

1.0 INTRODUCTION

Coastal zones and estuaries are particularly vulnerable ecosystems due to high population levels on the coasts and increased pollution loads into the systems (Boesch et al. 2001). As a result, habitat degradation is a frequent consequence of large population centers, and subsequently a potential loss of fish productivity. In the context of a changing climate, through sea level rise and warming, habitats are stressed even further (Parmesan and Yohe 2003; Walther et al. 2002). Decreases in fish productivity can be measured in a variety of ways including biodiversity, spawning stock biomass, or relative abundances (Bloomfield and Gillanders 2005; Duffy 2006). When considering the ecological integrity of fish populations, all three metrics are important attributes of the health of the coastal habitats.

In 2015, the National Fish Habitat Partnership (NFHP) produced the first national assessment of estuarine fish habitat. The purpose was to evaluate the cumulative disturbance index which represents the risk of current habitat degradation to estuaries in the contiguous U.S. and is a fairly conservative estimate of the anthropogenic disturbances affecting those estuaries (Crawford et al. 2016). Understanding how human activities are impacting fish habitat is important so resource managers can better manage these impacts and ultimately sustain estuaries and the fish populations that they support. Identifying estuaries with the best and worst relative condition, as well as the key impacts, will help to prioritize conservation and restoration efforts.

Estuarine habitats vary according to latitude and local geography but are generally defined as structural or water quality-related. Structural components (including reefs, seagrass beds, mangroves, etc.) offer refugia for both juvenile fish (of species who, as adults, are open-water dwellers) and forage species that spend the large part of their life within these habitats (Schaffler et al. 2013). Non-structural components (e.g. bottom type, water quality, etc.) are also important for supporting foraging or fitness for many species. The structure provides substrate for prey (hydroids, amphipods, etc.) and are therefore critical for sustained growth. Likewise, structure provides refugia from predation and larger piscivores are constrained from effective hunting due to visual obscurity or inability to reach into small areas. Water quality (dissolved oxygen concentration, temperature, salinity) is also considered habitat since fish require suitable levels for survival, growth, and reproduction. Species evolve life histories to thrive in particular environments. For example, in Chesapeake Bay, salinity is often the primary driving factor that affects fish distribution (Bulger et al. 1993; Wagner and Austin 1999). In this context, droughts or changes in precipitation (e.g., that might arise from climate change) may change the available habitat for a variety of species in the estuary. Similarly, with the increased frequency of hypoxic conditions in the coastal zones globally, including the Chesapeake Bay (Hagy et al. 2004), many studies have documented a shift in species or in assemblages (Brady and Targett 2013; Breitburg 2002; Buchheister et al. 2013; Campbell and Rice 2014). Campbell and Rice (2014) define the amount of available fish habitat for Atlantic Menhaden given the estimated volume of hypoxic water in the Neuse River. The implications are staggering considering the amount of water volume that becomes unavailable to most fish and; therefore, the fish are “squeezed” into sub-optimal habitats that may lead to vulnerability, predation or reduced fitness (Broszeit et al. 2013). These abiotic factors can influence the role of structural habitats as has been documented in the Chesapeake Bay (Schaffler et al. 2013).

Coastal habitats have been in decline worldwide for the past 200 years (Fisher et al. 2006; Pihl et al. 2006) and it has become evident that regional fish habitat assessments are an important tool to better understand the extent of important habitat to a variety of fish species and assemblages. Furthermore, habitat assessment tools are very useful for communicating the importance of protecting, conserving, and restoring aquatic habitat.

In this respect, a fish habitat assessment for the Chesapeake will provide synergistic strategies to meet habitat goals such as submerged aquatic vegetation (SAV) restoration goals and oyster restoration goals. The 2014 Chesapeake Bay Watershed Agreement established goals and outcomes for the restoration of the Bay and its tributaries (Figure 1-1), including the development of tools to protect and conserve fish habitat. Developing a fish habitat assessment is a very useful tool to meet this outcome. Co-benefits of such an assessment include progress on other outcomes, including forage fish, blue crab, and oysters. Additionally, SAV goals (through conservation and restoration) can benefit from an assessment.

In 2018, the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) funded a workshop to develop a Fish Habitat Assessment Framework for the Chesapeake Bay watershed (Hunt et al. 2018) to identify the condition and primary stressors to fish habitat. The first step to such an effort requires identifying sufficient data to make an assessment achievable and technically defensible. The Chesapeake Bay estuary and associated tributaries benefit from many survey programs that track fish populations and habitat characteristics, both for managed species and entire assemblages. State and federal resource management agencies lead many of these programs while others are conducted by several university research programs and other non-regulatory groups (e.g. Smithsonian Environmental Research Center). The Chesapeake Bay Program (CBP), via the Chesapeake Bay Trust, solicited applications to provide technical support for the Sustainable Fisheries Goal Implementation Team (GIT) to evaluate and inventory available fish and fish habitat data for the tidal Chesapeake Bay. This report presents Tetra Tech's effort at identifying the numerous datasets for the tidal Chesapeake Bay, including biological data and habitat data.

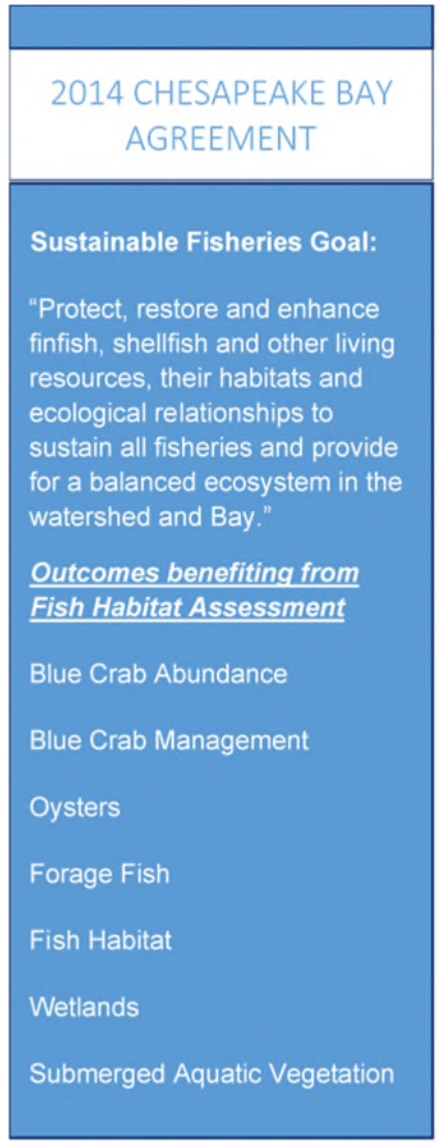

Figure 1-1: Goals and outcomes of the 2014 Chesapeake Bay Watershed Agreement

The goals of this inventory are to assess the availability of useful data to conduct a meaningful fish habitat assessment for the Chesapeake, in addition to summarizing data availability and utility. To the extent practical, we have applied quality control protocols to the data, focusing primarily on nomenclature and spatial integrity. In addition to acquiring datasets, we also compiled, particularly if the raw data was not available, a concise description of each sampling program, which was gathered into a metadata summary. Such an inventory, even when raw data is unavailable, is invaluable when approaching the ambitious task of conducting a fish habitat assessment for the Chesapeake region.

Tetra Tech was awarded the contract in May 2019 and coordinated with the NOAA project lead to set up a kick-off meeting with the project's interagency advisory team, which included representatives of NOAA's Chesapeake Bay Office and Cooperative Oxford Laboratory (COL), Maryland Department of Natural Resources, and the USGS Leetown Science Center The kick-off meeting served to define roles and expectations, begin to identify regional agencies and organizations holding relevant data, and set up lines of communication. Subsequent to the kick-off meeting, the Tetra Tech project team instigated weekly conference calls with the NOAA project lead (A.K. Leight, NOAA National Centers for Coastal Ocean Science, COL) to maintain regular contact and discuss sources of data and potential contacts. This proved a valuable tool as numerous datasets were identified that were not previously known to either partner.

Tetra Tech's team comprised two co-Principal Investigators (B. Murphy & N. Roth), with technical support from E. Leppo (database management/QC) and A. Walls (data review, graphics). The team (Figure 1-2) met regularly throughout the project duration to review the status of data acquisition, identifying potentially useful datasets and the data-holder contact information, as well as tracking metadata summaries and data quality. These internal meetings frequently mirrored conversations with the NOAA project lead. Quarterly updates were provided at in-person meetings whereby Tetra Tech updated the advisory team on data identification and acquisition, and the advisory team provided feedback and potential leads on additional data. Furthermore, these discussions provided opportunities to solve problems (e.g., address data provider questions and concerns, develop unique approaches to obtaining certain datasets) and discuss potential approaches to the fish habitat assessment.

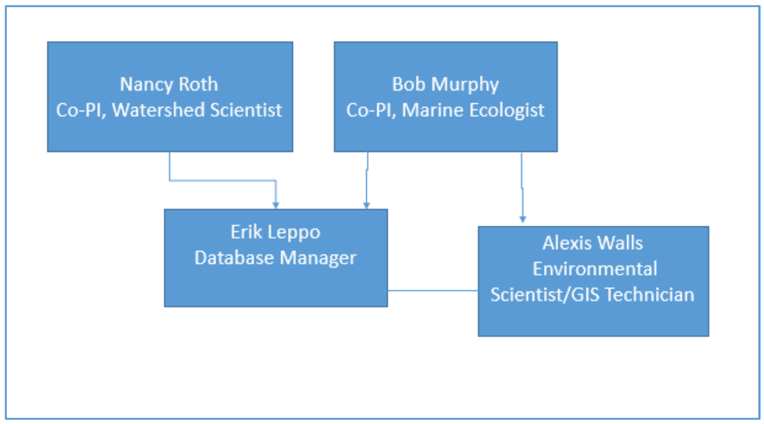

Figure 1-2: Tetra Tech team organization flow chart

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement CB96341401 to the Chesapeake Bay Trust. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

2.0 DATA COLLECTION

Several approaches were employed to identify datasets and other information about surveys conducted in Chesapeake Bay tidal waters that would be relevant to the fish habitat assessment. An initial source of information was the Microsoft Excel workbook of potential data sources from the April 2018 STAC Fish Habitat workshop (Hunt et al. 2018) which identified numerous potential surveys to review and organizations to contact. In addition, discussions were held with NOAA project lead and with the project advisory team to identify key surveys conducted within each of the tidal jurisdictions of the Bay watershed: Virginia, Maryland, Delaware, and the District of Columbia. Project staff worked with NOAA staff and the project advisory team to identify datasets to be acquired, to clarify data requests, and to facilitate data transfer. Coordination with the USGS Leetown Science Center staff involved in the non-tidal fish habitat data inventory, being conducted concurrently, was important for identifying datasets in tidal freshwater systems. The 2018 STAC workshop report (Hunt et al. 2018) and other references (Leight et al. 2015; Mangold et al. 2004; Maryland Department of Natural Resources 2018a; Maryland Department of Natural Resources 2018b) were used initially to identify a large number of datasets. Over the course of the project, additional data sources and surveys were identified through review of survey reports, web searches, personal contacts, and referrals from other data contacts. Through our investigations, we were able to identify more than 100 datasets that were deemed useful for assessing tidal fish habitat in the Chesapeake Bay region.

Contacts were made via a combination of email communications, telephone contacts, and in-person interviews. In some cases, data were available via direct download through online data repositories. Contact information for each data source was recorded, including the program name, agency/organization, contact name and position, contact information, program URL (if available), method of contact, and name of Tetra Tech team member who made contact.

Data providers were made aware of the intended use of data for the purpose of the fish habitat assessment. Those providing data were aware of this intended use, with the understanding that any other use of the data would require a potential user to get permission from the data provider directly. A standard description of the fish habitat assessment initiative and intended data use was provided with all email requests (see Appendix B).

Sources included state and federal agencies, academic researchers, and nonprofit organizations. Project staff worked with individual data providers to determine the simplest and most efficient data transfer approaches. Most often, data were able to be accessed via email or direct download; in a few cases data transfers were facilitated via FTP. In some cases, data were readily available from online sources. In these cases, data were downloaded and noted as publicly available.

Project team staff reviewed datasets received from data providers, as well as other documentation including data reports, summaries, and annual monitoring program reports, to glean metadata about additional datasets identified. Metadata associated with each dataset was cataloged, including agency/entity, survey period, locations, source contact, sampling methods, purpose, life stages collected, any restrictions on data use, sampling target, community (yes/no), gear type, and whether certain abiotic parameters were recorded (temperature, DO, oxygen saturation, conductivity, pH, depth, turbidity, salinity, tidal stage, bottom type, and SAV). To facilitate data management and summarization a combination of Excel (a spreadsheet program) and R (a statistical programming language) were used to store and then facilitate data management and summarization. Specifically, the dataset metadata was stored in Excel and an R Notebook (mix of code and text) was used to generate an HTML (web browser enabled) file. These files will be a part of the deliverable.

Reports that were reviewed to provide information about surveys included:

- Chesapeake Bay Finfish Investigations, US FWS Federal Aid Project F-61-R-13, 2016 - 2017 (Maryland Department of Natural Resources 2018a)
- Maryland Oyster Population Status Report 2017 Fall Survey (Tarnowski 2018)
- Estimating Abundance of Atlantic Menhaden in Chesapeake Bay: Comparing and Evaluating Methods and Retrospective Analysis (Secor and Houde 2014)
- A Retrospective Analysis of Spatial and Temporal Patterns of Growth and Abundance of Juvenile Anadromous Fishes in the Maryland Chesapeake Bay (Connelly and Houde 2014)
- Final Report: Part I: Estimating Abundance of Atlantic Menhaden in Chesapeake Bay: Comparing and Evaluating Methods and Retrospective Analysis, Part II: A Retrospective Analysis of Spatial and Temporal Patterns of Growth and Abundance of Juvenile Anadromous Fishes in the Maryland Chesapeake Bay (Houde et al. 2014)
- The 2012 User's Guide to Chesapeake Bay Program Biological Monitoring Data (Chesapeake Bay Program 2012)
- Habitat Requirements For Chesapeake Bay Living Resources (Chesapeake Bay Program 1987)
- The ICPRB 2013 American Shad Monitoring Survey,Task 5 Summary Report for the US Environmental Protection Agency, ICPRB Report # ICP13-11, Grant # I-98339411 (Cummins 2013)
- Potomac River American Shad Monitoring Survey, 2014 Summary Report, For the US Environmental Protection Agency, Grant # I-98339411, ICPRB Report # ICP14-7 (Cummins 2014)
- The Return of American Shad to the Potomac River: 20 Years of Restoration (Cummins 2016)
- Marine and Estuarine Finfish Ecological and Habitat Investigations, Performance Report for Federal Aid Grant F-63-R, Segment 8 (Maryland Department of Natural Resources 2018b)
- Choptank Ecological Assessment: Digital Atlas - Baseline Status Report (NOAA National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (Dorfman et al. 2016)
- National Overview and Evolution of NOAA's Estuarine Living Marine Resources (ELMR) Program (Nelson and Monaco 2000)
- 2016 Oyster Reef Monitoring Report (National Oceanic and Atmospheric Administration 2017)
- 2017 Oyster Reef Monitoring Report (National Oceanic and Atmospheric Administration 2018)
- Analysis of Monitoring Data from Harris Creek Sanctuary Oyster Reefs (National Oceanic and Atmospheric Administration 2016)
- Shad Abundance Ecosystem Health Assessment (Chesapeake Bay Program 2016)
- Chesapeake Fish Passage Prioritization: An Assessment of Dams in the Chesapeake Bay Watershed (Martin 2019)
- Inventory of Fish Species Within Dyke Marsh, Potomac River (Mangold et al. 2004)
- Comparison of fish community within the Blackwater River watershed before and after establishment of Northern Snakehead (Newhard and Love 2019)

- U.S. Fish & Wildlife Service Susquehanna River American Shad (*Alosa sapidissima)* Restoration: Potomac River Egg Collection, (Drake et al. 2017)
- 2019 Annual Report Estimating Relative Juvenile Abundance of Ecologically Important Finfish in the Virginia Portion of Chesapeake Bay (Tuckey and Fabrizio 2019)
- Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Progress Report:2018-2019 (Gallagher et al. 2019)
- Monitoring the Abundance of American Shad and River Herring in Virginia's Rivers - 2018 Annual Report (Hilton et al. 2019)
- 2018 Final Report Virginia Chesapeake Bay Finfish Ageing and Population Analysis (Liao et al. 2019)
- Virginia Wetlands Catalog: An Inventory of Wetlands and Potential Wetlands with Prioritization Summaries for Conservation and Restoration Purposes by Parcel, Subwatershed, and Wetland Boundaries (Virginia Department of Conservation and Recreation 2014)
- Final Report: Project RF 05-12 (Parthree et al. 2006)
- Baywide &Coordinated Chesapeake Fish Stock Monitoring (Bonzek et al. 2007)

In some cases, the preliminary response from data holders was to ask the project team to narrow the initial data request. In those cases, survey reports were reviewed and subsequent discussions with data holders were held to refine the request, for example limiting the dataset to certain years or data elements. For long-term surveys, if providers were unable to provide data over the entire time period, the period of data requested was narrowed to a 10-year interval, from year 2009 to the present.

3.0 METADATA INVENTORY SUMMARY

Metadata was compiled in a Microsoft Excel spreadsheet as relevant datasets were identified and recorded attributes including a contact person, contact phone/email, agency conducting the survey, survey purpose, study area, study length, sampling method, gear type, sampling target (i.e. species), target life stage and whether community data was collected. Abiotic measurements including temperature, dissolved oxygen, oxygen saturation, conductivity, pH, depth, turbidity, salinity, tidal stage, bottom substrate, and SAV were noted as either collected or not collected by a *yes/no* record in the metadata. Metadata was collected via direct agency contacts requesting information specific to the metadata spreadsheet; metadata was also found in acquired datasets, collected from survey reports (e.g. Maryland DNR, ICPRB), or gathered from reliable internet sources such as a program web page (e.g. Virginia Institute of Marine Science). A total of 108 datasets were identified (Appendix C) through communications with academic institutions, state and federal agencies, non-governmental organizations, or web-based data searches. Of the 108 datasets identified, 5 were suspected to be non-tidal or non-Chesapeake Bay surveys and, therefore, are not included in report metadata descriptions or figures below. These datasets were not actively sought out as they did not meet desired criteria but remained in the metadata spreadsheet to inform future users of their existence as they relate to target datasets. Requests for access to relevant datasets produced 51 collections in the form of spreadsheets, access to a web-based download, or interactive online applications. In this report datasets that have been successfully collected will be referred to as “acquired datasets”. “Not acquired” datasets are any dataset that was sought out, but not successfully attained. All datasets acquired or not acquired will collectively be called “identified datasets”.

