

Existing Longitudinal Data and Systems for Measuring the Human Dimensions of Resilience, Health, and Well-Being in the Gulf Coast

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Table of Contents

1. INTRODUCTION	4
1.1 The Capitals Framework	4
1.2 The Value of Measuring Community Resilience	5
1.3 Report Organization.....	6
2. APPROACH	6
2.1 Identification of Existing Longitudinal Resilience Data Systems.....	6
2.2 Systematic Assessment of Data Systems	7
2.3 Applying Expert Consensus Procedures to the Pedigree Analysis.....	9
2.4 Elimination of Data Systems from Further Review	10
3. ASSESSMENT RESULTS	13
3.1 Data Repositories for Understanding Resilience	13
3.2 Standalone Data Systems.....	13
3.3 Characteristics of Repositories and Data Systems.....	13
3.3.1 Relevance	14
3.3.2 Accessibility.....	15
3.3.3 Spatial, Temporal, Collection Properties	15
3.3.4 Gulf States Availability	16
3.4 Capital Specific Assessments	16
4. GAPS IN RESILIENCE DATA	17
4.1 Gaps based on Crosswalk Analysis.....	17
4.2 Gaps based on Pedigree Analysis.....	21
4.3 Identification of Gaps based on Proxy Variables	22
5. KEY MESSAGES	23
6. OPPORTUNITIES FOR INVESTMENT	25
7. REFERENCES	28
Appendix 1	32
Appendix 2	33

1. INTRODUCTION

The Gulf Research Program (GRP)'s mission is to support research, environmental monitoring, and education/training to catalyze advances in science, practice, and capacity to generate long-term social benefits for the Gulf of Mexico region and the nation in advancing 1) safer offshore energy systems, 2) healthy ecosystems, and 3) thriving communities. Given the 30-year planning and funding horizon, the GRP sought input on existing longitudinal data systems in the Gulf Region that routinely collect data that can inform the understanding of and changes in community resilience, health, and well-being. This commissioned white paper outlines the availability, accessibility, operability, and gaps of existing longitudinal data systems that address key aspects of community resilience. In doing so, the white paper highlights opportunities for long-term investments that can enhance capacity for monitoring community resilience in the Gulf Region.

This study draws on a conceptual framing of “community” as a dynamic system of systems that function individually and at different spatial scales but are interdependent and must work together to produce resilient places. A community is a geographically defined assemblage of people and the systems that support them at sub-state levels of jurisdiction. The National Academies’ definition of community resilience guides this review,

“[...] resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events” (NRC 2012, p. 1).

Meaningful measurements of resilience must therefore be both place specific and temporally expansive to account for changes over time and across space. Such measurements must also differentiate between measuring resilience as a process or outcome (Cutter 2016), the latter including the absence or presence of negative effects or positive attributes (Patel et al. 2017). Given the breadth of potential measurements, the GRP limited the scope of this study to the Gulf Coast and longitudinal “projects of five or more consecutive years (continuous or cross-sectional collected information) that track social, economic, and/or behavioral factors associated with understanding human dimensions of resilience, health, and/or well-being.”¹

For clarification purposes, data systems refer to the overarching collection system (goals, methodology, sampling, storage, access). These systems provide datasets defined as related facts or information in quantitative or qualitative forms. A dataset is a collection of related data tabular or matrix form such as in rows and columns or in some ordered collection (e.g., alphabetical, chronological). This definition of dataset includes qualitative data such as photographic, oral histories, etc., which provide important sources of understanding resilience as a process. Such catalogued qualitative data are often searchable online in tabular form, and as such fit our definition of dataset.

1.1 THE CAPITALS FRAMEWORK

The concept of capitals — the differing assets or resources to support community development — is widely used for understanding community development, reaching sustainable goals, and understanding resilience (Flora et al. n.d.; Ritchie et al. 2011). There is an emergent consensus on the basic forms of capital with widespread usage across many different disciplines. In the community

¹ Statement of work from the Invited Proposal Request for Proposals “Longitudinal Data Project for Resilience: Identifying Existing Longitudinal Data and Systems.” April 2018.

resilience field, these capitals generally fall under six broad thematic areas (Ritchie and Gill 2011; Cutter et al. 2014; Miles 2015; NIST 2016; NASEM 2019):

Natural/Environmental: This capital includes the natural resources that provide for the basic development of communities and the environmental conditions that enhance or detract from that development.

Built Environment/Infrastructure: The buildings and infrastructure that support a community's residential, commercial, and industrial sectors and the quality of those assets.

Financial/Economic: The totality of economic assets and conditions within communities that provide livelihoods, economic investment, and wealth.

Human Well-Being/Cultural: The cultural, demographic, physical, and psychological attributes of populations in terms of health, mental health, behavior, knowledge, skills, and cultural mores that enable community members to function.

Social/Community: The social connectivity and social networks within a community as evidenced by a sense of place or belonging to the community, social networks, religious affiliations, engagement in community service and so on.

Political/Institutional/Governance: The suite of institutions and governmental programs that provide access to resources and their distribution to facilitate community goals such as public safety, as well as collective community experiences, and engagement with the political process.

Communities differ from one another physically, economically, and socially. These differences lead to considerable spatial and temporal variability within and between communities which influence the impacts of disasters and the communities' abilities to respond to them. For example, when using the capitals approach for understanding resilience, the relative importance of the distinct capitals manifests itself differently not only between urban and rural places, but also geographically (Cutter et al. 2016). Given that resilience is a dynamic process, the measurement of and relative importance of the capitals shift over time (Cutter and Derakhshan 2018). Furthermore, the six capitals, while measured independently, are in fact, interdependent on one another in characterizing community resilience.

1.2 THE VALUE OF MEASURING COMMUNITY RESILIENCE

Measuring resilience is a prerequisite for informed community management and cuts across all areas of a community ranging from health, education, food security, housing, and public safety, to sustainable development and climate change adaptation. Understanding what drives community resilience and how it manifests itself locally provides not only opportunities for targeted investments, interventions, and risk reduction, but also increases awareness, accountability and transparency within a community (NASEM 2019). While a one-time resilience assessment establishes a baseline of a community's resilience, mainstreaming the use and utility of resilience measures into community planning and decision-making transforms resilience measures into performance metrics that can track advancement or deterioration of resilience over time and across space. This empowers communities to identify hotspot areas of low resilience, design transformational policies, and implement outcome-driven interventions. At a more granular level, measuring resilience even allows communities to design

investment strategies and screen community projects based on the highest resilience return on investment.

Along the Gulf of Mexico, each community's resilience differs based on variations in the underlying driving forces of resilience that are rooted in the history, environment, culture, economy and people that have shaped the community and their collective capacities to manage shocks and stressors. While some communities may be more resilient to sporadic, external shocks such as hurricanes or technological disasters, others have successfully managed to reduce chronic stressors such as high crime or poverty (Rodin 2014). It is important, therefore, to identify what makes a community more resilient, implement best practices and approaches to enhance it, and assess the outcomes. To accomplish this, some type of measurement scheme is needed along with data to support it.

1.3 REPORT ORGANIZATION

Section 2 details the methodology for the identification of longitudinal data systems and assessment criteria used in this report. The next section (Section 3) provides a narrative summary of the assessment of longitudinal data systems. Section 4 describes the gaps in the existing longitudinal data that are collected with the key messages of the report described in Section 5. The report concludes with a short discussion of the investment opportunities to support longitudinal data efforts by the Gulf Research Program including the creation of new datasets or the re-purposing of ongoing projects/activities to support resilience measurement in coastal environments. The full matrix is saved as an Excel spreadsheet. [<https://docs.google.com/spreadsheets/d/1kpHlgtpla0QUpcQFVrylF3mfYEBDypdQdal4cWDiOwo/edit#gid=1008311850>].

2. APPROACH

The methodology included both inductive and deductive approaches and was informed by the research team's extensive knowledge of community resilience research and its measurement, local knowledge of the Gulf States region, and years of practical and field-based experience in the region. Three distinct elements characterize this methodology:

- 1) Identification of existing and ongoing resilience-related longitudinal data systems using a capitals approach;
- 2) Systematic assessment of the data systems and their captured data based on
 - a. Relevance (e.g., capital covered, concepts measured, type of data)
 - b. Accessibility (e.g., open source, specialized access required, cost)
 - c. Temporal and spatial resolution (period of coverage, spatial coverage)
 - d. Availability (coverage of Gulf States);
- 3) Description of data gaps and other issues related to the utility for monitoring the human dimensions of resilience, health, and well-being in the region.