Datasets by Tributary

The 103 relevant identified datasets were from 33 Chesapeake Bay tributaries throughout Maryland, Virginia, Delaware and Washington, D.C and the bay mainstem. Figure 3-1, below, lists the tributaries and how many surveys were conducted in each. In creating Figure 3-1, each tributary sampled during a survey was counted once for that survey; in other words, if a survey sampled 5 different tributaries, that survey will be represented 5 times, thus explaining the total 494 occurrences.

The number of acquired datasets from each tributary, 365 in total, is displayed first in orange, followed by those that were not acquired displayed in yellow. Sub-tributaries have been counted under larger Chesapeake Bay tributaries for simplicity. If data was collected only in the sub-tributary it will be represented by the larger system in figures and reporting. Table 3-1, below, lists major tributaries in bold font and sub-tributaries indented on the lines below. Datasets are described as not acquired because of a lack of response to data requests or if it was deemed proprietary information by the agency representative. Some unusual tributary names are present in the chart below as a result of not acquired dataset; this occurred because without precise coordinates or a river name we were unable to determine a more precise sampling location than the information provided on program websites. Not acquired datasets from surveys described as baywide are counted as “Baywide MD & VA-lat/long unkn”, but if a state is specified then the survey will be categorized as “Baywide VA-lat/long unkn” or ”Baywide MD-lat/long unkn”. The single dataset under the tributary name “Delaware” is the result of an unavailable dataset from the Delaware Department of Natural Resources and Environmental Control (DNREC) tidal drainage survey. All other tributaries or bay mainstem sampling is assigned to its proper tributary name.

Flowing through three jurisdictions, it is no surprise that 28 out of 103 datasets identified were from surveys conducted in the Potomac River. Agencies and organizations from Maryland, Virginia, and Washington DC provided datasets that included sampling conducted in the Potomac River. Similarly, the Pocomoke/Tangier Sounds category includes surveys conducted in Maryland and Virginia due to its relative location on the state line and also since it encompasses many smaller tributaries (Table 3-1). Oyster and SAV restoration efforts and subsequent monitoring are cause for many datasets from the Choptank River which will be discussed in greater detail later in section 6. The tributaries with the fewest datasets identified are those that fall under the unusual classifications discussed in the previous paragraph. This is because their specific survey locations are unknown and would likely fall under one of the named tributaries.

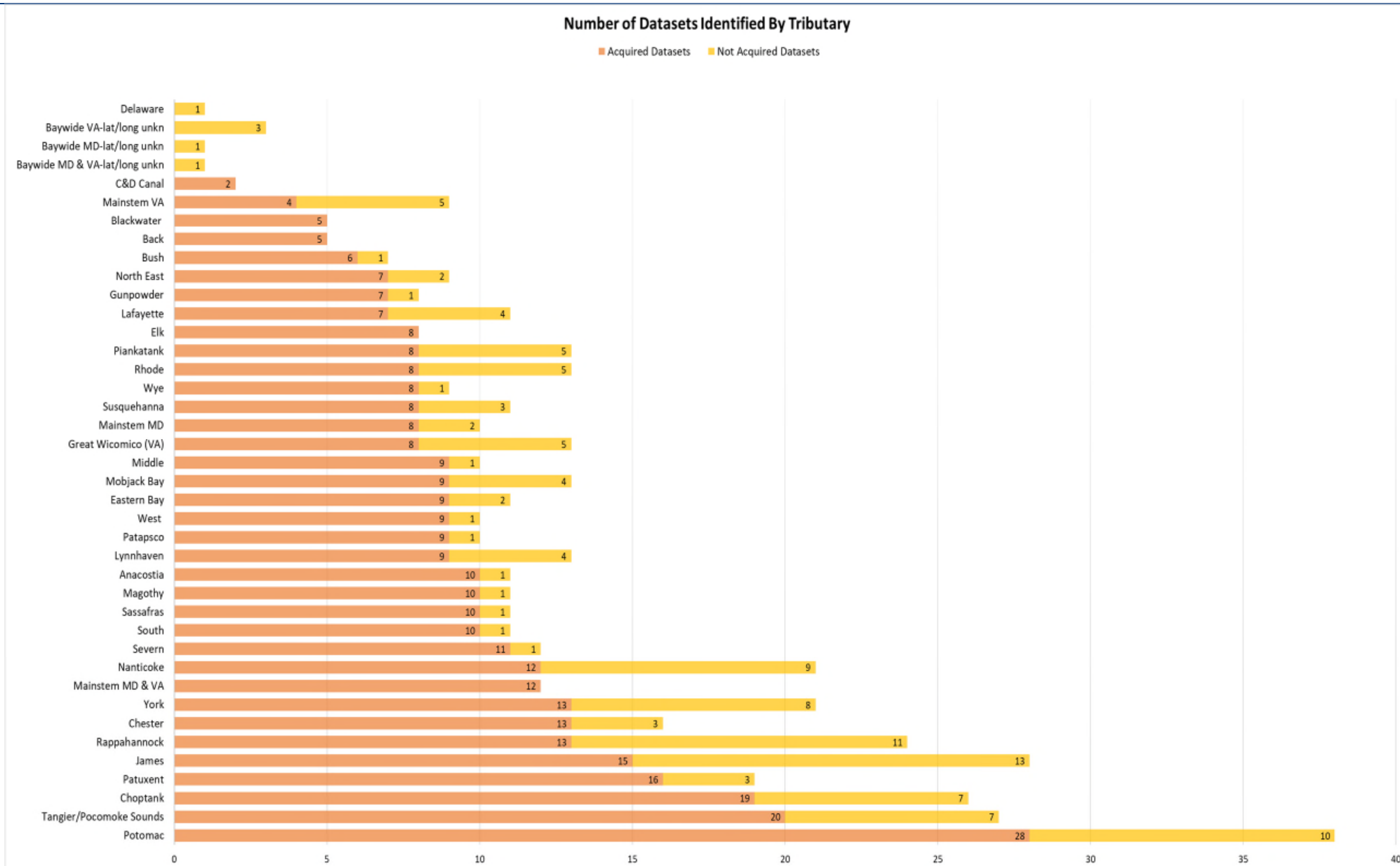

Figure 3-1: Distribution of identified datasets by tributary. Acquired datasets in orange and not acquired datasets in yellow.

Table 3-1: Sub-tributaries represented in datasets were grouped by major Chesapeake Bay tributaries. Major tributaries are listed in bold font and sub-tributaries are below, indented, and not bold.

MARYLAND	Manokin River
Back River	Big Annamessex River
Blackwater River	Pocomoke River
Little Blackwater River	Monie Bay
Bush River	**West River**
C&D Canal	Smith Creek
Chester River	**Wye River**
Corsica River	**DELAWARE**
Choptank River	**Nanticoke**
Little Choptank River	Broad Creek
Harris Creek	Marshyhope Creek
Broad Creek	Deep Creek
Tred Avon River	**VIRGINIA**
Tuckahoe Creek	**Great Wicomico River**
Eastern Bay	**James River**
Miles River	Chickahominy River
Elk River	Appomattox River
Bohemia	Elizabeth River
Gunpowder River	**Lafayette River**
Magothy River	**Lynnhaven River**
Middle River	Lynnhaven Bay
Nanticoke River	**Mobjack Bay**
Fishing Bay	Ware River
Transquaking River	**Piankatank River**
Wicomico	**Potomac River**
North East River	Aqua Creek
Patapsco River	Chopawamsic Creek
Patuxent River	Dogue Creek
King's Reach	Gunston Cove
Helen's Creek	Neabsco Creek
Potomac River	Occoquan Bay
Breton Bay	Potomac Creek
Mattawoman	**Rappahannock River**
Nanjemoy	Corrotoman River
Piscataway Creek	**Tangier/Pocomoke Sound**
St. Clement's Bay	**York River**
St. Mary's River	Pamunkey River
Wicomico	Mattaponi River
Rhode River	**WASHINGTON D.C.**
Sassafras River	**Anacostia**
Severn River	Washington Channel
South River	**Potomac**
Susquehanna River	
Tangier/Pocomoke Sounds	

Datasets by State

Tidal Chesapeake Bay surveys were conducted in Maryland, Virginia, Washington, D.C., and Delaware. The number of surveys and corresponding datasets that were conducted in each jurisdiction is presented in Figure 3-2. The category "multiple states" is a product of surveys conducted throughout the Chesapeake Bay, not bound to any particular jurisdiction. Though several state agencies do cross boundaries for cooperative monitoring programs, the primary source for surveys conducted in multiple states were non-profits, universities, and federal agencies. More datasets reported surveys conducted in Maryland and Virginia than any other jurisdiction, likely a result of their adjacency to the mainstem of Chesapeake Bay. Though tidal waters reach Washington DC and Delaware, opportunities for tidal Chesapeake Bay sampling are minimal compared to available areas in Maryland and Virginia. Washington D.C. Fisheries datasets were provided by a single individual which is why nearly all datasets from that jurisdiction were able to be obtained; unlike Maryland, Delaware, and Virginia where multiple individuals were contacted for various datasets decreasing the probability of obtaining a desired dataset due to unreturned correspondence and varying levels of staff availability or willingness to provide datasets. A result of the "multiple states" category, each of the 103 datasets is only represented in this chart once.

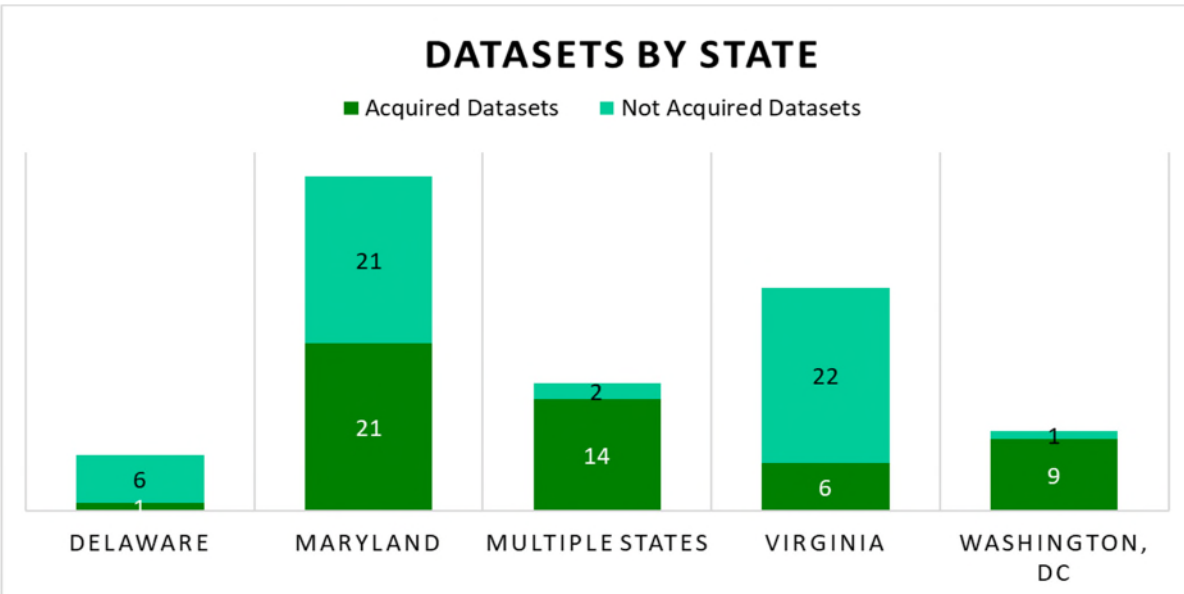

Figure 3-2: Acquired and not acquired datasets grouped by the jurisdiction in which the survey was conducted

Datasets by Agency

Figure 3-3 displays the 30 individual agencies represented in the identified datasets. These include universities and university-affiliated research centers, state, district, and federal agencies, regional partnerships, and a non-profit organization. Many of the agencies listed with only one identified dataset are cooperative programs between several organizations, while others may not typically focus on tidal Chesapeake Bay surveys. Maryland DNR, VIMS, and Washington D.C. Fisheries were found to have 23 acquired datasets between them, almost half of the 51 acquired datasets. Maryland DNR and Washington D.C. Fisheries are responsible for monitoring Chesapeake Bay fisheries and habitat health within their jurisdictions which is accomplished by conducting valuable long-term surveys. Of the 20 non-partnered VIMS surveys that were identified 8 included 20+ years of data collection. VIMS is among the top data producers in tidal Chesapeake Bay because as a state natural resource institution, it is legally mandated to provide regular monitoring to Virginia natural resource managers in addition to academic studies. These agencies contributed the most datasets overall, but Maryland DNR and VIMS can also be recognized as having the most data not acquired, a result of variable responses from many individuals within the organizations. Attempts at contacting survey-level managers in the Delaware DNREC proved unsuccessful and thus no datasets were acquired from that agency. The potentially valuable long-term (30+ years) datasets belonging to SERC were also not acquired for proprietary reasons.

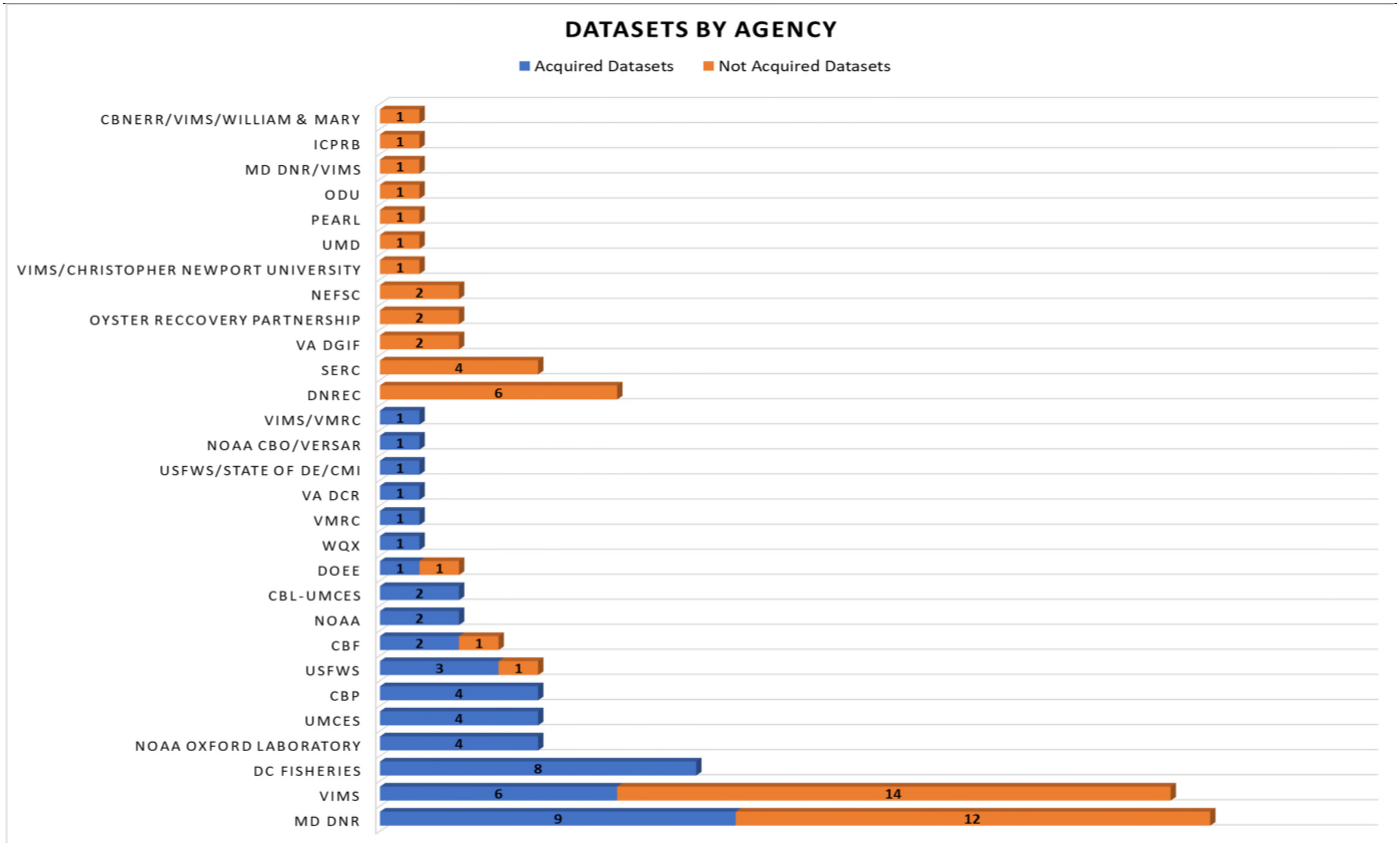

Figure 3-3: Numbers of acquired and not acquired datasets listed by the organization or partnership that conducted each survey

Datasets by Year

Metadata findings reported that survey time frames of identified datasets range from 1940-present. In Figure 3-4: Datasets arranged by years that surveys were conducted, depicting data-heavy time periods. Acquired datasets are in blue and not acquired datasets are orange. no datasets were collected for 2020 because the timing of this project did not allow time to ready datasets for sharing, so surveys that were found to be ongoing are counted as not acquired under the “present” category. Very few datasets were acquired from before 1984, which can be attributed to a lack of digital data storage at that time. During the collection of relevant datasets, many agency contacts asked that the data request be narrowed to a subset of years due to the difficulties in sharing especially large datasets which also hampered the accumulation of earlier datasets. When asked to specify a preferred subset of available data to receive, 2009-present (approximately a 10-year window) was requested. If data subsets were acquired, years of data before and after the acquired subset were counted as not acquired in Figure 3-4. The earliest data acquired, from 1971, 1974, and 1978-1981, was from the VIMS SAV web-based interactive application. Web-based applications allow for many years of data to be shared, but since they are publicly accessed, certain parameters such as site coordinates may not be available. Other web-based data identified was from the Virginia Oyster Stock Assessment and Replenishment Archive (VOSARA) database which compiles VIMS/VMRC cooperative Oyster Patent Tong Survey from 2000-present and the Chesapeake Bay Program SAV Synthesis Project with data from 1984-2016, both relatively large datasets. Datasets with unknown values are those unavailable datasets whose origin date or entire sampling duration could not be determined through researching metadata sources. MD, VA, DE, and DC Wetland Inventories start/end dates could not be identified from the metadata associated with the web-based download and since there was only the most recent edition available for download rather than a series of years, these datasets were only counted once each for 2019.

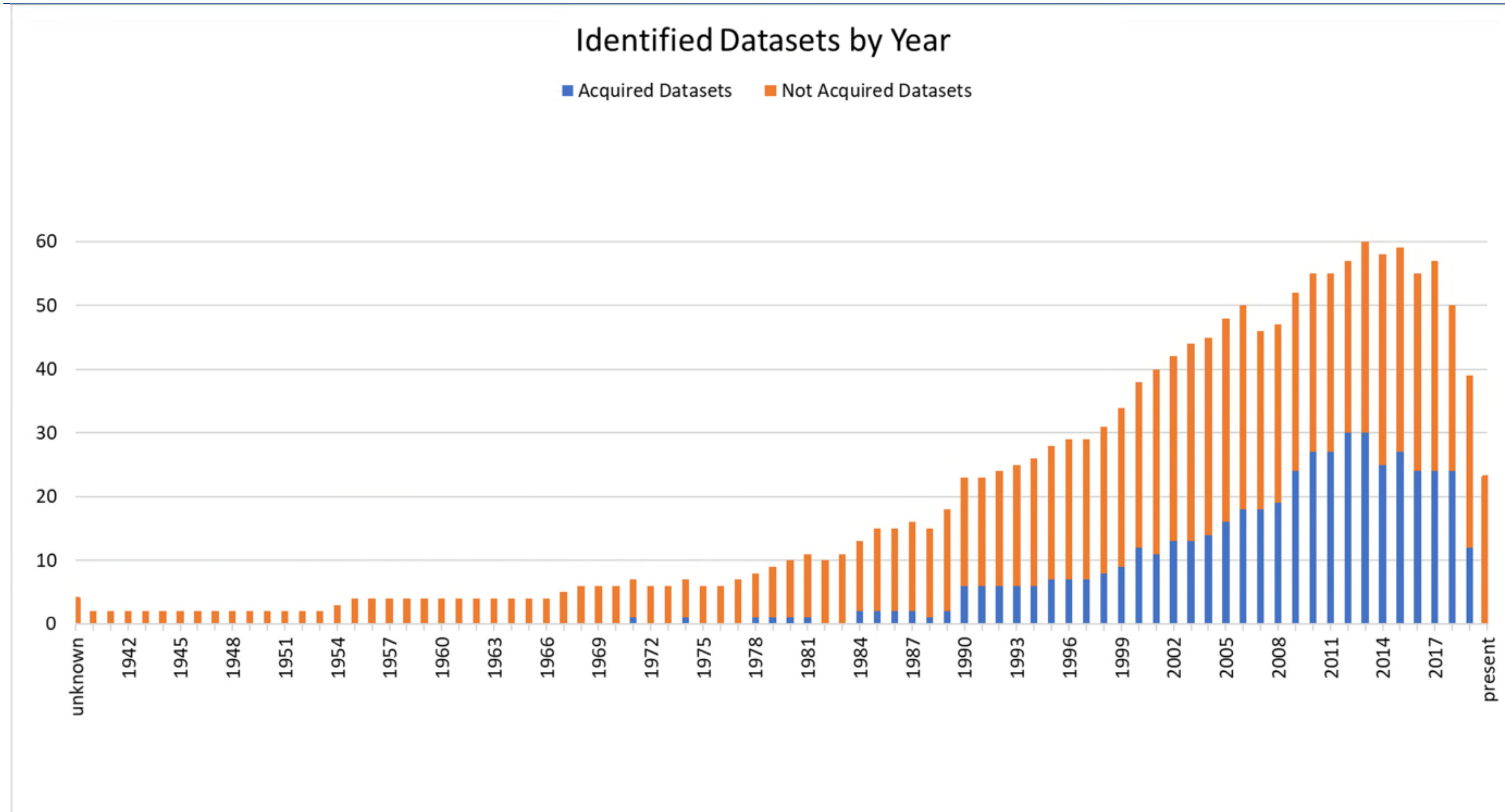

Figure 3-4: Datasets arranged by years that surveys were conducted, depicting data-heavy time periods. Acquired datasets are in blue and not acquired datasets are orange.

Datasets by Data Type

Types of data collected during identified surveys can be seen in Figure 3-5 and include benthic, crab, fish, habitat, oyster, SAV, shoreline, water quality, and wetland. Based on project criteria, fish and water quality were by far the two most robust categories of data collected. Multiple data types may be collected during a single survey, in which case the survey was assigned to two (or more) data types resulting in 163 data type values. This occurred often when water quality measurements were taken during a fish or oyster targeted survey, for example. It's important to note that a point, or several points, are given for each survey, but this does not represent the quantity of data we have for each category, rather the number of datasets per that data type. This is most apparent in the shoreline category, where the VIMS Shoreline Inventories for Maryland and Virginia are only two datasets, but they provide many years of data that include a great amount of land area.

Review of the datasets identified, time periods, and types of data collected can provide information about the degree of matching between different data types such as biological, water quality, and habitat. For example, of the 73 datasets containing fish data, 33 datasets include water quality data and 5 included habitat data collected in conjunction with the fish data, thus providing information that matches in time and location. A full list of the identified datasets with temporal coverage and data types collected is found in Appendix C.

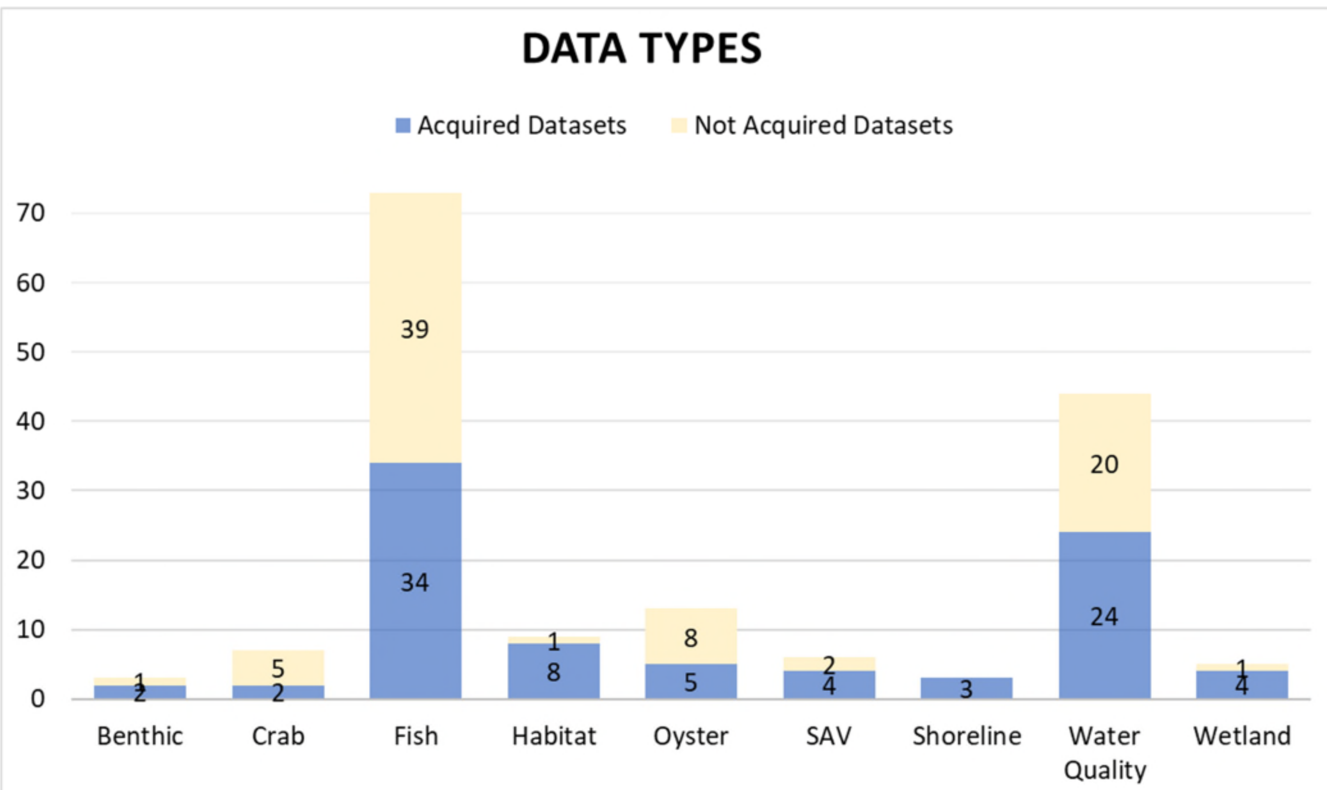

Figure 3-5: Number of datasets by data type, showing types of data collected by identified surveys. Many surveys collected more than one type of data while sampling.

Datasets by Gear Type

Many datasets reported the use of multiple gear types in their surveys. The addition of this category to Figure 3-6 allows each dataset to only be counted once, reporting 103 gear type values. The use of multiple gear types is needed to sample different habitats, adult vs. juvenile life stages, or for reaching difficult locations. For example, electrofishing surveys may utilize shocking boats, barges, or backpacks in order to reach especially shallow or deep areas effectively. When conducting a community population survey, it is necessary to reach shoreline and deep-water habitats by deploying fyke nets or a seine and a trawl. If a sampling team is recording abiotic and biotic information in the same trip their dataset will show that they used separate gear types for collecting sediment samples and collecting oyster data. Table 3-2 lists additional gear types not represented in Figure 3-6 because they were used during surveys that fell under the category of multiple gear types. Project specifications targeting fish data lead to the majority gear types being trawl and seine as they are commonly used for surveying fish communities. The six surveys categorized as unknown are related to datasets not acquired and whose gear type is not mentioned in the source where the dataset was identified.

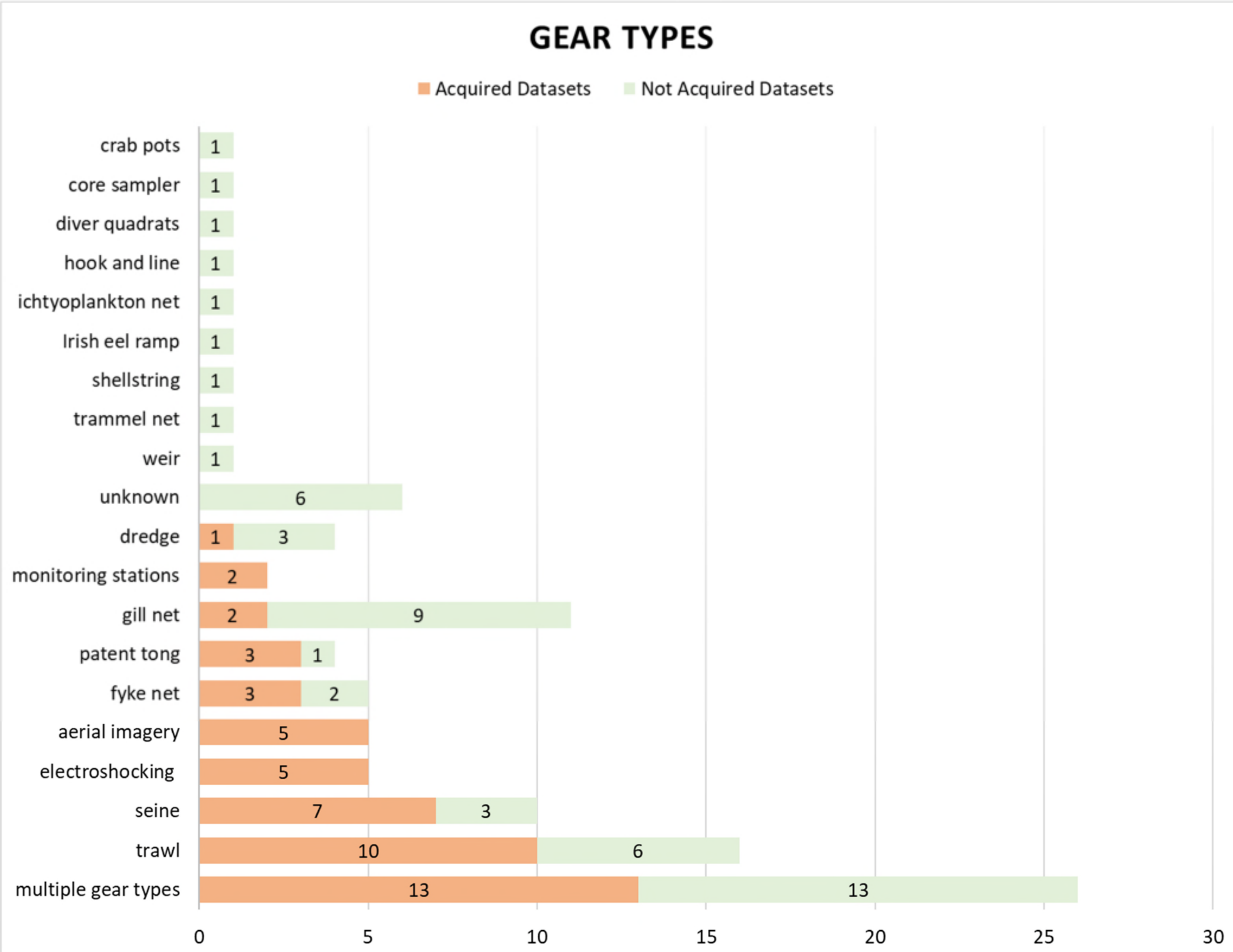

Figure 3-6: Number of datasets by gear type, showing types of gear used during data collection. The "multiple gear types" category indicates that more than one type of gear was utilized during an individual survey.

Table 3-2: Additional gear types that fall under the category of "multiple gear types" and are not listed in the gear types chart (Figure 3-6)

bank trap	dredge	minnow traps	secchi disk
cast net	eel pot	multibeam bathymetry	sediment hand grabs
clover traps	GIS	oyster hand dredge	sediment ponar grabs
color comparator kit	GPS	pound nets	side scan sonar backscatter
colorimeter	hand net	push net	surface water-peristaltic pump
crab pot	hatchery (egg collection & culture)	remote sensing technology	visual observation
crab scrape	kick net	ROV imagery	YSI 2030

Data Utility

To determine the priority level of obtaining identified datasets, a ranking strategy was established. The Tetra Tech team assigned scores to datasets ranging from 1-5 in the categories of desirability, availability, usability, and utility. Each of these categories can be defined by a question:

- desirability: how vast is the spatial and temporal data?
- availability: how easy was the data to obtain?
- usability: how usable is the data in the received format?
- utility: how relevant is the data content to the project?

In all categories a score of 5 is the most desirable from a collection standpoint, though it should be noted that within the categories each score corresponds to a unique description. Alternatively, a score of 1 is the least desirable from a collection standpoint. A score of NA (no data or not applicable) was given to a dataset if a category score could be determined without having the dataset in hand or metadata research did not return enough information about the dataset to designate a score. Scoring and score descriptions can be found in Appendix D.

Alluvial plots are designed to show categorical data that is grouped so each row can be traced across categories (columns). Below in Figure 3-7 is an alluvial plot summarizing the attributes all datasets. Each column shows the ratings that a dataset received for each attribute category (1 to 5 and NA for no data or not applicable). Above each column is a histogram showing the distribution of datasets by the column category. The rows represent the various datasets. The rows are color coded by the first column. Tracing a dataset from left to right through the columns shows the attributes of each dataset. For example, datasets with a low desirability (red) in the first column tended to have low availability (3rd column) and usability (4th column).

One particularly good example of a high scoring dataset was the Maryland DNR juvenile striped bass seine survey (Table 3-3). This survey scored a 5 for desirability because it samples 12 tributaries and includes over 20 years of data. Availability was not scored a 5 since it was not available via a website download, but 4 since it was easily acquired by email or phone call. The data was received in a Microsoft Excel spreadsheet and needed minimal/no modifications before being mapped in R thus receiving a score of 5 for usability. The primary target of this survey was fish, which is highly relevant, so it also scored a 5 for utility.

Table 3-3: *MD DNR juvenile striped bass seine survey as an example of the desirability, availability. usability, utility scoring*

Dataset	Desirability	Availability	Usability	Utility
MDDNR_SB_Seine	5	4	5	5

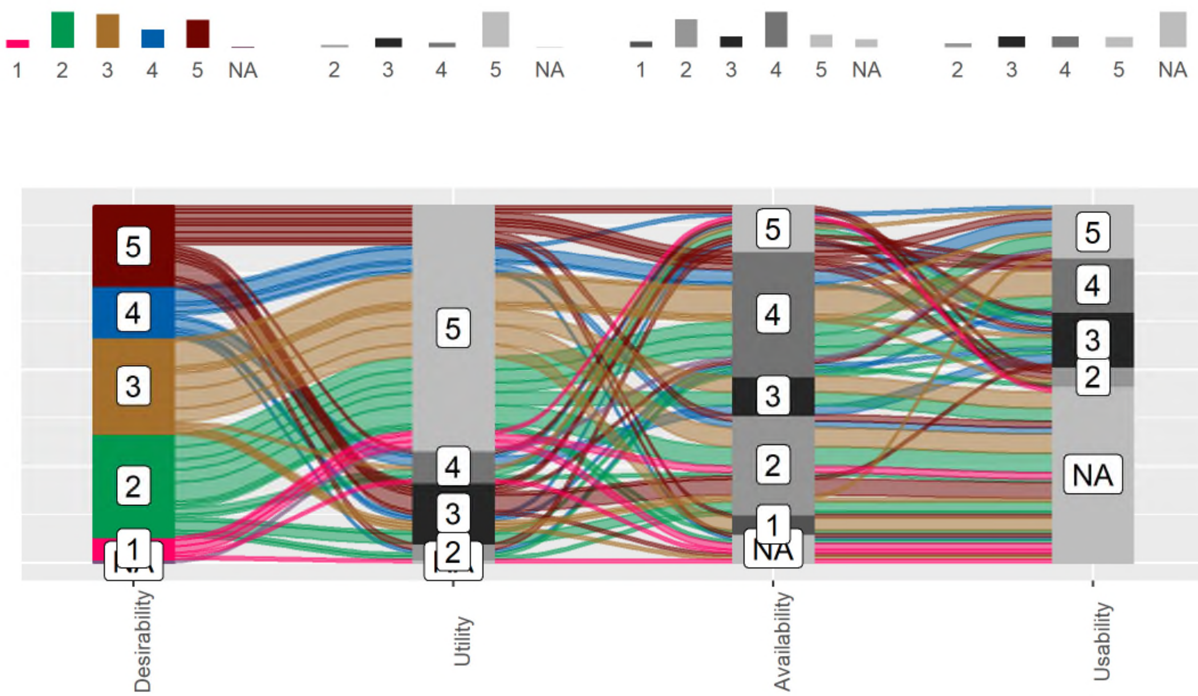

Figure 3-7: Alluvial Chart depicting dataset attributes.