2.1 IDENTIFICATION OF EXISTING LONGITUDINAL RESILIENCE DATA SYSTEMS

The identification of existing longitudinal data systems entailed both inductive and deductive elements. The inductive strategy consisted of:

- 1) Compilation of existing datasets relying on the research team's collective knowledge of the field of resilience metrics, federal data repositories such as the U.S. Census, Centers for Disease Control and Prevention (CDC), National Oceanic and Atmospheric

Administration's (NOAA) Digital Coast, and published review articles and reports (e.g., Ostadtaghizadeh et al. 2015; Beccari 2016; and Sharifi 2016); and

- 2) Bibliographic searches for relevant projects and data using *Google Scholar* and *Web of Science* supplemented with searches of federally-funded projects from the National Science Foundation (NSF), National Institutes of Health (NIH), U.S. Environmental Protection Agency (USEPA), National Aeronautics and Space Administration (NASA) and NOAA among others following a previously-developed review methodology and bibliometric analytics (Gall et al. 2015).

Given the specific interest in Gulf of Mexico communities, the team solicited locally- and regionally-specific datasets as part of the inductive search plan. The team had sufficient research experience and contacts in the Gulf States along with access through university libraries to ascertain which longitudinal datasets were available that originate locally or regionally. However, we also recognized that such a "global" search may have overlooked some smaller research studies with longitudinal datasets. To remedy this, we enhanced our dataset identification using a regionally-specific bibliographic search focusing on the northern Gulf of Mexico region and the states bordering it — Texas, Louisiana, Mississippi, Alabama, and Florida — involving both published and grey literature. We also reviewed local data repositories hosted by universities, state agencies, or nonprofits including the Texas Data Repository, Mississippi-Alabama Sea Grant Consortium, and SNAPSHOTS: Mississippi's Health Data Source.

The deductive approach began with known resilience indicators (based on published review articles). A targeted search of federal, public, and other data depositories for longitudinal data that might be applicable but do not routinely appear in resilience indicator studies to date followed. An illustrative example in the area of natural capital is the U.S. Department of Agriculture (USDA)'s Landfire Program, which is a repository of data products ranging from foundational data on vegetation cover, vegetation disturbance, and historical fires, to fuel data.

The combination of both inductive and deductive identification of relevant datasets ensures coverage longitudinally (e.g., five or more consecutive years of cross-sectional or continuous data collection) and thematically (tracking all capitals) illuminating the human dimensions of resilience, health, and/or well-being. This study identified 259 datasets and repositories for assessment.

2.2 SYSTEMATIC ASSESSMENT OF DATA SYSTEMS

The study utilized a crosswalk matrix evaluation procedure to assess culled identified longitudinal data systems (Patton 2008; FEMA 2012; Lyles and Stevens 2014). This approach enabled the subject matter experts (SMEs), in our case the senior team members, to systematically evaluate data systems. Four broad criteria: **relevance**, **accessibility**, **temporal/spatial properties**, and **availability** were the main components in the matrix with sub-criteria in each.

The matrix captured categorical (e.g., yes/no, type of capital) or descriptive phrases for each crosswalk item. A codebook developed for this study facilitated consistency in the categorical and descriptive phrasing. Along with the evaluation criteria, documented reference information such as citations or URLs, observations by the subject matter experts, and other supplemental information was included in a notes section. For example, if a dataset was not freely available (as indicated by a YES in item 3.3 under the cost criterion), then the assessor provided either the URL for pricing information in the matrix itself or added information about the dataset's cost in the notes section.

The subject matter experts (SMEs) evaluated each of the datasets in their domain area (e.g., financial/economic, human well-being/cultural) according to the crosswalk and served as a reviewer of at least one other capital area. This was done to reduce any unintentional biases in the evaluation and established good quality control and assurance (QA/QC) in the initial matrix.

The first assessment criterion, **relevance**, examined each dataset to evaluate specific resilience concepts (e.g., social connectivity, health status) and to identify specific proxy variables used to measure them (Beccari 2016; Ostadtaghizadeh et al. 2015; Sharifi 2016). We focused on both assets/attribute data as well as capacities/access data and information. In addition to resilience concepts and specific variables, other sub-parameters included the type of data (e.g., qualitative, quantitative) as well as the enumeration unit (e.g., individual, city, county) (Table 1).

Table 1 Assessment Criteria and Sub-criteria

Criterion: Relevance

1. type of resilience capital—social, cultural, infrastructure, etc.
2. resilience concept—social capital, health access, sense of place, etc.
3. sample resilience indicators—housing burden, elderly population, social security recipients
4. type of data—numeric, geographic, qualitative
5. enumeration reporting unit (i.e. finest scale available)—individual, household, city, county, state, nation

Criterion: Accessibility

1. open source or proprietary
2. digital or hard copy
3. cost (i.e. cost to access data itself)
4. confidentiality requirements (i.e. confidentiality restrictions to access)
5. special requirements for access (training, governmental certification/approval)
6. type of data available for download (spatial, tabular, other)

Criterion: Spatial, Temporal and Collection Properties

1. spatial coverage—national, regional, local
2. temporal coverage
3. collection type (e.g., single observation, panel or repeat, continuous)
4. time intervals (periodicity) of updates—annual, monthly, daily, hourly
5. spatial identifiers or spatially enabled—FIPS code, coordinates (longitude/latitude)

Criterion: Availability for Gulf States

1. coverage of Gulf States (complete or partial)
 2. individual state coverage
-

The **accessibility** criterion addressed variables such as the source of the relevant dataset, specialized requirements for access or retrieval, and other general issues related to operability. The notion of operability of datasets elicited **spatial, temporal, and collection properties**, which are important considerations in interoperability of datasets across domain areas. Table 1 lists the sub-criteria for accessibility and spatial/temporal coverage for each dataset.

The **availability** criterion captured access to downscaled data from national datasets and spatial coverage within each of the Gulf Coast states. For example, national public opinion polls generally cannot be downscaled to state, county, or local scales unless that was part of the initial research design. While the initial assessment of the spatial coverage of the datasets served as its own criterion, we further

analyzed the specific geographic extent of coverage by individual Gulf community, county, state, or the entire region.

While the crosswalk matrix provides a stand-alone, in-depth assessment of the content of each identified data system, it may not yield all the answers GRP is after regarding a systematic evaluation of longitudinal datasets for characterizing the human dimensions of resilience, health, and well-being in coastal environments. This study used the crosswalk matrix as input into a comparative evaluation across all the relevant datasets using the NUSAP/Pedigree Analysis approach. The **NUSAP** (Numeral Unit Spread Assessment Pedigree), is a notational-type system originally developed by Funtowicz and Ravetz (1990) to aid in the description of scientific uncertainty in risk modeling. The NUSAP incorporates quantitative data (**N**umeral or number, **U**nit or the measurement units such as percentage, dollars, and **S**pread or the margin of error in the numeral value). **A**ssessment integrates quantitative (statistical significance) or qualitative (high or low confidence) judgements about the information, while **P**edigree examines the information source in terms of originator (direct survey, indirect estimate), conceptual framing, etc. providing a series of quality judgements comparing across data/systems.

The entire NUSAP system synthesizes criteria across datasets (Sluijs et al. 2005), but in this analysis the Pedigree approach and scoring were used for the identification of the datasets in terms of how central the data are to measuring resilience, how widely used the dataset is in resilience studies, the data's uniqueness or opportunities for innovation, the overall quality and reliability of the dataset for measuring the human dimensions or resilience, health, and well-being, and the long-term availability of the dataset over the next 30 years.

The Pedigree uses a matrix form with scores/grades assigned to specific quality criteria as determined by the researchers or clients, in this case GRP. The criteria employ qualitative judgements which then convert to scores or grades for ranking purposes. The Pedigree criteria for this study consisted of five categories along with suggested scoring levels, listed in Table 2.

2.3 APPLYING EXPERT CONSENSUS PROCEDURES TO THE PEDIGREE ANALYSIS

After each independent rater provided the initial pedigree ratings, a formal consensus building procedure began. The goal of the expert consensus building was to (1) resolve any significant interrater discrepancies, and (2) form consensus from the panel on the strengths and weaknesses of the various datasets and systems. A number of formal methods for developing consensus among panels of experts are available, including the Delphi process, consensus development conferencing, and the nominal group technique (i.e. the expert panel) (Minas et al. 2010). Such methods typically derive summative, quantitative estimates through qualitative approaches and harness the accumulated experiences and knowledge of diverse experts (Jones and Hunter 1995). The premise of consensus building procedures assumes that individuals who have a high level of content knowledge and familiarity with a well-defined rating instrument should produce similar ratings (Jaffery et al. 2015).

For the current study, the expert panel engaged in formal consensus building over the course of a two-week period. Each of the 259 datasets was assigned to two experts to rate using the Pedigree Matrix, providing scores ranging from 1 to 4 across the five Pedigree Analysis content areas (i.e. Centrality, Acceptance, Innovation, Reliability, Long-term Availability). All experts had the entire crosswalk matrix for review when making their initial ratings. The crosswalk matrix included detailed information on each dataset (e.g., type of capital represented, sample variables, frequency of data collection, accessibility). Expert panel members were also able to consult external sources of information if needed (e.g., original source, previously published literature), in order to inform their initial set of ratings. Next, interrater

reliability was examined by comparing the scores of each pair of raters. Rater agreement was operationalized as having assigned identical scores or scores that differed by no more than 1 point; rater disagreement was defined as having assigned scores that differing by >1 point. Interrater reliability (i.e. total agreements / total opportunities for agreement) was then calculated, yielding an initial overall interrater reliability of 89.6%. Paired ratings that reached the desired level of consistency (i.e. ≤ 1 point difference between raters) were systematically reviewed and aggregated to yield final Pedigree Analysis rating scores.

Table 2 Pedigree Analysis Categories and Scoring Levels

Category	Scoring Levels			
	1	2	3	4
<i>Centrality:</i> How important is the dataset to measuring resilience?	Not at all	Peripheral	Relevant	Central
<i>Acceptance/Current Use:</i> How widely used is the dataset in resilience studies?	Seldom	Sometimes	Often	Almost always
<i>Innovation:</i> What are the opportunities of these datasets to contribute new insights into resilience?	Redundant and repetitive with no new insights	Trivial with marginally new insights	Moderate with good potential for new insights	Radical with great potential for new insights
<i>Reliability:</i> What is the level of confidence in the dataset to produce reliable and verifiable information?	None	Low	Medium	High
<i>Long-term Availability:</i> What is the likelihood that the dataset will continue to be updated over the next 30 years?	Very Unlikely	Unlikely	Likely	Very likely

Pedigree Analysis ratings that did not reach the desired level of consistency were then reviewed and rescored using the following consensus building procedure. Initially, the full expert panel met to discuss the Pedigree Matrix and ensure that all members understood the five criteria and scoring definitions. Next, all pairs of raters with discrepant scores (i.e. >1 point difference) held in-person or virtual consensus building sessions that lasted between 5- and 45-minutes depending on the number of discrepancies that needed to be resolved. Previous work suggests that holding consensus building discussions after initial rounds of independent rating is an effective approach for resolving differences and improving agreement between rater teams (McIntyre et al. 1984). During these consensus building sessions, the pairs explained the rationale behind their initial score and then discussed potential reasons for the rating discrepancy before finally agreeing on a consensus score. Aggregated consensus scores were added to the Pedigree Analysis scoring chart, yielding a complete set of final ratings for every dataset.

2.4 ELIMINATION OF DATA SYSTEMS FROM FURTHER REVIEW

After the detailed analysis by SMEs and the Pedigree Analysis, 96 of the original datasets (37%) were eliminated from further examination. There were multiple criteria for elimination of datasets, but the two most important were: (1) they did not have longitudinal data (at least five years, a requirement

set forth by the GRP in the original Statement of Work for this project) (54%); or (2) they had low spatial resolutions or included data only at the national level (20%). Such data, while useful for providing a broader context on national averages, could not be downscaled to examine differences between the Gulf Region and other U.S. regions, between individual Gulf States, or among specific Gulf communities. A review of the reasons for elimination is illustrated in Figure 1. A complete list of discarded datasets is included in the full matrix available online.²

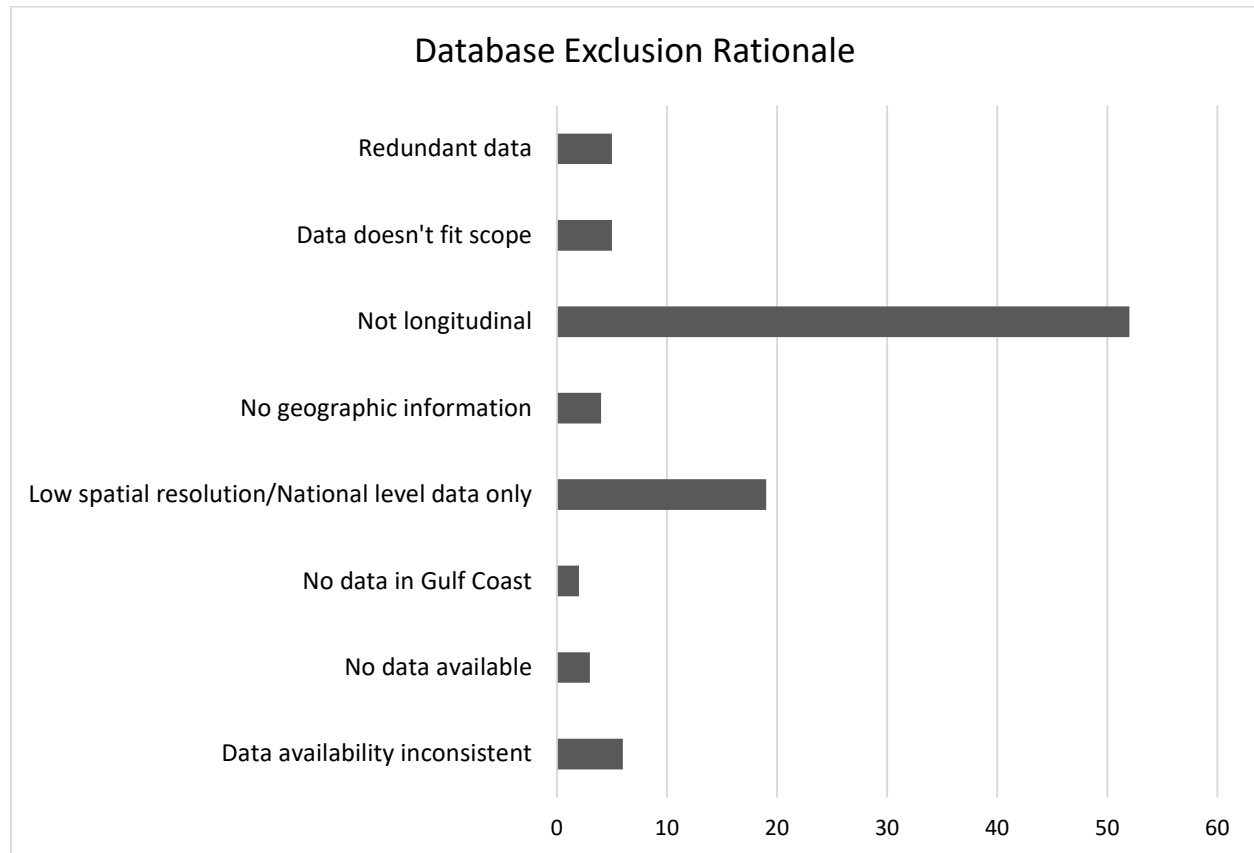


Figure 1 Reasons for discarding datasets (n=96) from further analysis.

While a lack of longitudinal (i.e. over 5 years) data was the most frequent reason to exclude datasets from further analysis, it is important to note that many excluded datasets contained interesting features that could inform future resilience studies. Several datasets, such as Climate Central’s Surging Seas, the Department of Health and Human Services (HHS)’s Empower map, and the Childhood Opportunity Index, provided interesting insights into resilience, but captured data at only one moment in time, thereby not fulfilling our requirement of the dataset containing 5+ years of data. Other datasets did not include data at a sufficient spatial scale relevant to a regional or local analysis of the Gulf Coast. Examples include Transparency International’s Corruptions Perceptions Index and the CDC’s National Survey of Family Growth, which only provide national level data and/or national estimates. Some other datasets were eliminated because of redundancy. For instance, the CDC’s National Immunization Survey

²<https://docs.google.com/spreadsheets/d/1kpHlgtpla0QUpcQFVryIF3mfYEBDypdQdal4cWDiOwo/edit#gid=1008311850>

– Flu (NIS-Flu) was eliminated as it contains aggregated data from three other datasets (i.e. NIS-Child, NIS-Teen, NIS-Influenza) that were all included in the master list of datasets and assessed separately.

The distribution of the capitals between the retained and discarded datasets remained essentially the same with the human well-being/cultural having the greatest number, and environmental/natural having the fewest (Figure 2). The raw number of datasets within a given capital is not a measure of quality or comprehensiveness of measuring resilience; however, it is simply used as an aggregate reference of each capital’s coverage.