4.0 DATA SUMMARIZATION

A total of 51 datasets were acquired for the fish habitat data inventory, as noted on the full list of datasets identified (Appendix C). Data were gathered from 17 agencies and organizations (Figure 3-3). In this section, we review the types of data collected by investigators, the spatial and temporal coverage provided by the datasets acquired for this inventory, and a summary of quality assurance/quality control (QA/QC) findings.

Data Types

The types of data in the datasets acquired for the tidal data inventory are summarized in Figure 3-5. Datasets including fish data were the most numerous (34), followed by water quality (24); habitat (8); oyster (5); SAV and wetland (4); shoreline (3); and benthic invertebrates and crabs (2). Some datasets included multiple types of data, for example, including both fish data and habitat parameters.

Table 4-1 describes the intended targets and types of data collected in the 34 surveys noted as having collected fish data. The columns labeled Survey Target Species show whether a survey targeted the entire community or a specific species. Of the 34 datasets, 14 targeted specific species which are named in the Single-Species column. It should be noted that the target catch of the Versar Oyster Restoration Survey was, in fact, oysters, but since bycatch was recorded this survey was counted as a survey collecting fish data. No matter the target, if all fish captured were recorded in the data then a check mark will be displayed under the Community Data Collection column, if only target species data was collected it will be blank such as for the USFWS Yellow Perch Fyke Netting. Some surveys targeted only adults or juveniles, while others targeted all life stages. Surveys like CHESFIMS, TIES, and PAXFIMS describe their target as juvenile and community fish and were therefore said to have been targeting all life stages. All surveys in the last category, Quantitative vs. Presence/Absence were listed as quantitative having collected counts of fish, except for the CBL Seine Survey which only told if a species was present or absent.

Table 4-1: Descriptions of acquired fish data

Dataset	Survey Target Species		Community Data Collection	Life-Stage Target	Quantitative vs Presence/Absence
	Multi-species	Single-species			
CBF Educational Field Trips	✓		✓	All	Quantitative
CBL Seine Cruises		Anadromous	✓	Juvenile	Quantitative
CBL Seine Survey		Bluefish	✓	All	Presence/Absence
CBL Seine vs Trawl		Menhaden	✓	Juvenile	Quantitative
CHESFIMS	✓		✓	All	Quantitative
DC Fisheries Alosine Survey		Alosines	✓	All	Quantitative
DC Fisheries Electrofishing Survey	✓		✓	All	Quantitative
DC Fisheries Largemouth Bass Survey		Largemouth Bass	✓	All	Quantitative
DC Fisheries Low Frequency Survey	✓		✓	All	Quantitative
DC Fisheries Push Net Survey	✓		✓	All	Quantitative
DC Fisheries Seining Survey	✓		✓	All	Quantitative
DC Fisheries Snakehead Survey		Snakehead	✓	All	Quantitative
DC Fisheries Striped Bass Survey		Striped Bass	✓	All	Quantitative
MD DNR Annual Winter Trawl Survey	✓		✓	All	Quantitative
MD DNR Choptank River Fyke Net Survey	✓		✓	Adult	Quantitative
MD DNR Fish Habitat and Ecosystem Program Seine	✓		✓	All	Quantitative

Table 4-1: Descriptions of acquired fish data

Dataset	Survey Target Species		Community Data Collection	Life-Stage Target	Quantitative vs Presence/Absence
	Multi-species	Single-species			
MD DNR Fish Habitat and Ecosystem Program Trawl	√		√	All	Quantitative
MD DNR Juvenile Striped Bass Seine		Striped Bass	√	Juvenile	Quantitative
MD DNR Striped Bass Spawning Stock Survey		Striped Bass	√	Adult	Quantitative
NOAA ChesMMAP	√		√	All	Quantitative
NOAA ELMR Mid Atlantic	√		√	All	Quantitative
NOAA Oxford Seine	√		√	All	Quantitative
NOAA Oxford Trawl	√		√	All	Quantitative
Oxford Tred Avon Seine Sampling	√		√	All	Quantitative
Oxford Tred Avon Trawl Sampling	√		√	All	Quantitative
PAXFIMS	√		√	All	Quantitative
TIES	√		√	All	Quantitative
USFWS Blackwater/Little Blackwater River Fyke Netting		Snakehead	√	Adult	Quantitative
USFWS Potomac Shad sampling		American Shad	√	Adult	Quantitative
USFWS Yellow Perch Fyke Netting		Yellow Perch		Adult	Quantitative
Versar Oyster Restoration Survey		Oyster	√	All	Quantitative

Table 4-1: Descriptions of acquired fish data

Dataset	Survey Target Species		Community Data Collection	Life-Stage Target	Quantitative vs Presence/Absence
	Multi-species	Single-species			
VIMS Juvenile Striped Bass Seine		Striped Bass	✓	Juvenile	Quantitative
VIMS Juvenile Fish and Blue Crab Trawl Survey	✓		✓	Juvenile	Quantitative
WQX	✓		✓	All	Quantitative

Some studies focus on characterizing temporal variation, for example the Maryland Striped Bass seining survey, which conducts repeat visits to the same sampling locations each year. Other surveys focus on spatial patterns of species distributions, and many surveys are designed to consider both with both spatial and temporal variation but are not easily classified as focusing on one or the other. For example, the long-term benthic data for the Chesapeake Bay includes a broad selection of sites chosen throughout the Bay and its tidal tributaries using a stratified random sampling approach, but also includes fixed sites for long-trends detection.

Spatial Coverage and QA Review of Spatial Information

The types of spatial coverage varied depending on the nature of the dataset. Most of the data corresponded to specific biological, water quality, and habitat parameters collected at specific sampling points, for which spatial coordinates were provided. Station locations are displayed on the map in Appendix E. In a few cases, data represented areal coverage and were provided as GIS polygons, for example, wetland mapping surveys. In other cases, data were provided as values representing summary-level information from an aggregation of individual sites. These data were provided in this manner to protect the collecting group's ability to retain data ownership.

Sample location data were reviewed for the accuracy of spatial information to assess whether locations matched the study areas described in the source data. All sample coordinates were plotted in R to visualize and confirm sampling locations.

Inconsistencies in sampling locations were resolved in cases where the correct locational information was easy to discern. Coordinates that were not in decimal degrees were converted to allow for mapping. Any stations in acquired data without coordinates or with unknown units were not included in further summaries. Further data manipulation was applied to get to the final latitude and longitude values, as follows:

- Converted latitude to positive
- Converted longitude to negative
- Only complete cases used
- Blank or null values were excluded
- Unknown units were excluded

Several datasets provided site locations that were not in a format that could be used for mapping. Two of the datasets provided only a map of sites, without coordinates. These maps were geolocated and the coordinates derived in ArcGIS. Two other datasets provided narrative locations that were plotted in ArcGIS and coordinates derived for mapping.

The datasets that were acquired represented surveys conducted within the tidal waters of Maryland (21), Virginia (6), Delaware (1), and Washington, DC (9) (Figure 3-2). Fourteen datasets included sampling conducted in multiple states.

The number of datasets, by tributary, is presented in Figure 3-1. Tributaries with the greatest number of datasets include the Potomac (28 datasets), Tangier/Pocomoke (20) and the Choptank (19).

Acquired data represent sampling locations within 76 of 78 named Bay segments; many of the segments are well-represented by numerous stations (Table 4-2 and Figure 4-1). Twenty-one segments, including the Bay mainstem and portions of large river tributaries, have more than 1000 stations apiece. The only two segments without any data are the tidal fresh portions of the Chester and Nanticoke Rivers (Bay segments CHSTF and NANTF). This summary only includes data represented by station locations (points) and does not include aggregated data, such as the VIMS trawl and seine data that had been provided by polygon areas. This is due to the provided polygon areas not mapping to the Bay segments.

Table 4-2: Segments by number of stations per Bay segment category.

Number of Stations Per Segment	Number of Bay Segments
0	2
1	4
2-10	11
11-100	30
101-1000	10
>1000	21

Out of all unique stations from acquired datasets with location information (approximately 371,046 total), there are 1,391 stations (0.37%) that do not fall on a segment. Inspection showed that in some of these cases, the location information data are imprecise (only one or two decimal points), while in other cases data are for near-shore samples (e.g., from seine surveys), non-tidal samples, or poorly recorded. The majority are near-shore seine samples and are just outside of a segment. Seine stations falling outside but within a short distance of a segment boundary could be assigned to that segment with reasonably good confidence. Datasets provided as aggregated data by polygon areas are not included in this assessment as individual site location information was not included.

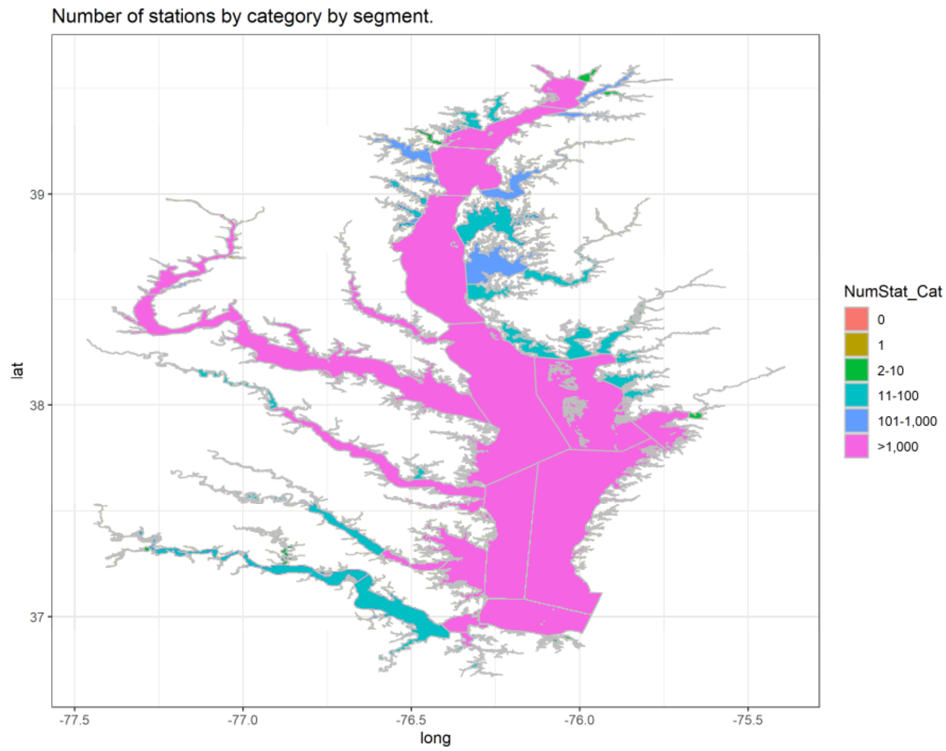

Figure 4-1: Number of stations by Bay segment

Temporal Coverage

The temporal coverage of data spans a range from 1971 to 2019. In Figure 3-4, datasets are arranged by years that surveys were conducted; acquired datasets are shown in blue. The earliest data was from the VIMS SAV survey, which at 40 years was also the longest time series of data. Note that VIMS SAV data is downloadable as spatial datasets by year. Because of large file sizes, VIMS SAV data was not actually pulled into the inventory but can be readily downloaded as needed.

Survey durations spanned 1 to 40 years (Figure 4-2). Of the longest-term surveys, nine datasets spanned 20 or more years of data collection:

- VIMS SAV
- CBP SAV
- DC Fisheries Striped Bass, Seine, and Electrofishing Surveys
- UMCES Seine
- VIMS/VMRC VOSARA
- Maryland DNR Juvenile Striped Bass Seine and Striped Bass Spawning Stock Survey

For several long-term surveys, the original data request was reduced to a shorter duration for practical reasons, both to reduce the size of the requested dataset and to restrict it to more recent years, which would be most applicable for the intended use in the fish habitat assessment. These surveys included:

- CBP Baywide Benthic Database, Baywide Fluorescence Database, and Water Quality Data
- Maryland DNR Juvenile Striped Bass Seine, Striped Bass Spawning Stock Survey, and Annual Winter Trawl Survey-Upper Bay
- NOAA ELMR Mid Atlantic
- VIMS Virginia Shoreline and Tidal Marsh Inventories

Seven datasets included just one year of data. This included statewide wetland mapping (for MD, VA, DC, and DE), which were recorded as occurring in 2019, although they represent current wetlands status and are resurveyed periodically, approximately every ten years.

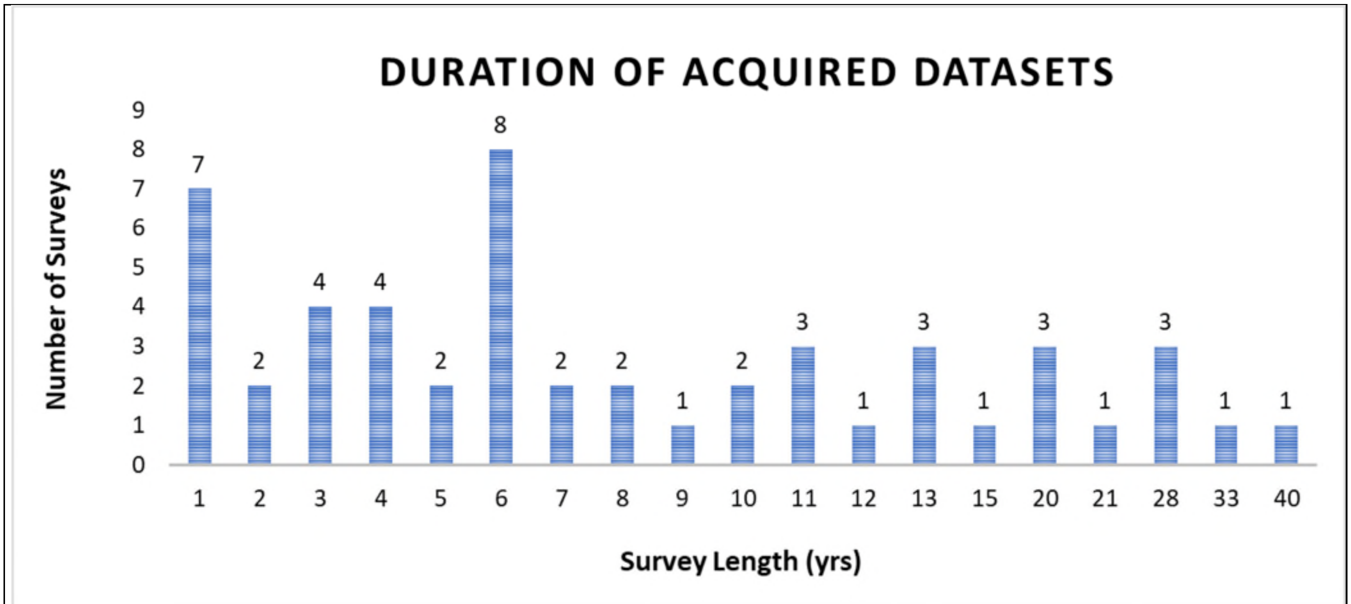

Figure 4-2: Distribution of acquired datasets by survey length (number of years).

Gear Types

Gear types for acquired datasets are summarized in Figure 3-6. Thirteen datasets include multiple gear types. Trawl and seine surveys were the next most common gear types; other gear types included electrofishing, patent tong, fyke net, gill net, and dredge, as well as surveys employing aerial imagery and monitoring stations.

QA Review of Species Names

A QA/QC review was conducted for species names and sample location data. Fish species names were reviewed for conventions employed, including the use of scientific or common name, abbreviations or codes, and consistency with American Fisheries Society standard nomenclature (Lawrence et al. 2013). Most surveys used common names for fish and were easily mapped to accepted AFS protocols. That is, the names may not have followed the capitalization rules of AFS but were easily modified. Taxa names with extra information (e.g., young of year, YOY) that could be readily resolved were rectified in the datasets. Some datasets provided only codes for the collected taxa. In these cases, the data providers were contacted and in cases were able to provide the translation to either scientific or common name.

After matching the provided names with the AFS list the type and frequency of inconsistencies in species names are summarized in Table 4-3. Inconsistencies were noted but not corrected in the acquired data.

Additional standardization of species names across different surveys and other inconsistencies should be resolved prior to data analysis. One area in need of standardization is the use of hybrid, other, unidentified, and miscellaneous taxa.

Table 4-3: Unique common name comparison to AFS master taxa list

Category	Count	Percent	Description
Ok	177	51.3	Matched AFS list
Ambiguous	61	17.7	Non obvious misspelling or only a partial name such that the
Not listed, non-fish	56	16.2	Record was not a fish
Spacing	19	5.5	Extra spaces included in name preventing a match
Not listed, non-AFS	8	2.3	Name is a fish but not listed on the AFS list
Misspelled	6	1.7	Obvious misspelling
Extra name	5	1.4	Partial match with AFS but full name does not match
Hybrid	4	1.2	Name is a hybrid not a common name
Non-common name	4	1.2	Scientific or other name incorrectly included by data provider as a common name
No data	3	0.9	Name was left blank
Abbreviation	2	0.6	Abbreviation of part of name
TOTAL	345	100	

5.0 RECOMMENDATIONS

The fish populations of Chesapeake Bay are very well-studied and are subject to rigorous survey and monitoring programs. In addition, we have noted that there are several long-term datasets that potentially provide insight to fish assemblage responses to changes in habitat condition. Furthermore, species-specific data can also be used to predict presence or abundance of a species of interest or to use a single species to reflect an assemblage of ecologically similar taxa. With these options in mind, it is instructive to consider fish habitat assessment approaches successfully undertaken elsewhere and how that experience might inform efforts in the Chesapeake Bay.