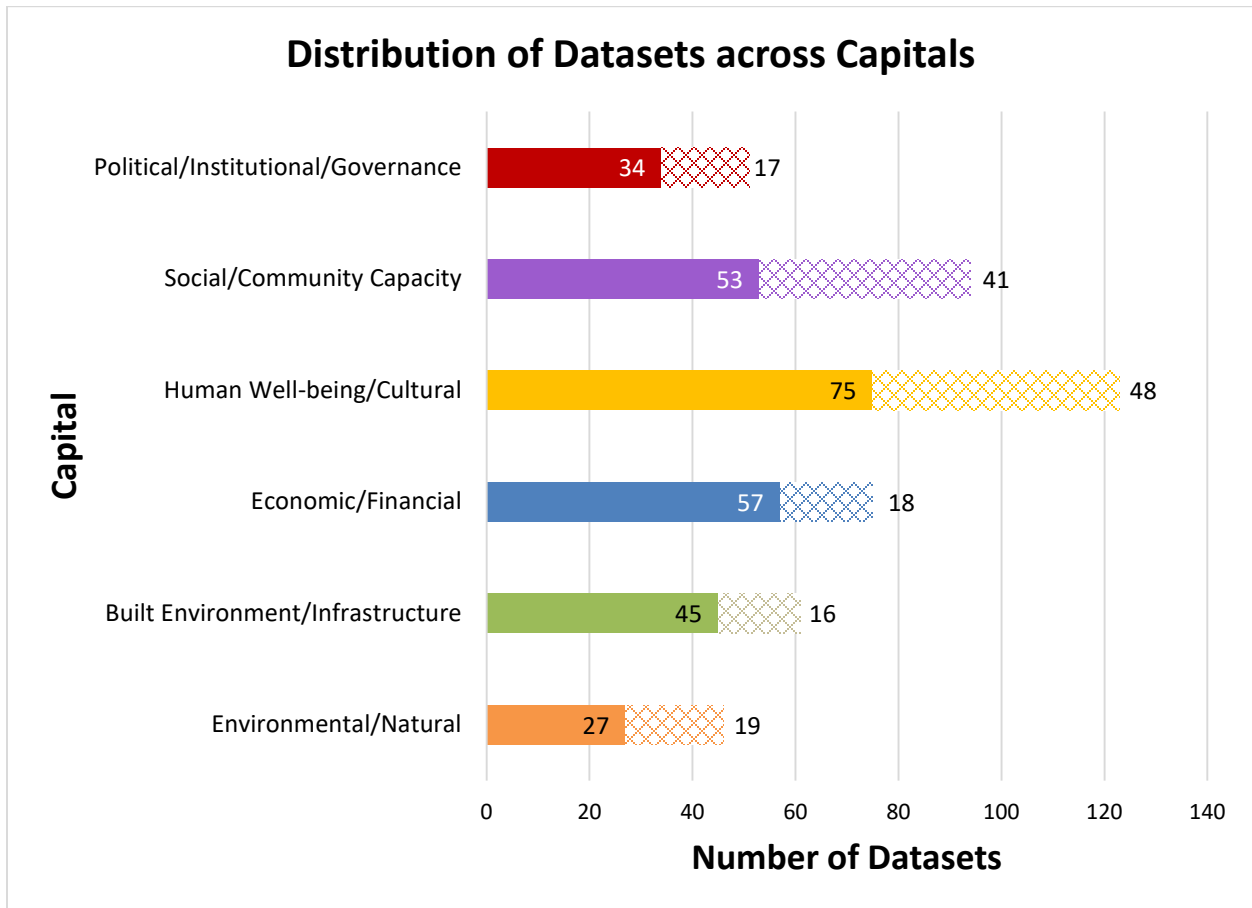


Figure 2 Distribution of all datasets (n=259) across the six capitals. Some datasets represent multiple capitals, so the total number by capital is greater. Hatched lines represent discarded datasets.

Several projects capturing data on human resilience recently funded by the Gulf Research Program were also reviewed by SMEs. While many of them would fit the relevance criteria to be included in the current study; they did not meet other criteria for inclusion, such as the requirement for longitudinal data availability (five years) or requirements related to geographical scale (spatial and temporal properties). For example, projects funded under the "Understanding of Gulf Ocean Systems Grants" provide data for the environmental resilience capital, but they are directed towards specific locations and limited to certain timeframes. Another example is the projects funded under the category of "Capacity Building Awards" which are primarily focused on middle-to-high school student outreach and education, but lack longitudinal surveys. Projects under "Thriving Communities Grant Awards" focus on specific locations, direct community engagement, and policy implementation, while "Healthy Ecosystems Grant

Awards” projects concentrate on local restoration projects and policies. However, neither meet the temporal inclusion criteria of this study.

3. ASSESSMENT RESULTS

The review of the 163 datasets that met the inclusion criteria found a variety of types of datasets ranging from those that included multiple capitals to those that were specific to one capital. These included large national surveillance systems with multiple datasets, sector or regionally specific efforts, or collections of datasets and standalone projects. The diversity also included a range of qualitative and quantitative datasets derived from physical measurements to population samples.

3.1 DATA REPOSITORIES FOR UNDERSTANDING RESILIENCE

Among the 163 datasets, 58 were data compendiums containing multiple data systems that could be used to assess and monitor resilience. We term these **repositories** as they are essentially collections of datasets stored in one central location. Datasets are not necessarily added to the repository by the data collector, developer, or publisher, but by the repository host, such as the Florida Geographic Data Library (FGDL). FGDL provides a collection of other datasets from many publishers, for instance the U.S. Geological Survey, Florida Department of Environmental Protection, Federal Emergency Management Agency, or U.S. Department of Transportation. In other instances, the repository host may be the data collector or associated with the data collector, such as the CDC’s National Vital Statistics System (NVSS), which contains vital statistics collected and disseminated by the National Center for Health Statistics through inter-jurisdictional collaboration. A repository may or may not include variables spanning multiple capitals. For instance, while FGDL contains datasets such that the multiple variables contained within them address different aspects of resilience in all six of our defined capitals. NVSS on the other hand, is a collection of multiple datasets containing variables associated with only the human well-being/cultural capital.

3.2 STANDALONE DATA SYSTEMS

Most (n=105) of our datasets are standalone data systems (i.e. not a collection of multiple datasets). For instance, the USDA’s National Agricultural Statistics Service provides a single dataset on crops - the Cropland Data Layer (CDL) - spanning from 1997 to 2018. Standalone data systems may be listed in multiple data repositories, and as such, may not be directly represented in our assessment if we felt it appropriate to analyze the repository within which they may be contained. For instance, standalone geographic data on Electric Power Transmission Lines developed and published by Oak Ridge National Laboratory is not directly included in the crosswalk matrix but is included in FGDL and Homeland Infrastructure Foundation Level Data repositories (which we have included). Similar to repositories, standalone data systems may or may not span multiple resilience capitals. CDL, for example, represents only the environmental/natural capital. On the other hand, the U.S. Census Bureau’s American Community Survey is an extensive, comprehensive, standalone data system containing variables spanning economic/financial, human well-being/cultural, and social/community capitals.

3.3 CHARACTERISTICS OF REPOSITORIES AND DATA SYSTEMS

The crosswalk matrix assessed the datasets and systems using the four main criteria – relevance, accessibility, spatial/temporal/collection properties, and availability for the Gulf Coast. Each are detailed below along with some of the sub-criteria.

3.3.1 Relevance

Initially, we reviewed the 163 datasets that met the inclusion criteria to assess the relevance of the dataset for measuring resilience. This included coding which capital(s) were measured by the dataset, as well as identifying resilience-related constructs and sample variables. Categorical coding was also used to define what type of data were collected by the system (e.g., numeric, geographic, qualitative) and to identify the finest scale at which data were available.

Across the 163 datasets, the number measuring only one capital of resilience (e.g., natural/environmental or social/community) was almost exactly equal to those measuring more than one capital (82 datasets vs. 81 datasets, respectively) (Figure 3a). Three datasets (2%) covered such a wide variety of concepts that the contained measurements represented all six capitals. Among the six capitals, human well-being had the most datasets (Figure 2), with 75 (46%) capturing some aspect of well-being and culture. This was likely due to the large number of health-related surveillance systems maintained by the CDC and state public health agencies that collect vital statistics and health indicator data for federal and state purposes. Among the other capitals, social/community capital (32%) and economic/financial capital (35%) were represented more frequently across the datasets than the built environment/infrastructure (28%), political/institutional (21%), and environmental/natural capital (17%).

Each of the six capitals was represented by a diverse range of constructs that have been previously identified through either theoretical or empirical work as predictors of resilience. For example, the human well-being/community capital included broad constructs such as individual health status, access to healthcare, and exposure to environmental toxins (Chandra et al. 2011). Specific indicators used to operationalize the capitals concepts are described later (see Section 4.3).

We next identified several sample variables measured by each dataset. A full listing of all variables included in each dataset was beyond the scope of this project, as numerous systems included thousands of variables within them. However, the crosswalk analysis provides a clear conceptual framework for resilience that moves from broad capital (e.g., environmental/natural) to resilience indicator (e.g., environmental quality) to specific resilience-related variable (e.g., proximity to toxic air pollutant source).

The vast majority of systems (83%) collected only quantitative (i.e. numeric) data. However, we also identified some systems that collected geographic (2%), qualitative (4%), or contained multiple types of resilience-related data (11%; Figure 3b). A final important consideration for relevance of data systems was the granularity of data, the lowest level of data available for analysis. As shown earlier (Figure 1), lack of granular spatial resolution was a frequent reason why datasets were excluded from final analysis, with 19 out of 96 eliminated systems using the nation as the unit of analysis. Among systems that we did include in the final sample, they varied widely in their unit of analysis and, by extension, their scale. Systems that included environmental data frequently reported highly granular data (e.g., geocoded climate data from the National Centers for Environmental Information). In contrast, the finest level of analysis for many of the human well-being/community systems was state or county level data.