Approaches Employed in Other Regional Fish Habitat Assessments

The Gulf of Mexico regional fish habitat assessment (Crawford et al. 2016; Miller et al. 2018) provides one useful model for a large regional assessment. The assessment began by assembling response data from nearly 70,000 state and federal trawl surveys from 33 estuaries across the northern Gulf of Mexico from Texas to Florida. Predictor variables representing anthropogenic stressors and natural variability were developed. These included “event-level” data collected along with sampling events and that would characterize natural heterogeneity, such as water temperature, salinity, and distance to shore, and “estuary-level” variables descriptive of broadscale stressors and physical conditions such as nutrient loadings, land use, estuary volume, and freshwater inflows. The original species list was reduced to a list of 57 fish and invertebrate species whose ranges were distributed widely across the study area and whose occurrence in the dataset would support modeling analysis, defined as species that were (1) represented in at least six of the seven monitoring programs and (2) caught in a minimum of 120 trawls (Miller et al. 2018).

Hierarchical logistic models were developed to examine the influence of both the event-level and estuarine-level predictors, first as single stressor models using hierarchical models for individual species, predicting presence or absence of individual fish and invertebrate species. Predictor variables were then combined into multi-stressor models via backward selection, developing a model for each species. Once the multi-stressor models were built, they were used to develop an index to assess anthropogenic disturbance in Gulf estuaries by comparing condition at the time of sampling to “least disturbed” and “minimally disturbed” reference conditions.

Predictions in the Gulf study apply to whole estuaries. The authors (Miller et al. 2018)note that the Gulf estuaries assessment was not designed to estimate variation in biological condition at a sub-estuary scale, but that if sufficient data were available and organized by estuary subsection, that species presence could be predicted using additional local factors such as shoreline hardening. The authors also note that future investigations could explore temporal variability, considering how watershed development affects species presence.

The hierarchical modeling approach employed in the Gulf of Mexico assessment could be applied to the Chesapeake regional assessment. In the Chesapeake Bay, the variation across different tributaries or subsets of tributaries (i.e., Bay segments) is one scale of interest. With sufficient data, fish sampling data could be organized by these finer geographic units. Segment-specific data such as land use, nutrient loads, shoreline condition, wetlands, bottom type, and SAV could be used in predictive models at this scale.

If even finer scale assessments are sought, for example, to assess individual site locations for the purpose of evaluating impacts of proposed permitted actions, scale analyses could be explored as part of a pilot study. This would provide the ability to determine whether data are sufficient to support this type of finer-scale assessment. The resolution of predictor data may indeed support assigning fish habitat ratings to finer scale units, but the question remains whether sufficient biological data exist to provide calibration and validation of predictions at a finer scale within an acceptable range of uncertainty. When considering how fine a scale can be assessed, there are tradeoffs to consider, in terms of “lumping” vs. “splitting”. Grouping up to a larger area may provide more data and therefore reduce variability but may also obscure the ability to characterize finer-scale differences. On the other hand, splitting data to assess finer-scale units may result in smaller sample sizes per unit, potentially resulting in greater uncertainty.

The Chesapeake Bay region is rich in data describing landscape and stressor conditions that could be used to build the sub-estuary level (and potentially finer-scale) predictors. The CBP’s recent Chesapeake Healthy Watersheds Assessment (CHWA) (Roth et al. 2020) developed a suite of metrics to characterize current watershed condition and vulnerability at the NHDPlus catchment scale (with an average catchment size of 2 km^2 in Chesapeake Bay watershed), which could be aggregated to the Bay segment scale. CHWA metrics include watershed and riparian forest, impervious cover, and wetlands; nitrogen loads from SPARROW modeling; nitrogen, phosphorus and sediment loads from the Bay model; protected lands; future development; climate stress; and others.

Regarding temporal variability, future analyses could potentially consider how species presence changes over time, with changes such as watershed development, SAV cover and density, or wetland loss as potential predictor variables. High-resolution land use and land cover data is currently available for the Chesapeake Bay watershed for 2013-2014. Planned updates include 2017-2018 and 2021-2022 (Claggett et al. 2020). SAV data are updated annually and can provide good long-term trends indications, although year-to-year fluctuations can occur, influenced by temperature and precipitation. Wetland data are typically updated about every 10 years. Interannual variability in salinity, temperature, and freshwater inflows would be additional factors to address.

A regional fish habitat assessment prepared for the Southeastern U.S. (Hoenke et al. 2019) relied primarily on GIS-based analysis to characterize factors affecting estuarine habitats. Regional datasets were used to characterize landscape-scale factors indicative of anthropogenic influence. Eight variables were employed in the northern Estuarine Conservation Scenarios, which covered estuarine watersheds from southern Virginia to north Florida. Points were assigned to each variable if ranking in the top tier for positive elements (such as wetland habitat) or lowest values for stressors (such as amount of hardened shoreline). Fine-scale data (e.g., 1-km hexagons) were aggregated to assess larger areas. Scores were combined across all variables to yield an overall score. Geospatial results were mapped to represent priority conservation areas.

The Southeast assessment included a number of variables that can be readily calculated for the Chesapeake region from the data identified for this data inventory and other landscape data. Relevant variables include seagrass and oyster reef habitat, wetland habitat, water-vegetation edge, proximity to development, water quality, and hardened shoreline. As in the Gulf of Mexico assessment, these factors could be used to characterize estuarine (actually sub-estuarine) conditions for incorporation into hierarchical models.

Scale of Analysis

A particularly vexing problem with conducting an estuary-wide habitat assessment is the issue of scale. Estuarine habitats such as those within the Chesapeake Bay system and those along the coast of northern Gulf of Mexico vary significantly in geomorphology, species distributions, salinity, and land-use. While it might be simpler to pool all the data into a single analysis, it would greatly oversimplify the variability (or miss it altogether) if multiple levels of variability went unaccounted for (Olden and Jackson 2002). Applying a hierarchical modeling (Haefner 1996; Miller et al. 2018) approach was useful in the northern GOM assessment and the approach would likely work well for the Chesapeake Bay. This type of model allows for predictions using multiple, related levels of predictor variables. For hierarchical models, the intercept and/or slope parameters can vary among different groups in the model. The GOM assessment defined groups as sub-estuaries and states (FL, AL, MS, LA, and TX). “Random effects” in hierarchical models account for group-level differences that are not accounted for by the available predictor variables. For example, some variation between estuaries is due to different morphologies and physical features that are not easily quantified. This approach is well-suited for the Chesapeake Bay whereby several options for grouping variables exist.

Our Chesapeake Bay data inventory identified multiple levels within the 103 datasets, ranging from state-level surveys to tributary (sub-estuary) level data. In the case of the Chesapeake estuary, the state level data may be too coarse to be effective in decision-making for habitat protection. However, the tributary-level grouping of data may prove a viable means of fully assessing fish habitat. One caveat with this approach is that within the tributaries, variability exists in land use, salinity, and other abiotic parameters. Because the CBP has adopted a segmentation scheme to track and monitor various living resources, and these segments are defined by tributary AND salinity regime, the best assessment would likely be at the segment-level group.

It should be noted that some important threats to fish and fish habitat that were not pursued and therefore not incorporated into the inventory including historical land use, precipitation, hydrologic changes, sedimentation and woody debris, water quality impairments such as contaminants, channel and bottom morphology, and regional habitat stressors (e.g. septic impacts, dredging, etc.). As a pilot habitat assessment progresses (Choptank River), we recommend incorporating these parameters to the extent possible based on data availability.

It is also important to consider that assessment of a single sub-estuary system, such as the Choptank, might also be informed by incorporating data from a broader context, such as other eastern or western shore tributaries. This larger data pool could provide improved species predictions, better elucidate relationships with stressor variables, and provide a larger dataset for defining least- or minimally-disturbed reference conditions.

Data Type

The inventoried fisheries datasets include records of single species surveys (“targeted”) or, more commonly, population and community surveys. Most of the targeted surveys collected full population-level data, thereby assemblage and diversity parameters can potentially be used to model change. Similarly, the data can also be reduced, at the species level, to just presence-absence for each sample point. The decision on which approach to use is difficult and requires a full understanding of the life history status of each species, or the general structure of an assemblage. Population level data for a species can be useful to detect trends in relative abundance and may be correlated to specific habitat types and changes in the extent of those habitats. Similarly, assemblage analysis can provide insight to the diversity of the system and how it responds to changes in habitat. However, assemblage data is typically driven by abundance of a few species (Murphy and Secor 2006) and therefore will likely be biased towards those species in any given sample.

Presence-absence data can be useful to fisheries managers in a wide variety of contexts, from monitoring populations at large spatial scales to identifying habitats that are of high value to specific species of conservation or commercial concern. However, a key issue is that a species may be declared "absent" from a landscape unit simply as a result of not detecting the species using the prescribed sampling methods. The effect of this imperfect detection is that parameter estimates will be biased, and any modeling of the data provides a description of the surveyors' ability to find the species on the landscape. The reliability of "presence-absence" data for making sound management decisions and valid scientific conclusions could therefore be questioned. However, after collecting appropriate data (i.e., repeated surveys of landscape units within a relatively short timeframe), statistical models can be used to obtain unbiased parameter estimates. We recommend reducing available data to presence-absence data as it is better suited for hierarchical modeling described above, and follows similar efforts in the national fish habitat assessment.

Fisheries survey data is also biased due to gear selection and the habitats suited for these gears. For example, seine surveys will only reflect those species that prefer shallower (< 2m) regions and are near shore. Comparing seine survey data to that of trawl (which samples the midwater to demersal regions) data would not be feasible since they differ substantially in the catch per unit effort (CPUE), the habitat sampled, and the species and life history stages targeted. However, the hierarchical model may address these inconsistencies by nesting gear data within the tributary or segment group. Such an approach would characterize relationships in shallow water nearshore regions between fish populations and SAV beds, for example, since SAV beds generally do not grow in depths > 2 m in the Chesapeake (Batiuk et al. 2000). Similarly, trawl data analyses might reveal associations between bottom type habitat (reef, shell, sediment type) and concomitant fish assemblages or species associations.

Generalized Additive Model (GAM) Application

Within the Chesapeake Bay, researchers have developed a general additive model (GAM) framework to evaluate nonlinear, seasonally-varying changes in water quality variables over time (Murphy et al. 2020). This approach uses a combination of penalized, thin-plate regression and cyclic-cubic regression splines depending on the independent variable. Interaction terms are created using a tensor product of splines. Currently, the GAM framework used in the Chesapeake Bay program accounts for wet/dry years by including observed salinity or upstream flow; and explicitly includes terms for methodology changes. Many of these features could likely be adopted for fish population evaluations as they share similar features. For example, inclusion of concomitant data (i.e., data collected at same time and space such as salinity and temperature) allows direct modeling of potential stressors and account for seasonal variations. This might allow integrating data from monitoring programs with varying index periods. Changes in sampling methodology or event-level stressors such hurricanes, treatment plant upgrades, etc. can be modeled as interventions.

The approach currently used to evaluate water quality trends in the Chesapeake Bay would need to be expanded to include non-comitant data such as fish habitat (seagrass, oyster reef, proximity to development, etc.). Similar to hierarchical logistic models described earlier, hierarchical GAMs can be developed to model non-linear relationships where the functional shape varies between groups (Pedersen et al. 2019).

Collaboration

In addition to using other regional assessments to inform successful quantitative approaches, there should also be a collaborative structure put forward. The large amount of data available from a multitude of agencies and investigators requires strong collaboration. The data, in addition to the various tributaries from where it originated, is often very well-known to the principal investigators who can provide insight that otherwise might be missed in the context of a larger review. This approach also has the benefit of potentially bringing in additional agency resources that would strengthen the outcome of the assessment.

Summary of Recommendations

- Explore analytical approaches including GAM and hierarchical predictive models
- Develop list of focal species to consider species most indicative of stressor gradient and those with sufficient data to support statistical analyses (e.g., remove the most common and/or rare species)
- Develop datasets of local and estuarine-scale variables
- Use pilot study for Choptank River as opportunity to explore options for analyses at Bay segment and potentially finer scale
- Include institutions and individuals most familiar with data to participate and consult on development of fish habitat assessments

6.0 CHOPTANK RIVER PILOT STUDY

As an initial step in developing a Chesapeake Bay tidal fish habitat assessment, NOAA and the project advisory team has proposed developing a pilot study in the Choptank River system. The Choptank River is a major tributary of the Chesapeake Bay and the largest river on the Delmarva Peninsula (Figure 6-1). The non-tidal river originates in Kent County, DE, runs through Caroline County, MD and forms much of the border between Talbot County on the north, and Caroline County and Dorchester County on the east and south. The Choptank is navigable (and tidal) from its mouth at the Chesapeake Bay 45 miles upriver to Denton, MD, while the head of tide is near Greensboro, MD. The Choptank contains four CBP segments, representing a variety of salinity regimes and estuarine habitat types from tidal freshwater to mesohaline. The watershed encompasses 2,360 km^2 (583,344 acres), of which 1,916 km^2 (473,456 acres) are land and 445 km^2 (109,888 acres) are open-water habitat, including oyster reefs, SAV beds, and open pelagic water (Dorfman et al. 2016). Additionally, the Choptank has extensive fringing tidal marshes throughout the system.

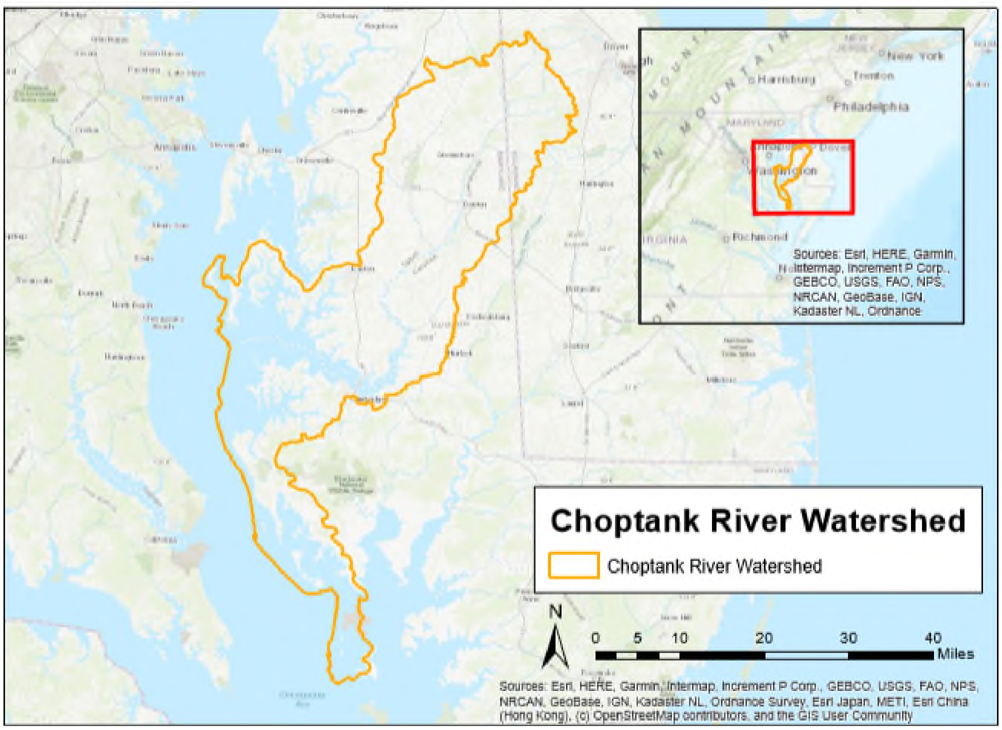

Figure 6-1: Choptank River watershed on eastern shore of Maryland

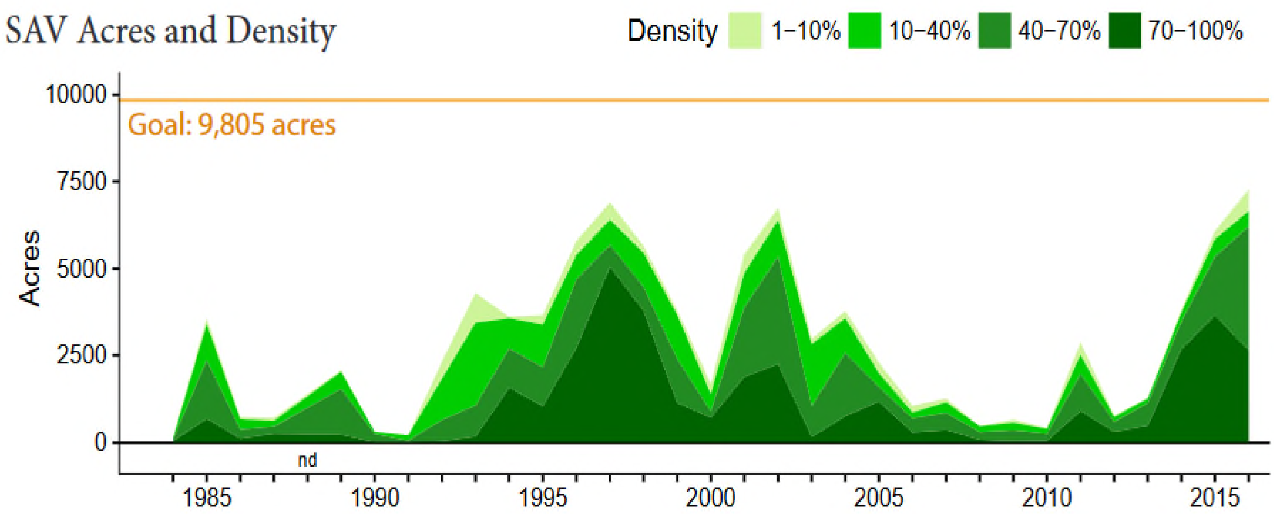

Figure 6-2: SAV trends for lower Choptank River, CB Segments CHOMH1, CHOMH2 (courtesy CBP SAV Factsheets)

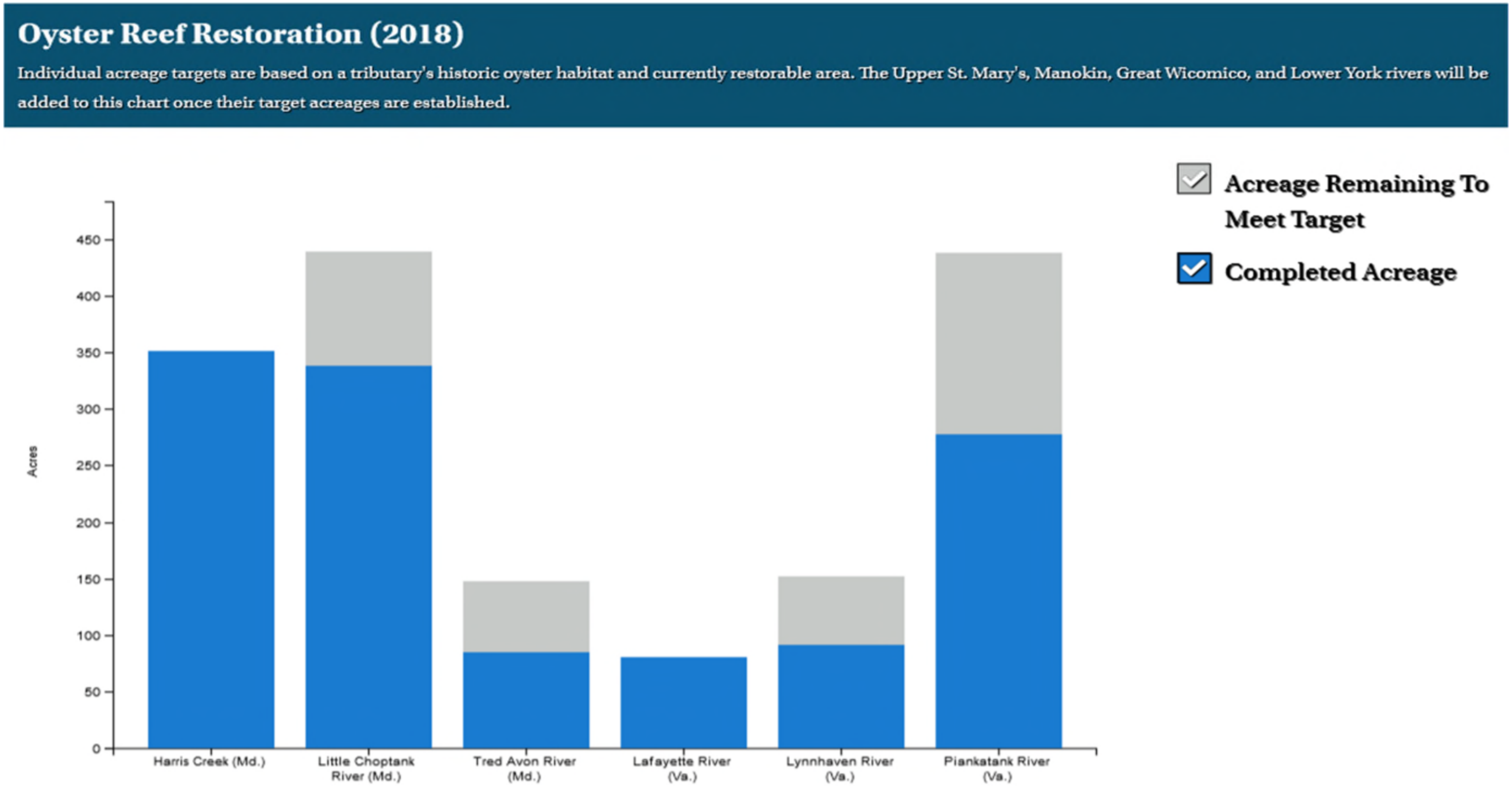

Figure 6-3: Oyster reef restoration progress as of 2018 (courtesy CBP)

Like several other Bay tributaries, the Choptank is well-studied and long-term data (biological and abiotic) is extensive. It has been demonstrated that the system has a legacy of degradation due to eutrophication, primarily from agricultural inputs (Fisher et al. 2006) with the system being mostly nitrogen limited, albeit with phosphorus limitation of phytoplankton during spring river flows. Fisher et al. (2006) also noted that insufficient action has been taken to improve the water and habitat quality of the Choptank, although reduced eutrophication in dry years suggests that the estuary will respond to significant decreases in nutrients. This, in turn, could spur resurgence of SAV throughout the system, as evidenced by recent trends (Figure 6-2). In addition to SAV habitat, the Choptank has also been targeted for oyster reef restoration. The 2014 Bay Agreement targeted 10 tributaries for oyster restoration, including the Choptank River (including the Tred Avon, Harris Creek, and the Little Choptank). These large efforts have shown some success over recent years (Figure 6-3). Some of the monitoring data from these restoration activites was captured in our metadata collection (Section 3). Tracking the change in oyster reef habitat, similar to SAV, is a factor that can be useful in relating habitat availability to fish occurrences.

Our review of data shows that the Choptank River is well represented in numerous surveys (Figure 6-4 and Figure 6-5 show datasets acquired) and much of that data is highly relevant for use in a fish habitat assessment.

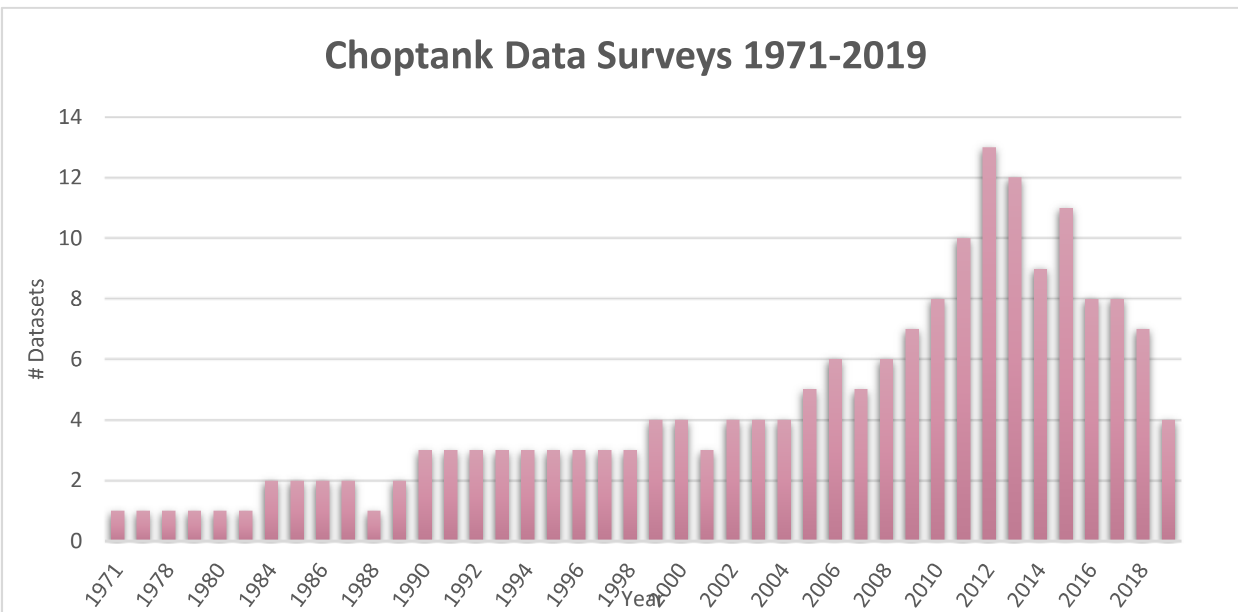

Figure 6-4: Number of surveys in the Choptank River 1971-2019.

In addition, NOAA has previously conducted an ecological assessment in 2016 (Dorfman et al. 2016) which provides an excellent baseline to build upon. A further benefit is that this baseline report also contains land use data which was not part of the inventory effort, but would be an integral piece to developing a fish habitat assessment, considering anthropogenic influence at the landscape scale, as discussed in our Recommendations (Section 5). The baseline report summarizes SAV, oyster coverage, nutrient loadings, and several fish surveys.

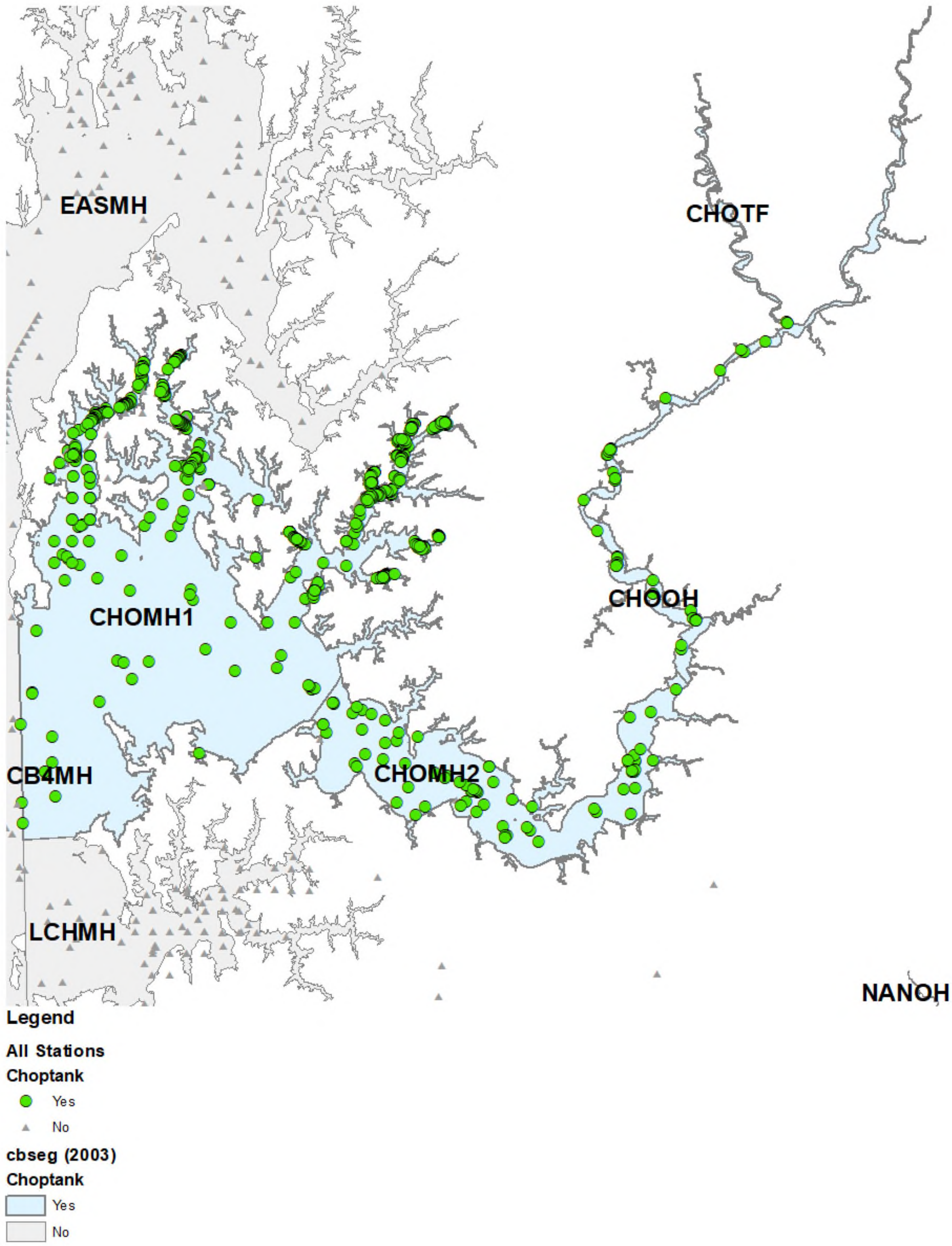

Figure 6-5: Sample locations (circles) within the Choptank River system, from datasets acquired for the fish habitat data inventory

Table 6-1 shows the 106 species (fish and invertebrates) represented in the Choptank River datasets, based on all data acquired in our inventory. This list provides a comprehensive selection of species to choose for an assessment, even if assemblage analyses are not possible, due to multiple gear types and methods used. For a pilot study, we recommend selecting a suite of species of interest, representing those fish that are typical taxa exploiting particular habitats or ecological niches. These could include, for example, Atlantic Silverside (pelagic, multiple salinities), Eastern Silvery Minnow (tidal freshwater), Northern Pipefish, (brackish-marine, SAV), White Perch (ubiquitous euryhaline), and Summer Flounder (demersal).

Because these five species are fairly common, models using either presence-absence data, or relative abundance would be useful as these species are regularly collected. Another option would be to retain a longer list of focal species to be used in modeling. This list would focusing on those with the best potential for showing response across a broad range of environmental gradient. Rare species (those found in small numbers or in a small percentage of surveys) would be eliminated, as their numbers would likely not support statistical analysis. Species that are ubiquituous, if any, would also be candidates for elimination, because they are not sensitive to degradation and therefore would not provide a strong response signal.

There are many studies demonstrating local effects of habitat preferences among fish in coastal systems (Bell et al. 1992; Coen et al. 1999; Connolly and Hindell 2006; Lehnert and Allen 2002; Orth and Heck Jr. 1980; Shervette and Gelwick 2008). These studies typically compare a discrete reef or seagrass bed to adjacent bare regions to detect differences. However, there is a lack of research into scaling up effects on fish productivity associated with habitat alteration in open tidal systems (Bell et al. 1988; Pierson and Eggleston 2014). Applying some of the recommendations from Section 5 to a Choptank River habitat assessment would be a unique opportunity to test the robustness of hierarchical modeling in the mid-Atlantic, as well as evaluating the efficacy of potential predictor variables.

Table 6-1: Species recorded during Choptank River sampling during the following surveys: CBL Seine vs Trawl, CBL Seine Cruises, MD DNR Juvenile Striped Bass Seine, NOAA ELMR Mid Atlantic, Oxford Tred Avon Seine, Oxford Tred Avon Trawl, USFWS Yellow Perch Fyke Netting

ALEWIFE	DUSKY PIPEFISH	ROUGH SILVERSIDE
ALOSA SPP.	EASTERN OYSTER	SATINFIN SHINER
AMERICAN EEL	EASTERN SILVERY MINNOW	SCUP
AMERICAN LOBSTER	FLOUNDER	SEVENSPINE BAY SHRIMP
AMERICAN SAND LANCE	FOURSPINE STICKLEBACK	SHEEPSHEAD MINNOW
AMERICAN SHAD	GIZZARD SHAD	SHORTNOSE STURGEON
ATLANTIC COD	GOBIES	SILVER PERCH
ATLANTIC CROAKER	GOLDEN SHINER	SILVERSIDES
ATLANTIC HERRING	GOLDFISH	SILVERY MINNOW
ATLANTIC MACKEREL	HADDOCK	SKATES
ATLANTIC MENHADEN	HALFBEAK	SKILLETFISH
ATLANTIC NEEDLEFISH	HARVEST FISH	SOFTSHELL CLAM
ATLANTIC SALMON	HICKORY SHAD	SOUTHERN KINGFISH
ATLANTIC SILVERSIDE	HOGCHOKER	SPANISH MACKEREL
ATLANTIC STINGRAY	INLAND SILVERSIDE	SPOT
ATLANTIC STURGEON	INSHORE LIZARDFISH	SPOTFIN SHINER
ATLANTIC THREAD HERRING	KILLIFISHES	SPOTTAIL SHINER
ATLANTIC TOMCOD	LARGEMOUTH BASS	SPOTTED SEATROUT
BANDED KILLIFISH	MULLETS	STRIPED ANCHOVY
BAY ANCHOVY	MUMMICHOG	STRIPED BASS
BAY SCALLOP	NAKED GOBY	STRIPED BLENNY
BLACK CRAPPIE	NORTHERN KINGFISH	STRIPED KILLIFISH
BLACK DRUM	NORTHERN PIPEFISH	STRIPED MULLET
BLACK SEA BASS	NORTHERN PUFFER	SUMMER FLOUNDER
BLUE CRAB	NORTHERN SEAROBIN	SUNFISH
BLUE MUSSEL	NORTHERN SHRIMP	TAUTOG
BLUEBACK HERRING	OYSTER TOADFISH	TESSELLATED DARTER
BLUEFISH	PINFISH	THREADFIN SHAD
BLUEGILL	PIPEFISH	WEAKFISH
BROWN SHRIMP	POLLOCK	WHITE CATFISH
BUTTERFISH	PUMPKINSEED	WHITE PERCH
CARP	QUAHOG	WINDOWPANE FLOUNDER
CHANNEL CATFISH	RAINBOW SMELT	WINTER FLOUNDER
COWNOSE RAY	RAINWATER KILLIFISH	YELLOW PERCH
CUNNER	RED DRUM	
DAGGERBLADE GRASS SHRIMP	RED HAKE	

Within the combined group of datasets acquired, there are vast differences in the number of data points by segment (Table 6-2), but our metadata inventory suggests that substantial additional data exists for the oligohaline and tidal fresh portions of the river that are not represented in the acquired datasets. As noted by Miller et al. (2018), an extension to developing a fish habitat assessments can also include using data to evaluate trends. The availability of long-term data in the Choptank (Table 6-3), and elsewhere, may be highly useful in examining temporal changes.

Table 6-2: Distribution of Choptank River sample sites by CBP segment, within datasets acquired

CBP Segment	# Sample locations (excluding polygon data)
CHOMH1	754
CHOMH2	76
CHOOH	35
CHOTF	3

A review of the acquired data for the Choptank, makes it possible to examine matches between different types of data (habitat, stressor, and biological). Data acquired for the Choptank River system included 14 datasets across the four Chesapeake Bay segments, with data from a total of 875 stations. Of the Choptank datasets containing fish data, eight also included water quality data, and three also included habitat data.