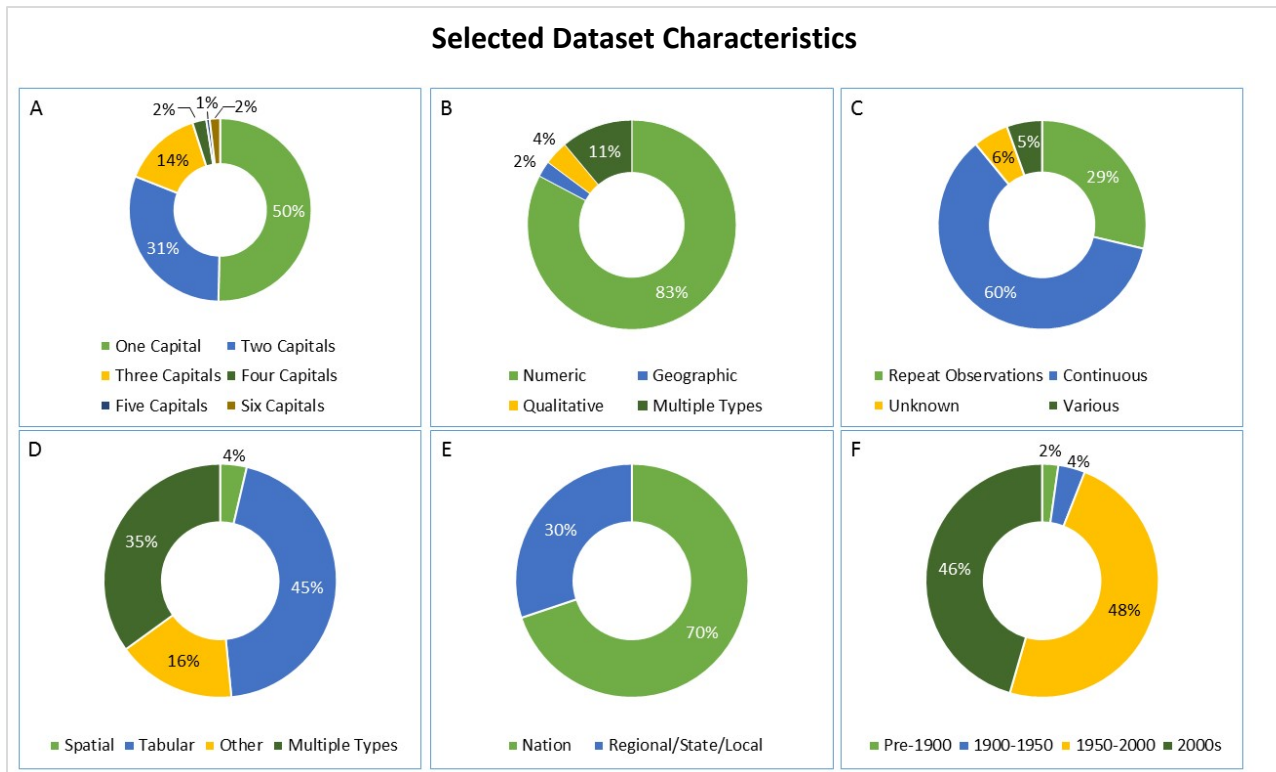


Figure 3 Dataset characteristics including A) number of capitals represented; B) data types; C) collection methods; D) download options; E) coverage; and F) data collection start year.

3.3.2 Accessibility

Accessibility to datasets is high overall, with little variability. Most datasets are open access (88%), found in digital form online (99%), free to use (92%), and have no confidentiality restrictions (95%) or special requirements to access (90%), thus making the datasets easily accessible to researchers interested in resilience data for Gulf States. Two data systems (local government building permits and local coastal zone management permits) are only available in hard copy form. While some communities might have an internal dataset from which to easily access this type of data, collecting such localized data for some communities might require a visit to local government offices (Stevenson et al. 2010). Data available for download was classified in three ways: spatial downloads, such as ArcGIS shapefiles (.shp) and Google Earth’s mapping files (.kmz); tabular downloads, including Microsoft Excel files (.xls) and SPSS data files (.sav); and other downloads, such as Adobe reports (.pdf) and image files. For our 163 datasets, 45% provide downloads only in tabular form, while only 4% of datasets were limited to spatial downloads (Figure 3d). Over one-third of the datasets had multiple options for download type, further increasing accessibility. Download types vary slightly depending on the capital; for example, when looking at the environment/natural capital, datasets contained downloadable spatial data 48% of the time.

3.3.3 Spatial, Temporal, Collection Properties

Most of our identified datasets (70%) provide information coverage across all or nearly all the United States (Figure 3e). Among the reviewed datasets, 28% possess a regional or state focus such as the data offered by the Gulf of Mexico Research Initiative (GoMRI) or the Florida Department of Health’s CHART dataset that generates community-level health assessments. Only 2% were highly localized such as the Brookings Institution’s New Orleans Index, which provides resilience data for the New Orleans area only. Whether they have national, regional, or statewide coverage, the majority (81%) of datasets use

enumeration units at a sub-state level. About 56% of the datasets offer information below county level (e.g., city, census tract) with 37 out of the 163 datasets (23%) reporting at the address (including spatial coordinates) or household/individual level.

The historic record of the reviewed datasets varies significantly (Figure 3f). Nearly 90% offer data for the 2010s, which drops to 59% for the 2000s, and 42% for the 1990s. About 23% of data repositories offer a historic record exceeding 30 years. A few datasets such as the CDC's National Environmental Public Health Tracking Network incorporate information dating as far back as 1895. The wide variety of data collection start dates illustrated in Figure 3f, highlights the increase in available datasets since the 2000s.

Nearly 74% of the datasets are updated regularly (i.e. at least once a year). Environmental data such as those provided by the National Centers for Environmental information or the U.S. Geological Survey are in (near) real-time. On the other hand, other datasets, such as those including Census data or land use/land cover data, are only available every 5 or 10 years. Analysis of the collection methodology shows that most datasets (60%) provide near-continuous data (Figure 3c). The second most common collection methodology is using repeat observations, including cohort and panel studies (29%). Cohort studies such as the National Longitudinal Survey, which collects data on health and well-being at the individual level since 1979 use variable time intervals and/or are limited to public use files at the national level although access to more granular data may be granted upon request. Only one panel study is in this review - the U.S. Religion Census, conducted decennially over the past 70 years.

3.3.4 Gulf States Availability

The assessment of data availability for the Gulf States indicates that 115 of the retained datasets had nationwide coverage (70%). The other 48 datasets have more localized coverage for one, two, or more states. The datasets with partial coverage are either from state agency datasets, county datasets, or from specific case studies like the Brookings Institution's New Orleans Index. The total number of datasets for each state is not significantly different among the individual Gulf States: 123 for Alabama (75%), 125 for Mississippi (77%), 126 for Louisiana (77%), 128 for Texas (79%) and 129 for Florida (79%). There are minor differences among the states' data in terms of capitals represented. Mississippi has more datasets in social/community capital, while Louisiana has more datasets in human well-being/cultural and political/institutional capitals. However, the distribution of datasets for each state is similar between the six capitals and follows the same trend of data availability.

3.4 CAPITAL SPECIFIC ASSESSMENTS

As expected, environmental or natural capital datasets are mostly long-term, real-time or near real time observational measurements such as the oil spill data from the National Response Center or air quality data from USEPA. The majority of these datasets are from government sources and have better geocoding making them more amenable to mapping outputs at various spatial scales. One example of a qualitative dataset for environmental capital is GoMRI's Information & Data Cooperative (GRIIDC) data system. This effort provides a catalog of all information and data collected through GoMRI and makes it readily available to other researchers and the public. This includes scientific publications to K-12 lesson plans.

The human well-being/cultural capital datasets have a wealth of longitudinal data derived from long standing annual or biennial surveys on crime statistics, demographics, and health. While some of these datasets report perceptual data on the physical or built environment (e.g., The American Housing Survey asks respondents questions regarding neighborhood quality), such perceptions are not linked to the objective data on physical or built environment conditions.

Datasets with indicators fitting into the economic/financial capital are largely measured at the county or city level, often lacking specificity on households and/or neighborhoods. The only dataset to measure at the household level is the National Housing Preservation Database, which requires a subscription (with cost) to access.

The social/community capacity capital datasets measure resilience by looking at education and religious ties, as well as volunteerism and social friction (e.g., Southern Poverty Law Center Hate Map, a census of hate groups across the U.S.). Data collected on social/community capacity is primarily quantitative, only providing qualitative data when the dataset also included measures of human well-being/cultural capacity or the built environment. Most of these datasets are devoid of any measures of social connectivity or social networks.

The political/institutional/governance capital focuses on political participation and government programs, rather than leadership or quality of governance. Examples include disaster insurance plans and losses (National Flood Insurance Program participation), and political engagement as measured by voting participation (e.g., percent voting by party in most recent election). As with the social/community capacity capital, no datasets were identified that contained qualitative data. This is true as well with the datasets that were previously eliminated from assessment.