*Table 6-3: Datasets acquired for the Choptank River system, with number of stations by Bay Segment, years, and types of data included. *Geospatial data for SAV, shoreline, and wetlands are available throughout the system, not for individual stations.*

Survey	Number of Stations by Bay Segment				*Total*	Years	Data Types									
	CHOMH1	CHOMH2	CHOOH	CHOTF			Fish	Water Quality	Habitat	Oyster	Crab	Benthos	SAV*	Clam	Shoreline*	Wetland*
MDDNR_FHEP_Trawl	266	0	0	0	*266*	2012-2015	x	x	x							
Oxford_TA_Trawl	200	0	0	0	*200*	2015-2017	x	x								
Oxford_TA_Seine	141	0	0	0	*141*	2015-2017	x	x								
MDDNR_FallOysSurvey	46	24	0	0	*70*	2010-2018		x		x						
CBL_UMCES_SeineCruises	4	22	23	0	*49*	2011-2013	x									
MDDNR_FHEP_Seine	45	0	0	0	*45*	2012-2015	x	x	x							
CBP_Benthic	12	20	8	0	*40*	2008-2013		x				x				
VERSAR_Oyster	32	0	0	0	*32*	2012	x	x	x	x	x					
CBL_UMCES_seine_vs_trawl	0	5	3	2	*10*	2006-2013	x	x								
ChesMMAP	7	0	0	0	*7*	2002-2013	x									
MDDNR_BC_Trawl	6	0	0	0	*6*	1989-2017	x	x			x					
MDDNR_SB_Seine	0	4	0	1	*5*	1999-2018	x	x	x				x			
CBP_WQ	1	1	1	0	*3*	2005-2019		x								
TIES_CHESFIMS_PAXFIMS	1	0	0	0	*1*	1995-2000	x									
Total	*761*	*76*	*35*	*3*	***875***		*11*	*11*	*4*	*2*	*2*	*1*	*1*	*0*	*0*	*0*

Finally, there is potential for employing field verification to evaluate or validate model predictions. While not proven, there would be value in a 1-2 year sampling program that can be designed to evaluate modeling results of habitat effects (directional). Other well-developed models for long-term water quality analyses for the Bay used the R script *baytrends* which reduced interannual variability after developing a GAM (see Section 5) that better describes nonlinear, seasonally-varying variables over time, similar to fish populations and habitat variability (Murphy et al. 2019). This worked well for assessing long term water quality variables in several Chesapeake Bay tributaries and shows promise for application to the fish habitat assessment parameters. As noted in the Recommendations section, an analysis by CBP segment in the Choptank would be useful as it would enable addressing local attributes and coupling fish data with local habitat variation. Because virtually all of the available data is georeferenced, this approach is certainly attainable and can be coupled with efforts such as the CBP SAV Factsheets, water quality analyses, and other management strategies that are tailored to the Bay segment scale.

7.0 CONCLUSIONS

The development of a fish habitat assessment for the Chesapeake is central to meeting the fish habitat outcome outlined in the 2014 Chesapeake Bay Agreement and can serve as a model for large complex estuaries nationally. The first step in conducting an assessment is inventorying as much relevant data as possible and understanding and describing the nature of that data. In this report, we have described more than 100 datasets of biological and related data from tidal waters of the Chesapeake Bay, including information on spatial coverage, data type, and temporal duration. Furthermore, the datasets were assessed for their potential utility for fish habitat assessment. This, in combination with reviewing other regional assessments, has allowed us to make defensible recommendations on proceeding with the fish habitat assessment in the Chesapeake Bay. The next step recommended is to conduct a pilot assessment, which will provide an opportunity to make use of diverse data at a sub-estuarine scale to refine an analytical assessment approach that can be applied more broadly. Focusing on a sub-estuary such as the Choptank allows for the opportunity to explore and refine models that will perform well given the diversity of data types and duration. As with any effort to obtain large numbers of datasets, it is impossible to acquire them all. This is understandable as many studies and surveys remain valuable sources to address research questions, particularly within the regional academic community. Recognizing the knowledge base of the many data holders throughout the region, we believe that the best path forward will involve inclusion of additional expert collaborators as the fish habitat assessment progresses. With the wealth of institutional knowledge invested in the 50 years of data identified, it is imperative to include voices from those who know the data best.

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9.0 APPENDICES

9.1 APPENDIX A: LIST OF PREPARERS

Name	Organization	Title	Role
Bob Murphy	Tetra Tech (Tt)	Sr. Fisheries Ecologist	Principal Author
Nancy Roth	Tt	Sr. Watershed Scientist	Principal Author
Erik Leppo	Tt	Data Management	Data Management & QC; Geospatial Analyses
Alexis Walls	Tt	Data Management	Data Management; Metadata Inventory; Contributing Author
Jon Harcum, Ph.D.	Tt	Statistician / Modeler	Contributing Author
Carol Gallardo	Tt	Environmental Scientist	Technical Editor

9.2 APPENDIX B: CHESAPEAKE BAY FISH HABITAT ASSESSMENT – DATA REQUEST

Background: The 2014 Chesapeake Bay Agreement identified a need to "continually improve the effectiveness of fish habitat conservation and restoration efforts...". In order to achieve this outcome, a team of scientists from the National Oceanic and Atmospheric Administration, U.S. Geological Survey (USGS), Tetra Tech, Inc., and MD Department of Natural Resources are performing a Bay-wide assessment of fish habitat. The intended uses of the Chesapeake Bay Fish Habitat Assessment are to 1) improve restoration and conservation project siting (e.g., Best Management Practices and shoreline protection), 2) identify and influence factors affecting fish resources outside the authority of fishery managers, and 3) document the spatial extent and distribution of significant fish and habitat resources.

Although a national assessment of fish habitat has been conducted, that assessment is insufficient to guide decisions in the Chesapeake Bay. It is limited to nationally available datasets, excludes any information about fish or shellfish, and has a very coarse geographic scale. The Chesapeake Bay Assessment is intended to draw from a much richer set of data, including fish and habitat data, and be focused at finer spatial scale.

What we are looking for: We are reaching out to you to request access to any fish, shellfish, and/or habitat data that you may have collected. For fish data, we are focusing on spatially referenced presence, absence, and abundance information sampled within tidal waters of the Chesapeake Bay. In particular we would like records of fish life stage as well as location, count, and species, in addition to associated data collections such as time and water quality if possible.

How the data will be used: Your data will be standardized to a spreadsheet format developed by USGS and Tetra Tech. Use of the data will be restricted to scientists that are part of this assessment team, specifically for the purposes of this assessment, unless the data is publicly available or you agree that it may be used more broadly. The data will be used to evaluate the condition and distribution of fish habitat and fisheries resources. Summary descriptions of the data that were used to determine habitat condition will be reported. Your dataset will be acknowledged in all publications that use your data.

9.3 APPENDIX C: ATTRIBUTES OF DATASETS IDENTIFIED

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
CBF_Education	CBF Educational Field Trips	CBF	Multiple states	yes	1108	2016-2019	X				X	X				
CBF_LafRv_Trawl	CBF Lafayette River Trawl Surveys	CBF	Virginia	no	NA	1999-2019	X	X			X	X				
CBF_WQ_GIS	CBF Educational Field Trips	CBF	Multiple states	yes	NA	2013-2018		X								
CBL_Seine	CBL Seine Survey	UMCES	Maryland	yes	1	1998-2018	X	X								
CBL_UMCES_seine_vs_trawl	CBL Seine vs Trawl	CBL-UMCES	Maryland	yes	33	2006-2013	X	X								
CBL_UMCES_SeineCruises	CBL Seine Cruises	CBL-UMCES	Maryland	yes	91	2011-2013	X									
CBP_Benthic	Baywide Benthic Database	CBP	Multiple states	yes	1563	2008-2013		X					X			
CBP_Flourescence	Baywide Fluorescence Database	CBP	Multiple states	yes	359053	2000-2012		X								
CBP_SAV	Chesapeake Bay Program SAV Synthesis Project	CBP	Multiple states	online access	NA	1984-2016		X		X						
CBP_WQ	Chesapeake Bay Program Water Quality Data	CBP	Multiple states	yes	246	2005-2019		X								
ChesMMAP	NOAA ChesMMAP	VMRC	Multiple states	yes	3957	2002-2013	X									
CMES_BenthicHabitat	CMES	NOAA	Multiple states	yes	NA	2009-2010			X				X			
DC_Alosine	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2013-2018	X									
DC_Electrofishing	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes	41	1990-2011, 2013-2018	X									
DC_LMB	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2005-2010	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
DC_Low_Frequency	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2012-2018	X									
DC_Push_Net	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2006-2018	X									
DC_Rock_Creek	(suspected non-tidal) Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2007-2018	X									
DC_Seining	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		1990-2005, 2007-2018	X									
DC_Snakehead	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		2011-2018	X									
DC_STB	Washington DC Fisheries Survey	DC Fisheries	Washington, D.C.	yes		1990-2006, 2008-2018	X									
DC_WetlandsInv	Washington DC Wetlands Inventory	USFWS	Washington, D.C.	yes	NA	unknown-2019										X
DE_Abundance	Nanticoke River American/Hickory Shad Abundance	DNREC	Delaware	no	NA	1999-2019	X									
DE_Bass	Tidal Bass Population Enhancement and Monitoring	DNREC	Delaware	no	NA	1989-2019	X	X								
DE_NRSA	(suspected non-tidal) National Rivers and Streams Assessment	DNREC	Delaware	no	NA	2008-2009, 2013-2014, 2018-2019			X							
DE_Pond	(suspected non-tidal) Pond Fish Management	DNREC	Delaware	no	NA	1950-2019	X	X								
DE_Restoration	Nanticoke River American Shad Restoration	DNREC	Delaware	no	NA	2000-2019	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
DE_Sturgeon	Nanticoke River Sturgeon Assessment	DNREC	Delaware	no	NA	2015-2019	X									
DE_Tidal	Delaware Stream and Tidal Tributary Survey	DNREC	Delaware	no	NA	2019-2020	X									
DE_Toxic	Delaware Toxic sampling in Watersheds that Flow to the Chesapeake Bay	DNREC	Delaware	no	NA	2017-2018	X									
DE_WetlandsInv	Delaware Wetlands Inventory	USFWS/ DE/CMI	Delaware	yes	NA	unknown-2019										X
DOEE_Mapping	DOEE's Wetland Mapping Project	DOEE	Washington, D.C.	no	NA	unknown-2019		X								X
ICPRB_AmShad	ICPRB American Shad Monitoring Survey	ICPRB	Multiple states	no	NA	1995-2014	X	X								
MD_WetlandsInv	Maryland Wetlands Inventory	MD DNR	Maryland	yes	NA	1990-2019										X
MDDNR_AmShad_H&L	American Shad hook-and-line Survey	MD DNR	Maryland	no	NA	2017	X									
MDDNR_Bass	Freshwater Fisheries Program	MD DNR	Maryland	no	NA	1999-2020	X	X								
MDDNR_BC_Dredge	Blue Crab Winter Dredge Survey	MD DNR	Maryland	no	NA	2009-2019		X			X					
MDDNR_BC_Trawl	Blue Crab Trawl Survey	MD DNR	Maryland	no	53	1977-present	X	X			X					
MDDNR_Choptank_Fyke	Choptank River Fyke Net Survey	MD DNR	Maryland	yes	NA	2009-2019	X	X								
MDDNR_Choptank_Gill	Choptank River Gill net Survey	MD DNR	Maryland	no	NA	2013-2017	X	X								

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
MDDNR_FallOysSurvey	Fall Oyster Survey	MD DNR	Maryland	yes	403	2010-2018		X				X				
MDDNR_FHEP_Seine	Fisheries Habitat and Ecosystem Program	MD DNR	Maryland	yes	225	2012-2015	X	X	X							
MDDNR_FHEP_Trawl	Fisheries Habitat and Ecosystem Program	MD DNR	Maryland	yes	266	2012-2015	X	X	X							
MDDNR_Herring_Seine	Juvenile River Herring Seining Survey	MD DNR	Maryland	no	NA	2005-2006	X									
MDDNR_Ichthyo	FHEP Icthyoplankton Sampling	MD DNR	Maryland	no	NA	2005-2017	X									
MDDNR_Nanticoke_Fyke	Nanticoke River Fyke net Survey	MD DNR	Maryland	no	NA	1989-2017	X									
MDDNR_NE_Gill	North East River Gill Net Survey	MD DNR	Maryland	no	NA	2013-2017	X									
MDDNR_Normandeau	Normandeau Associates observation at Conowingo Dam fish lifts	MD DNR	Maryland	no	NA	NA	X									
MDDNR_Patent_Tong	MD DNR Oyster Sanctuary Patent Tong Surveys	MD DNR	Maryland	yes	NA	2011-2015, 2018			X			X				
MDDNR_Potomac_Gill	Potomac Gill Net Broodstock Collection: Anadromous Fish	MD DNR	Maryland	no	NA	1996-2017	X									
MDDNR_SB_Seine	Juvenile Striped Bass Program	MD DNR	Maryland	yes	44	1999-2018	X	X	X	X						
MDDNR_SB_Spring	Striped Bass Program	MD DNR	Maryland	yes	71	2000-2019	X	X	X	X						
MDDNR_UB_Fyke	Upper Bay Fyke Net Survey	MD DNR	Maryland	no	NA	2001-2006	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
MDDNR_VIMS_OysterCoop	Cooperative oyster monitoring program	MD DNR/VIMS	Maryland	no	NA	1994-2006						X				
MDDNR_Winter_Trawl	Annual Winter Trawl Survey	MD DNR	Maryland	yes	1101	2009-2019	X	X								
NOAA_ELMR	NOAA ELMR Mid Atlantic	NOAA	Multiple states	yes	NA	1990-2000	X									
ODU_VA_Age&Growth	VA Age and Growth Program	ODU	Virginia	no	NA	2001-2018	X									
ORP_Diver	MD Oyster Restoration Monitoring Diver Surveys	ORP	Maryland	no	NA	2015-2019		X				X				
ORP_PatentTong	MD Oyster Restoration Monitoring & Ground Truthing Patent Tong Surveys	ORP	Maryland	no	NA	2012-2019		X				X				
Oxford_Seine	NOAA Oxford Lab	NOAA Oxford Lab	Maryland	yes	335	2007-2012	X	X								
Oxford_TA_Seine	Oxford Tred Avon Seine Sampling	NOAA Oxford Lab	Maryland	yes	46	2015-2017	X	X								
Oxford_TA_Trawl	Oxford Tred Avon Trawl Sampling	NOAA Oxford Lab	Maryland	yes	150	2015-2017	X	X								
Oxford_Trawl	NOAA Oxford Lab	NOAA Oxford Lab	Maryland	yes	716	2007-2013	X	X								
PEARL_BC	PEARL Blue Crab Survey	PEARL	Maryland	no	12	1968-2019		X			X					
SERC_Benthic	Rhode River Benthic Infauna Survey	SERC	Maryland	no	NA	1980-2019	X						X			
SERC_Herring	(suspected non-tidal) River Herring spawning study	SERC	NA	no	NA	2016	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
SERC_Seine	Rhode River Seine Survey	SERC	Maryland	no	NA	1979-2019	X	X								
SERC_Trawl	Rhode River Trawl Survey	SERC	Maryland	no	NA	1981-2019	X									
SERC_Weir	Rhode River Weir Survey	SERC	Maryland	no	NA	1983-2019	X									
TIES_CHESFIMS_PAXFIMS	CHESFIMS	UMCES	Multiple states	yes	692	2001-2005	X	X								
TIES_CHESFIMS_PAXFIMS	PAXFIMS	UMCES	Maryland	yes		2004	X	X								
TIES_CHESFIMS_PAXFIMS	TIES	UMCES	Multiple states	yes		1995-2000	X									
UMD_Oyster	Choptank oyster restoration site monitoring	UMD	Maryland	no	NA	2011						X				
USFWS_BW	Blackwater/Little Blackwater River Fyke Netting	USFWS	Maryland	yes	6	2006-2007, 2018-2019	X	X								
USFWS_Inv	Inventory of Fish Species within Dyke Marsh	USFWS	Virginia	no	NA	2001-2004	X	X								
USFWS_Potomac	Potomac Shad sampling	USFWS	Multiple states	yes	1	2006-2018	X	X								
USFWS_YellowPerch	Yellow Perch Fyke Netting	USFWS	Maryland	yes	NA	2017-2019	X									
VA_WetlandInv	Virginia Wetlands Inventory	VA DCR	Virginia	yes	NA	unknown-2019										X
VADGIF_James	James River American Shad stocking	VA DGIF	Virginia	no	NA	2003-2014	X									
VADGIF_Rapp	Rappahannock River American Shad stocking	VA DGIF	Virginia	no	NA	1992-2017	X									
VECOS	VECOS (Virginia Estuarine and Coastal Observing System)	CBNERR/VIMS/William & Mary	Virginia	no	NA	1985-2019		X								

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
VERSAR_Oyster	MD Oyster Pre-Restoration Monitoring and Ground Truthing Patent Tong	NOAA CBO/ VERSAR	Maryland	yes	53	2012	X	X	X		X	X				
VIMS_AmShad	American Shad monitoring	VIMS	Virginia	no	NA	1998-2019	X	X								
VIMS_AtSurfClam_Quahog	(suspected non-Chesapeake Bay) Molluscan Ecology Research-Atlantic Surf Clam and Ocean Quahog	VIMS	NA	no	NA	NA								X		
VIMS_BC_Dredge	Blue Crab Winter Dredge Survey	VIMS	Virginia	no	NA	1990-2019					X					
VIMS_BlueCat_Move	Blue catfish movement study	VIMS	Virginia	no	NA	2012-2015	X	X								
VIMS_BlueCat_Pop	Blue catfish population and survival study	VIMS	Virginia	no	NA	2012-2014	X	X								
VIMS_CTILS	CTILS (Chesapeake Bay Trophic Intersections Lab Services) Program	VIMS	Multiple states	no	NA	2003-2006	X									
VIMS_Eel	Eel YOY Survey	VIMS	Virginia	no	NA	NA	X	X								
VIMS_Herring_Gill	Adult Herring monitoring	VIMS	Virginia	no	NA	2014-2019	X	X								
VIMS_Herring_Juv	Juvenile Herring and American Shad monitoring	VIMS	Virginia	no	NA	2014-2019	X	X								
VIMS_MDShoreline_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	Maryland	yes	NA	2002-2006									X	
VIMS_NEAMAP	NEAMAP	VIMS	Virginia	no	NA	2007-2011	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
VIMS_Oyster_Dredge	Molluscan Ecology Research-Oysters Dredge	VIMS	Virginia	no	NA	1940s-2019						X				
VIMS_Oyster_PatentTong	Molluscan Ecology Research-Oysters Patent Tong	VIMS/CNU	Virginia	no	NA	1993-2019						X				
VIMS_Oyster_Shellstring	Molluscan Ecology Research-Oysters Shellstring	VIMS	Virginia	no	NA	1940s-2019						X				
VIMS_SAV	SAV Mapping Program (Aerial survey data)	VIMS	Multiple States	online access	NA	1971,1974, 1978 -1981, 1984-1987, 1989-2018				X						
VIMS_SB	Striped Bass Monitoring and Tagging	VIMS	Virginia	no	NA	1987-2006	X									
VIMS_Seine	Juvenile Striped Bass Survey	VIMS	Virginia	yes	NA	2009-2018	X	X								
VIMS_Trammel	Trammel Net Survey	VIMS	Virginia	no	NA	NA				X						
VIMS_Trawl	Juvenile Fish and Blue Crab Trawl Survey	VIMS	Virginia	yes	NA	2009-2018	X	X								
VIMS_Trout	Acoustic Tagging of Speckled Trout	VIMS	Virginia	no	NA	2016-2017	X									
VIMS_VAShoreline_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	Virginia	yes	NA	2010-2015									X	
VIMS_VATidalMarsh_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	Virginia	yes	NA	2010-2015									X	
Virgina_Seine	1967-2010 Virginia Major tributaries in lower Chesapeake Bay Seine	NEFSC	Virginia	no	NA	1967-2010	X									

Dataset	Program	Agency	State	Dataset Acquired for Inventory	No. of Sites	Years of Survey	Fish	Water Quality	Habitat	SAV	Crab	Oyster	Benthic	Clam	Shoreline	Wetland
Virgina_Trawl	1955-2011Virginia Lower Chesapeake Bay and major tributaries Bottom Trawl	NEFSC	Virginia	no	NA	1955-2011	X									
VOSARA	VOSARA Oyster Surveys	VIMS/VMRC	Virginia	online access	NA	2000-2019		X	X			X				
WQX	WQX (STORET)	WQX	Multiple states	yes	78	2005-2006	X									

9.4 APPENDIX D: DATASET RANKINGS

Rankings of identified datasets; shaded rows are suspected non-tidal or oceanic datasets that were retained.