4. GAPS IN RESILIENCE DATA

Gaps in the assessed resilience datasets were determined in three general ways: the crosswalk analysis of the dataset features/characteristics; the Pedigree Analysis; and a detailed analysis of concepts/proxy variables. Each are described below.

4.1 GAPS BASED ON CROSSWALK ANALYSIS

Disparities in temporal and spatial coverage limit opportunities to merge data across capitals and highlight the need for investment in methodological work on how to optimize data integration. In terms of spatial coverage, environmental datasets are more likely to contain data that are geocoded and mapped. In contrast, datasets representing other capitals rarely include data that are georeferenced at sub-county scales. Datasets that do include spatial data frequently utilized administrative census boundaries, such as block group or tract level, for mapping purposes. This presents a potential problem for the Gulf of Mexico region. These census units are delineated by population size to ensure statistical reliability, thus the spatial resolution for rural communities such as those in the Gulf region may be poor due to the large area covered by tracts and block groups. In terms of temporal coverage, while many environmental datasets are updated at (near) real-time intervals, this was not the case for datasets representing other capitals. For instance, many repeat, large-scale population surveys such as those conducted by the U.S. Census often occur at 5- or even 10-year intervals for complete sampling coverage.

Data systems purposefully designed to measure resilience using a strategic data collection approach are rare. Datasets currently being used for resilience research are typically “repurposed” datasets that originate from data collection systems that serve another primary purpose (e.g., BRFSS, U.S. Census). None of the existing data systems appear to have been intentionally designed to capture resilience as a key outcome (see Text Box 1), though they may provide useful information for the measurement of community resilience through proxy variables. For the current study, datasets that were rated as having the highest “centrality” for resilience focus heavily on aspects such as social capital or disasters. Data on the intersection of resilience and sustainability such as food security and water security

are rarely explored. Similarly, dedicated or agreed upon measures of resilience outcomes across capitals are unclear.

Text Box 1 Opportunities to Enhance the Study of Community Resilience

This white paper highlights a paucity of longitudinal datasets developed specifically to measure and monitor community resilience. While many proxy variables exist that have utility for measuring the ability of local communities to respond to and recover from disaster, resilience-specific tools and datasets are limited at this time. In contrast, a number of measures developed to evaluate resilience at the individual-level, are widely employed in the field of psychology. Most notably, in 2003 the initial psychometric data for the Connor-Davidson Resilience Scale (CD-RISC) was published, providing support that the 25-item rating scale was a reliable and valid tool for measuring individual resilience in both general and clinical populations (Connor & Davidson 2003). The self-report scale asked individuals to rate the extent to which each item described their experiences and feelings over the past month. Sample items included, “I tend to bounce back after illness or hardship”, “I know where to turn for help”, and “I am able to adapt to change”. The development of the CD-RISC reflected the psychology field’s shift away from models of pathology (i.e. illness, risk) and ushered in a new era of individual scales designed to measure positive psychosocial constructs (e.g., hopefulness, positive coping, posttraumatic growth). Since the initial validation of the scale, 10-item and 2-item versions of CD-RISC have also been developed that enable rapid measurement of an individual’s ability to “bounce back” from hardship (Campbell-Sills et al. 2009; Vaishnavi et al. 2007). Validation studies have provided support for the CD-RISC-10, showing that individuals who score high on this measure are more likely to experience positive outcomes (e.g., low psychiatric symptoms) after significant adversity (e.g., childhood maltreatment) than individuals who score low (Campbell-Sills and Stein 2007). These resilience-based measures have been used to establish norms for general US adults, as well as clinical populations (e.g., patients with post-traumatic stress disorder and generalized anxiety). More recent applications include efforts to translate CD-RISC into other languages and cultures and evaluating the efficacy of resilience-based psychosocial interventions for children exposed to early adversity (Li et al. 2017).

Datasets related to household/individual resilience and community resilience remain siloed making it difficult to study interaction effects. Survey techniques such as panel and cohort approaches, methodologies widely utilized in the health arena, find limited utilization in the context of resilience research (see Text Box 2). It seems prudent to adopt these methodologies in order to uncover cross-scalar and cross-capital relationship and linkages. For example, what is the long-term, perhaps even intergenerational financial impact of disasters (or the threat thereof) and what are the implications for community resilience? It is extremely difficult to design resilience assessment approaches that are equally meaningful to individuals, households, neighborhoods, communities, counties, and the federal government. Most assessment approaches presume the need for consistency in datasets across scale and units of analysis which produces methodologies that are driven by data availability rather than creating novel and original datasets and/or assessment strategies (see section 4.3).

Text Box 2 Lessons Learned from the Study of Resilience in Human Development

Within the field of developmental psychology, formal study of human resilience is typically dated to the 1955 launch of the *Kauai Longitudinal Study*, when an interdisciplinary research team began to study the development of 698 infants born on the Hawaiian island during that year (Werner 2013). Researchers closely monitored this cohort over the next 40 years in order to identify resilience factors that enabled some individuals to thrive despite the experience of significant adversity (e.g., chronic poverty, parental mental illness) (Werner and Smith 1982; 1992). Since that time, developmental resilience research has undergone at least four distinct waves (Wright et al. 2013) as it has progressed from the identification of individual-level assets (e.g., intelligence, agreeableness) that broadly predict better later life outcomes to the recognition that resilience is a dynamic process that is deeply imbedded within complex ecological systems (Luthar et al. 2000; Masten and Narayan

2012). As the field of prevention science developed, resilience researchers moved from merely trying to *describe* the phenomenon to attempting to “build resilience” through the development and evaluation of resilience-based psychosocial interventions. Such interventions generally seek to equip individuals with coping skills and intrapersonal resources that can help them positively adapt to major life challenges. These resilience-based interventions are increasingly multi-level—aiming to strengthen not only the individual, but also key support systems surrounding the individual (e.g., interpersonal relationships, community resources), which are often critical for responding to major life challenges. Today the study of developmental resilience is moving into new territory as scientists try to understand the biological underpinnings of resilience through the incorporation of neurological and genetic approaches. Over the past 70 years of resilience-related research, a cornerstone of the field has been a commitment to using rigorous measurement tools and methodologies, as well as a willingness to cross traditional disciplinary boundaries (e.g., psychology, medicine, social work, sociology) in order to deepen our understanding of complex human reactions to adversity.

There are few longitudinal data systems that include qualitative data. For the purpose of the present study, a relatively broad definition of qualitative data was utilized (Denzin et al. 2005), which included collections of life stories, interviews, narrative case studies, diaries, oral histories, or photographs. Despite this broad operational definition, few longitudinal qualitative collection systems were found. One example of a longitudinal qualitative dataset was a photographic archive of demolished and refurbished buildings in Ocean Springs, MS which dates back to 1900. This dataset includes not only photographs of the structures, but also a brief architectural narrative about the home, and in some instances the address as well. This type of dataset may be useful for documenting a “sense of place” and is notable in that it involved both built environment and social/community capitals. However, this dataset is specific to one particular home site - similar ones documenting broader community change over time could not be located.

There is an abundance of relevant data collected at local levels as part of standard management practices (e.g., permits). Such data are often inaccessible and thus rarely used in resilience assessments. Relatively few local datasets met inclusion criteria or were accessible for review. For example, parcel level (or cadastral) data serves many purposes for local governments (e.g., taxation, zoning, development), states, and federal agencies, yet such data are not publicly available for the entire U.S. (von Meyer et al. 2016). These local datasets need to be digitized, consolidated and standardized to embed and leverage existing data in resilience assessments as well as research (see Text Box 3). A case in point is the new ISO 37123 *Indicators for Resilient Cities*, which proposes resilience domains to be captured but allows communities themselves to operationally define resilience and select the most appropriate and relevant data collection systems. These gaps in consolidated access to standardized data make it difficult to develop effective interventions, compare communities, design best practices or evaluate the direct effects and unintended consequences of built environment policies across all government levels – both pre- and post-disaster.

The methodologies for human well-being/social and community capitals datasets are largely confined to surveys and interviews with limited utilization of new technologies. Advances in technologies such as artificial intelligence, “Big Data” analytics, and the Internet of Things (IoT) devices (e.g., wearable technology, smartphones), nearly ubiquitous connectivity, and innovative applications for human health and well-being have spurred interest in how “everyday” technology can be used to measure and improve behavioral and physical health, particularly for vulnerable populations (Kumar et al. 2013). Usage of such technologies in collecting data and capturing information relevant to community well-being and disasters could dramatically increase both the temporal and spatial resolution of resilience data. In addition,

incorporating more advanced technologies into the measurement of resilience may yield new insights into how connected technologies can be optimized to help communities prepare for and respond to disasters.