Score	Desirability	Availability	Usability	Utility
	Is the data the focus of this project?	How easy to obtain the data?	How usable is the data in the received format?	How pertinent is the data in the current format to the project?
5	Large Extent, Many Years	Easy, Web Download, Email/Call	Easy	Fish Data
4	Large Extent, Few Years	Easy, Email/Call	Slight modification (e.g., extract from GIS)	Habitat
3	Limited Extent, Many Years	Medium, Questioned about use, extent, etc.	Major modifications needed.	Other Biological Data
2	Limited Extent, Few Years	Difficult, multiple contact attempts	Summary only, aggregated, location and/or numbers	Non-biological, Non-habitat
1	Quality Unknown	Unavailable, Non-digital, Old format, etc.	Near Impossible (e.g., non-digital)	Outside of Scope

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
CBF_Education	CBF Educational Field Trips	CBF	4	4	3	5
CBF_LafRv_Trawl	CBF Lafayette River Trawl Surveys	CBF	3	2	NA	5
CBF_WQ_GIS	CBF Educational Field Trips	CBF	4	4	4	2
CBL_Seine	CBL Seine Survey	UMCES	3	4	2	5
CBL_UMCES_seine_vs_trawl	CBL Seine vs Trawl	CBL-UMCES	3	4	4	5
CBL_UMCES_SeineCruises	CBL Seine Cruises	CBL-UMCES	2	4	3	5
CBP_Benthic	Baywide Benthic Database	CBP	4	5	3	3
CBP_Flourescence	Baywide Fluorescence Database	CBP	5	5	4	2
CBP_SAV	Chesapeake Bay Program SAV Synthesis Project	CBP	5	5	2	3

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
CBP_WQ	Chesapeake Bay Program Water Quality Data	CBP	5	5	4	2
ChesMMAP	NOAA ChesMMAP	VMRC	5	4	5	5
CMES_BenthicHabitat	CMES	NOAA	2	4	3	2
DC_Alosine	Washington DC Fisheries Survey	DC Fisheries	2	4	4	5
DC_Codes	Washington DC Fisheries Survey	DC Fisheries	NA	4	5	5
DC_Electrofishing	Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_Fisheries	Washington DC Fisheries Survey	DC Fisheries	5	4	3	5
DC_LMB	Washington DC Fisheries Survey	DC Fisheries	2	4	4	5
DC_Low_Frequency	Washington DC Fisheries Survey	DC Fisheries	2	4	4	5
DC_Push_Net	Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_Rock_Creek	(suspected non-tidal) Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_Seining	Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_Snakehead	Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_STB	Washington DC Fisheries Survey	DC Fisheries	3	4	4	5
DC_WetlandsInv	Washington DC Wetlands Inventory	USFWS	2	5	3	4
DE_Abundance	Nanticoke River American/Hickory Shad Abundance	DNREC	3	2	NA	5

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
DE_Bass	Tidal Bass Population Enhancement and Monitoring	DNREC	3	2	NA	5
DE_NRSA	(suspected non-tidal) National Rivers and Streams Assessment	DNREC	4	2	NA	5
DE_Pond	(suspected non-tidal) Pond Fish Management	DNREC	4	2	NA	5
DE_Restoration	Nanticoke River American Shad Restoration	DNREC	3	2	NA	5
DE_Sturgeon	Nanticoke River Sturgeon Assessment	DNREC	2	2	NA	5
DE_Tidal	Delaware Stream and Tidal Tributary Survey	DNREC	2	2	NA	4
DE_Toxic	Delaware Toxic sampling in Watersheds that Flow to the Chesapeake Bay	DNREC	2	2	NA	2
DE_WetlandsInv	Delaware Wetlands Inventory	USFWS/ DE/CMI	2	5	3	4
DOEE_Mapping	DOEE's Wetland Mapping Project	DOEE	1	NA	NA	4
ICPRB_AmShad	ICPRB American Shad Monitoring Survey	ICPRB	3	3	NA	5
MD_WetlandsInv	Maryland Wetlands Inventory	MD DNR	5	5	3	4
MDDNR_AmShad_H&L	American Shad hook-and-line Survey	MD DNR	2	NA	NA	5
MDDNR_BC_Dredge	Blue Crab Winter Dredge Survey	MD DNR	5	2	NA	3
MDDNR_BC_Trawl	Blue Crab Trawl Survey	MD DNR	5	2	3	3
MDDNR_Choptank_Fyke	Choptank River Fyke Net Survey	MD DNR	3	4	3	5
MDDNR_Choptank_Gill	Choptank River Gill net Survey	MD DNR	2	3	NA	5
MDDNR_FallOysSurvey	Fall Oyster Survey	MD DNR	5	4	5	3

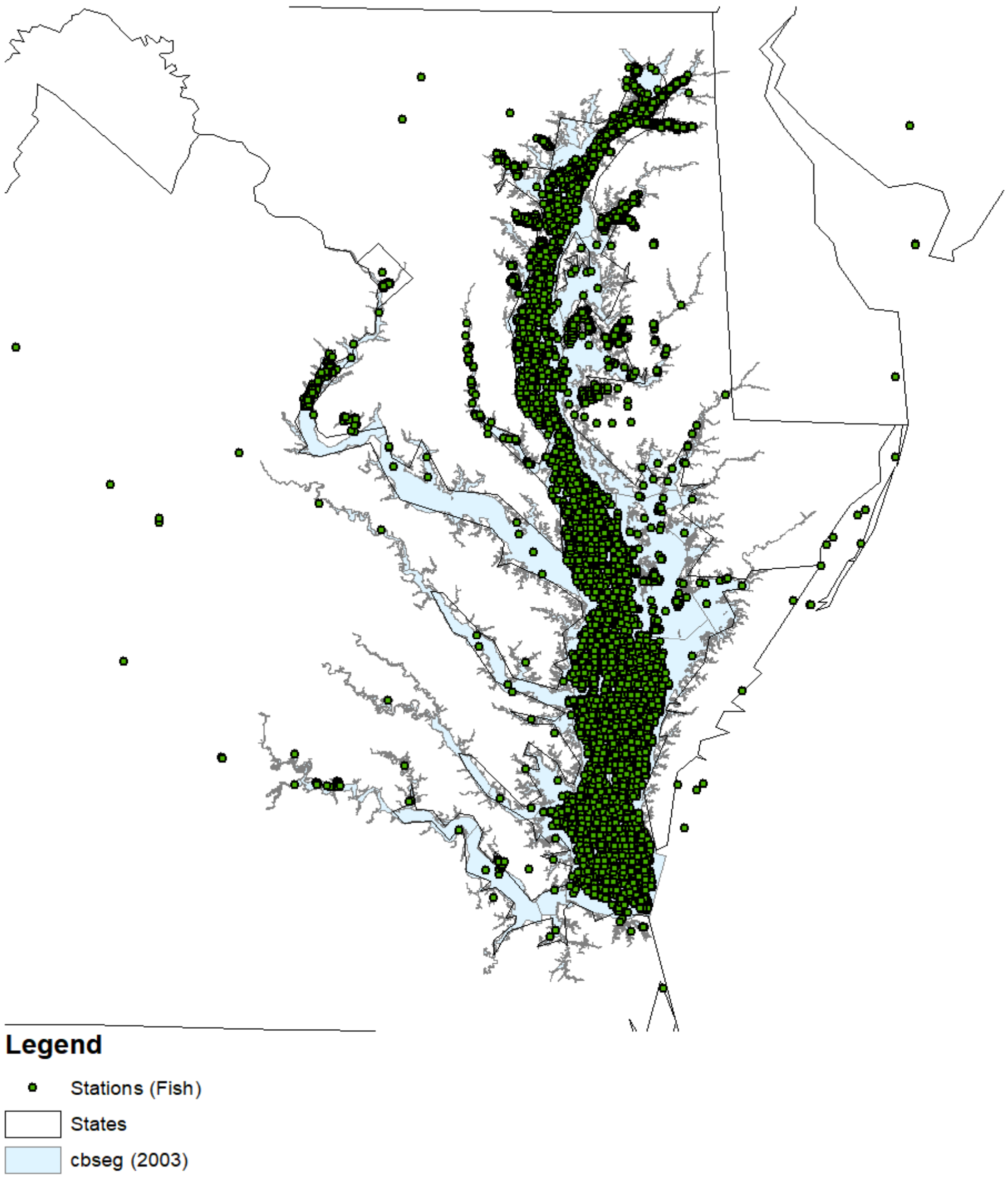
Dataset	Program	Agency	Desirability	Availability	Usability	Utility
MDDNR_FHEP_Seine	Fisheries Habitat and Ecosystem Program	MD DNR	2	4	5	5
MDDNR_FHEP_Trawl	Fisheries Habitat and Ecosystem Program	MD DNR	2	4	3	5
MDDNR_Herring_Seine	Juvenile River Herring Seining Survey	MD DNR	2	3	NA	5
MDDNR_Ichthyo	FHEP Icthyoplankton Sampling	MD DNR	3	2	NA	3
MDDNR_Nanticoke_Fyke	Nanticoke River Fyke net Survey	MD DNR	3	3	NA	5
MDDNR_NE_Gill	North East River Gill Net Survey	MD DNR	2	3	NA	5
MDDNR_Normandeau	Normandeau Associates observation at Conowingo Dam fish lifts	MD DNR	1	NA	NA	5
MDDNR_Patent_Tong	MD DNR Oyster Sanctuary Patent Tong Surveys	MD DNR	4	4	3	3
MDDNR_Potomac_Gill	Potomac Gill Net Broodstock Collection: Anadromous Fish	MD DNR	3	3	NA	5
MDDNR_SB_Seine	Juvenile Striped Bass Program	MD DNR	5	4	5	5
MDDNR_SB_Spring	Striped Bass Program	MD DNR	3	4	5	5
MDDNR_UB_Fyke	Upper Bay Fyke Net Survey	MD DNR	2	3	NA	5
MDDNR_VIMS_OysterCoop	Cooperative oyster monitoring program	MD DNR/ VIMS	3	NA	NA	3
MDDNR_Winter_Trawl	Annual Winter Trawl Survey	MD DNR	5	4	4	5
NOAA_ELMR	NOAA ELMR Mid Atlantic	NOAA	5	5	2	5
ODU_VA_Age&Growth	VA Age and Growth Program	ODU	5	NA	NA	5
ORP_Diver	MD Oyster Restoration Monitoring Diver Surveys	ORP	2	2	NA	3
ORP_PatentTong	MD Oyster Restoration Monitoring & Ground Truthing Patent Tong Surveys	ORP	2	2	NA	3
Oxford_Seine	NOAA Oxford Lab	NOAA Oxford Lab	4	4	5	5

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
Oxford_TA_Seine	Oxford Tred Avon Seine Sampling	NOAA Oxford Lab	2	4	5	5
Oxford_TA_Trawl	Oxford Tred Avon Trawl Sampling	NOAA Oxford Lab	2	4	5	5
Oxford_Trawl	NOAA Oxford Lab	NOAA Oxford Lab	4	4	5	5
PEARL_BC	PEARL Blue Crab Survey	PEARL	3	2	5	3
Riverkeepers	Riverkeepers	Riverkeepers	1	NA	NA	NA
SERC_Benthic	Rhode River Benthic Infauna Survey	SERC	3	1	NA	5
SERC_Herring	(suspected non-tidal) River Herring spawning study	SERC	5	1	NA	5
SERC_Seine	Rhode River Seine Survey	SERC	3	1	NA	5
SERC_Trawl	Rhode River Trawl Survey	SERC	3	1	NA	5
SERC_Weir	Rhode River Weir Survey	SERC	3	1	NA	5
CHESFIMS	TIES_CHESFIMS_PAXFIMS	UMCES	4	4	5	5
TIES	TIES_CHESFIMS_PAXFIMS	UMCES	4	4	5	5
PAXFIMS	TIES_CHESFIMS_PAXFIMS	UMCES	2	4	5	5
UMD_Oyster	Choptank oyster restoration site monitoring	UMD	2	2	NA	3
USFWS_BW	Blackwater/Little Blackwater River Fyke Netting	USFWS	2	4	3	5
USFWS_Inv	Inventory of Fish Species within Dyke Marsh	USFWS	2	1	NA	5
USFWS_Pinkney	Multiple fish surveys	USFWS	1	NA	NA	5
USFWS_Potomac	Potomac Shad sampling	USFWS	3	4	4	5
USFWS_YellowPerch	Yellow Perch Fyke Netting	USFWS	2	4	4	5
VA_WetlandInv	Virginia Wetlands Inventory	VA DCR	4	5	3	4
VADGIF_James	James River American Shad stocking	VA DGIF	3	3	NA	5
VADGIF_Rapp	Rappahannock River American Shad stocking	VA DGIF	3	3	NA	5

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
VECOS	VECOS (Virginia Estuarine and Coastal Observing System)	CBNERR/ VIMS/ William &Mary	5	5	NA	5
VERSAR_Oyster	MD Oyster Pre-Restoration Monitoring and Ground Truthing Patent Tong	NOAA CBO/ VERSAR	2	4	2	3
VIMS_AmShad	American Shad monitoring	VIMS	3	2	NA	5
VIMS_AtSurfClam_Quahog	(suspected non-Chesapeake Bay) Molluscan Ecology Research-Atlantic Surf Clam and Ocean Quahog	VIMS	5	NA	NA	3
VIMS_BC_Dredge	Blue Crab Winter Dredge Survey	VIMS	5	2	NA	3
VIMS_BlueCat_Move	Blue catfish movement study	VIMS	2	2	NA	5
VIMS_BlueCat_Pop	Blue catfish population and survival study	VIMS	2	2	NA	5
VIMS_CTILS	CTILS (Chesapeake Bay Trophic Intersections Lab Services) Program	VIMS	4	NA	NA	5
VIMS_Eel	Eel YOY Survey	VIMS	1	2	NA	5
VIMS_Herring_Gill	Adult Herring monitoring	VIMS	2	2	NA	5
VIMS_Herring_Juv	Juvenile Herring and American Shad monitoring	VIMS	2	2	NA	5
VIMS_MDShoreline_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	4	3	3	4
VIMS_NEAMAP	NEAMAP	VIMS	1	5	NA	5
VIMS_Oyster_Dredge	Molluscan Ecology Research-Oysters Dredge	VIMS	5	2	NA	3
VIMS_Oyster_PatentTong	Molluscan Ecology Research-Oysters Patent Tong	VIMS/ CNU	5	2	NA	3
VIMS_Oyster_Shellstring	Molluscan Ecology Research-Oysters Shellstring	VIMS	5	2	NA	3

Dataset	Program	Agency	Desirability	Availability	Usability	Utility
VIMS_SAV	SAV Mapping Program (Aerial survey data)	VIMS	3	5	5	4
VIMS_SB	Striped Bass Monitoring and Tagging	VIMS	3	2	NA	5
VIMS_Seine	Juvenile Striped Bass Survey	VIMS	5	4	2	5
VIMS_Trammel	Trammel Net Survey	VIMS	1	2	NA	5
VIMS_Trawl	Juvenile Fish and Blue Crab Trawl Survey	VIMS	5	4	2	5
VIMS_Trout	Acoustic Tagging of Speckled Trout	VIMS	2	2	NA	5
VIMS_VAShoreline_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	4	3	3	4
VIMS_VATidalMarsh_Inventory	VIMS Shoreline and Tidal Marsh Inventory	VIMS	4	3	3	4
Virgina_Seine	1967-2010 Virginia Major tributaries in lower Chesapeake Bay Seine	NEFSC	5	2	NA	5
Virgina_Trawl	1955-2011Virginia Lower Chesapeake Bay and major tributaries Bottom Trawl	NEFSC	5	2	NA	5
VOSARA	VOSARA Oyster Surveys	VIMS/ VMRC	5	5	4	3
WQX	WQX (STORET)	WQX	4	5	5	5

9.5 APPENDIX E: MAP OF SURVEY SITES FROM DATASETS THAT PROVIDED GPS COORDINATES OF SITE LOCATIONS



** plotted points outside of study area are attributed to surveys whose survey sites go beyond the tidal Chesapeake Bay*