The power and utility of proprietary data has yet to be explored given limited access to such databases. While we know that there are many private big data sources of individual and community data that provide insight to human wellbeing (e.g., private insurance claims, building characteristics, credit scores), their proprietary nature limits their use in current resilience studies. This hampers both our understanding of key systems involved in resilience and our ability to leverage the knowledge gained from these datasets. This also stymies the development of technology-driven data mining efforts as well as the development of new resilience assessment approaches. Access to proprietary data and the ability to conduct research that can be disclosed could generate new insights. Thus non-traditional partnerships, such as efforts between resilience researchers and private insurance companies, may offer new opportunities in the measurement of community resilience.

Text Box 3 Local, Often Inaccessible, yet Critical Data Systems

There is a myriad of resilience data collected at local levels nationwide, yet most of these datasets are not easily accessible such as building codes, building permits, or elevation above base flood elevation for structures. These data are useful for assessing existing levels of resilience and could help predict level of recovery following a disaster. For instance, the effectiveness of strong building codes may be undermined by an insufficient number of permit officials, lax code enforcement, or minimal training requirements for building officials. Being able to integrate datasets that exist at municipal/jurisdictional levels may result in better understanding of the effects of and linkages between resilience capitals. Greater online accessibility of local data would also improve the ability to compare relative risk across local communities, identify communities that may be most vulnerable, and target resources and supports as appropriate.

At present, conducting a nationwide evaluation of the relationship between local building codes and disaster impacts would require a herculean effort to access, digitize, consolidate, and standardize local building code data across 89,004 local governments in the U.S. (Census Bureau 2012). At present, there are a few resources available to resilience researchers for this purpose. These include the Insurance Institute for Business and Home Safety (IBHS)'s residential building code ratings of coastal states (IBHS 2018), the Community Rating System (i.e. data on flood-related building codes for communities that participate in the National Flood Insurance Program), and academic as well as FEMA-sponsored post-disaster case studies (Dumm et al. 2011; FEMA 2018a; FEMA 2018b; PEW 2018). Outside of these resources there is little information on how proactive (or not) communities are in mitigating the effects of natural hazards through the implementation and modification of building codes. Which communities have the most effective building codes? Which codes are associated with the greatest "savings" in terms of disaster mitigation? What processes and key stakeholders have enabled such communities to implement and enforce these codes? How long have such codes been in effect and what economic benefits have they yielded?

After catastrophic events, building codes are frequently updated. However, there is often either a moratorium on implementing more stringent codes or a relaxation of existing codes, allowing residents to rebuild using outdated or less restrictive building codes—in the hope of speeding up recovery in the short term, but not necessarily with resilience in mind. What are the long-term implications for resilience when communities rebuild but do not "build back better" as some suggest (Lazarus et al. 2018)? Better building codes and higher standards have implications not only for building damage. When buildings withstand the impact from natural hazards, residents are less likely to be injured or killed and more likely to recover more quickly and able to contribute to their community without suffering physical, emotional or financial stress. Access to such data is especially salient for the GOM region where, with the exception of Florida, statewide building codes and enforcement have not been effective until Hurricane Katrina struck (Ingargiola and Ghorbi 2015). Furthermore, the region including Florida sees frequent calls by lobbying groups and politicians to weaken existing codes or allow local communities more "flexibility" (Flavelle 2018).

4.2 GAPS BASED ON PEDIGREE ANALYSIS

The Pedigree Analysis revealed some interesting aspects of the evaluation of the datasets. The Pedigree Analysis agreement was 91.5% on the retained datasets. Overall, there is convergence in the average evaluation scores in centrality and long-term availability and a bit more divergence in acceptance, innovation, and reliability (Figure 4). For example, while many of the human well-being/cultural datasets are important in measuring resilience, many are seldom used for this purpose. The same is true for the social/community capacity datasets. On the other hand, these same capital datasets have medium-high reliability with long-term availability. This is directly related to federal legislative mandates for population counts, vital statistics, social mandates, and economic indicators. Datasets such as CDC's Compressed Mortality (pedigree score: 19.5/20) and the U.S. Census Bureau's American Community Survey (pedigree score: 18.5) achieved a near perfect pedigree score across all five pedigree categories (centrality, acceptance, innovation, reliability, and long-term availability). Despite both datasets being commonly used to measure resilience, we considered their potential for innovative contributions to the measurement of resilience as high due to the wealth of information not yet leveraged in both datasets as well as the agencies' abilities to possibly collect more/new resilience-relevant data. The only non-federal dataset with a similarly high pedigree score was the County Health Rankings and Roadmaps (18.5), a collaboration between the Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute. These three datasets, along with the Spatial Hazard Events and Losses Database for the United States (Arizona State University), were also the only datasets with a high (4) acceptance rating.

The fact that most datasets received a low acceptance rating highlights three aspects. First, there is no established common core of resilience datasets beyond health and census data. Second, the inclusion/exclusion of datasets into measurements of resilience depends heavily on the conceptual and theoretical construct underpinning each resilience assessment, which as research shows (Cutter 2016) tend to reflect discipline-specific definitions that subsequently produce siloed operationalization of resilience. And third, the barriers to accepting new datasets as adding value to measuring resilience is exceedingly high given the challenges surrounding the empirical validity and utility of resilience metrics at large. This creates a feedback loop reinforcing the reliance on established resilience datasets with limited resources devoted to identifying better/more effective datasets to quantifying resilience.

4.3 IDENTIFICATION OF GAPS BASED ON PROXY VARIABLES

Five different meta-studies of empirical assessments of community resilience (Beccari 2016; Cutter 2016; Ostadtaghizadeh et al. 2015; Patel et al. 2017; Sharifi 2016) were examined for specific concepts and proxy variables used to measure various aspects of resilience. These five meta studies were supplemented with three community disaster baseline resilience indices (BRIC 2015; ISO 37120; ISO 37123) which include specific enumerated variables in addition to concepts (Appendix 2). It was noteworthy that BRIC is reviewed in each of the meta-studies. The ISO efforts are included as international attempts to develop baselines and comparative measures at international scales – a goal similar to BRIC for the U.S.

Interestingly, most of the meta-studies include some form of variable grouping either clearly identifying capitals and/or components influencing resilience. However, there are a few that make no distinction between resilience, vulnerability, and disaster risk methodologies and include variables representing all three concepts as though they mean the same thing (e.g., Beccari 2016), or evaluated the

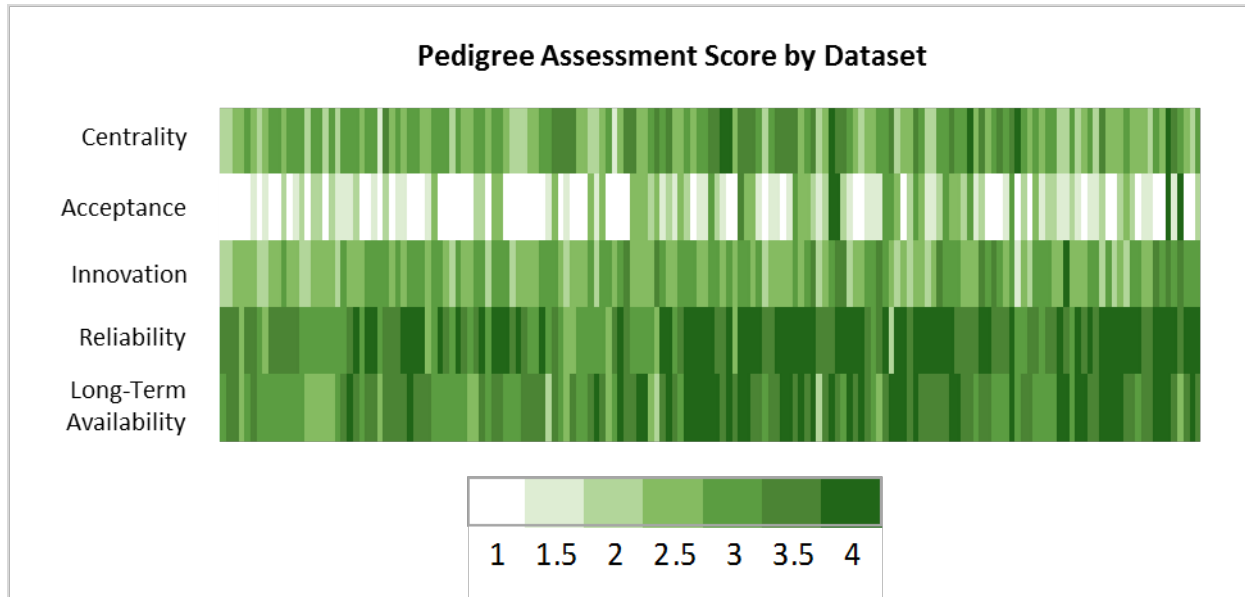


Figure 4 Pedigree Assessment scores of retained datasets (n=163). Each dataset is represented by one column. Darker colors represent higher evaluation scores in each category.

resilience measurements against specific criteria such as addressing multiple dimensions, capturing temporal dynamism, including participatory approaches and so forth (Sharifi 2016). Some reviewed the tools or indices themselves (Ostadtaghizadeh et al. 2015; Cutter 2016; Sharifi 2016) which included 17, 27, and 36 examples, while the remaining two provided more of a literature review of definitions and descriptions of resilience (Patel et al. 2017). Finally, Asadzadeh et al. (2017) reviewed 17 tools (including BRIC) in terms of their methodology for indicator construction but did not include specific input variables and is only considered here for methodological reference.

It is difficult to compare the operationalization of resilience at the variable level across these studies given differences in orientations (static outcome or dynamic process) and purpose (monitoring baseline assets or enhancing capacity), and that an optimal indicator would be based on the choice of orientation, purpose, or both. So while it is tempting to develop a core set of variables, as done by Cutter (2016), the next generation of resilience measurement tools should improve efforts to operationalize resilience based on real and perceived needs of local communities and their stakeholders, thus ensuring both top down and bottom up measurement schemes.

Given some of the overlap identified in Appendix 2 the “consistency” in variables is most likely driven by data availability and prior use in ground-breaking and oft-cited empirical studies rather than specific data needs for operationalizing the resilience concept for measurement. Several concepts that we know are important to community resilience based on the literature (not necessarily empirical assessments of resilience), however, are not operationalized well. For example, social connectivity (feeling of belonging to a community, sense of place, place attachment) is one factor influencing resilience. While there are some proxy variables from the U.S. Census (mobility measures), these are not ideal in identifying social networks. The availability of big data sources such as Twitter may have great utility for developing a social connectivity variable, for example through mining regionally-specific geo-located Tweets using network analytics applied to social media. For example, Twitter data have been used to successfully monitor hurricane evacuation behavior (Kryvasheyev et al. 2015; Martin et al. 2017), situation awareness

during emergencies (Huang and Xiao 2015), and sentiments toward healthy and unhealthy food (Widener and Li 2014). But, none of the datasets we examined took this approach. Another crucial factor is community leadership (Patel et al. 2017), which is described but with no clear measurement provided.

5. KEY MESSAGES

1. Data representing fine-level patterns and processes of community resilience are lacking in their spatial scale and temporal coverage.

Long-term economic and financial data at finer levels of geographic scale are incomplete or missing for a majority of Gulf of Mexico areas. Additional data specific to long-term financial health at individual, household, and community levels is needed to understand how changes in these capitals affect communities into the future.

The literature is rich with anecdotes and qualitative indicators proving that social characteristics and community capital are important in measuring and monitoring resilience. However, evidence from this assessment indicates that numerical representations of the community capital are slow to materialize. Furthermore, qualitative assessments of social fabric, social support, and other forms of community social capacity are neither collected comprehensively across the coast nor replicable from place to place. Social/community capital datasets, especially among those not meeting our assessment criteria, maintain high innovative potential. A focus on this area of resilience is needed to move the needle on resilience into the future.

The most temporally reliable datasets (government-supported with all indications of continued collection into the future) are often also the least geographically specific. Many national datasets, while reliable, are insufficient for monitoring and use at community scales. Collecting this breadth of information across all resilience capitals at lower levels of geographic scale is critical to understand place-based interactions and resilience outcomes. Also, the finest level of available data varies within and between states. For example, Mississippi has finer level data available through their Mississippi Automated Resource Information System (MARIS), and Florida's State Geospatial Data Library provides thousands of spatial data files across nineteen different categories, but other GOM states do not have as many detailed datasets.

2. Promising datasets were identified but did not meet the 5-year longitudinal criteria.

Restricting data longitudinally in determining which datasets were retained for this assessment has identified a cohort of data that will become more useful for resilience studies if collection continues into the future. Included are fifty-two datasets that did not meet the required criterion for temporal coverage of at least 5 consecutive years or 5 linear data points. Changing this criterion or maintaining current collection strategies will result in more high-quality datasets for future analysis.

More than 50% of those datasets disregarded in this assessment were highly innovative and central to resilience studies according to our Pedigree Analysis but did not meet the longitudinal (at least 5 years of data) criteria. Attention should be given to ensure the survival of these promising datasets into the future. These datasets should include locally-generated data (such as those identified in Text Box 3) that could be archived or warehoused in a central repository or distributive data portal for all data and/or information holdings relevant to community resilience and human well-being in the region. A list of discarded datasets that were identified as highly innovative (scored 3 or higher in the Pedigree Analysis) but did not meet the longitudinal definition is available in Appendix 1.

3. Resilience data continue to be collected in capital-specific silos, with little integration across capitals.

Datasets both aiding our understanding of resilience drivers and providing quality outcomes for measuring resilience from past to future are slowly maturing and being utilized, but mostly in discipline-specific silos. Unfortunately, lack of integration across research fields compounded by limited integration across disciplines has resulted in stove-piped growth in resilience science and practice. Among those datasets reviewed here only three data repositories (Inter-University Consortium for Political and Social Research, Florida Geographic Data Library, and Alabama GeoHub) contain separate data representing all six capitals, but are not integrated across them. Only truly transdisciplinary teams can spend the requisite time and effort to bridge these gaps in theory development and practical solutions.

4. Current support for longitudinal studies is not in line with the need to link resilience predictors with outcome measures at various scales from local to regional and beyond.

Gaining accurate, precise, complete, and consistent measurements of Gulf Coast resilience across the various resilience capitals discussed throughout this report is only possible with an increase in longitudinal “panel-type” studies of residents, communities, and regional areas. These longitudinal studies are the only way to truly understand driving forces of increased resilience. Unfortunately, however, disaster-related impacts are not tracked in a consistent and comparable way. Conceptually we understand resilience and its drivers but less understood is how drivers are manifested at the household level. What is the linkage between the resilience of a person, household, or structure (individual) and community resilience (systems level) and what indicators (and at what scale) are most useful for gaining such understanding?

5. Cutting-edge technology currently has limited influence on what types of data are being collected.

Data collection still relies on traditional measures/methods although technological innovations over the past decade have opened new pathways for large scale and precise data collection. While there may be use of Big Data, artificial intelligence, or biomarkers in regionally or topically specific resilience studies, such data are not captured or archived for general use. How do we leverage cutting-edge technology for data collection and resilience assessments while developing innovative ways to measure the seemingly unmeasurable (such as social networks)? How do we systematically link and curate data in regional social observatories that enable us to understand people in context (Hofferth and Moran 2017)?

6. Data availability primarily from administrative national data systems are driving resilience measurement.

There are few, if any, datasets measuring all attributes or community processes that help enhance resilience. Communities lack information on pre-disaster resilience, and often only become aware post-disaster of the importance of such information for responding to and planning for disasters and recovery from them. Given that resilience means different things to different communities, there is no consistent set of proxy variables for measuring resilience that capture this variability in meanings across communities. There exists a need for locally-based information/measures or innovative approaches for downscaling and integration into cross-scale analyses. For example, dynamic downscaling—a methodology employed in climate research to generate better information regarding the local effects of climate change—relies on the integration of local models into global models. These types of dynamic approaches are thus far non-existent in resilience research and the data systems that inform such research.

7. Qualitative data systems exist, but they are limited in accessibility, scope, and coverage.

There are a few examples of qualitative datasets (with digital catalogues), but we assume there are many more than what we've uncovered that could be useful for understanding human well-being and community resilience in the Gulf of Mexico area. Oral history archives exist across the Gulf States, but most do not have digitally-accessible repositories. Preserving communities' lived experiences through photos, oral histories, maps, artifacts, and historic documents, are very useful for understanding cultural reactions to and changes related to disaster events. One example is the oral history digital archive at the University of Southern Mississippi's Center for Oral History and Cultural Heritage. This dataset includes interviews regarding Hurricane Camille (1969) and other hurricanes, the Mississippi River Floods (1927), the Pearl River Flood of 1979, Hurricane Katrina (2005), and the BP Oil Spill (2010). In addition, empirical investigations leveraging qualitative data to document a nuanced understanding of a community's resilience are needed. Disaster-related narratives often lack a longitudinal view of resilience because they primarily focus on or document lived experiences during recovery and reconstruction.

6. OPPORTUNITIES FOR INVESTMENT

The effects of chronic stressors (e.g., poverty) unfold slowly over time and produce outcomes that are entrenched and difficult to change. In contrast, disasters based on shocks from naturally- or technologically-caused events are sudden and responses to them are often focused on quick response and recovery. In addition, disasters create vastly disparate impacts across the landscape, affecting some areas significantly, but leaving other areas nearby relatively unscathed. Traditional census methods, which are often used to capture important information on the human experience among the general population, frequently have poor temporal and spatial resolution and are therefore unable to detect the full picture of adverse impacts or monitor the effects of recovery activities and interventions in a timely fashion. While such census methods may provide useful data at a regional or national level, they rarely suffice when the goal is to understand the localized impacts of a disaster. In addition, because so few data systems have been purposefully designed to measure community resilience, researchers typically must utilize a "patchwork" approach to capture key resilience information across capitals. Alternatives to census-style data collection do exist, including rapid collection of data post-disaster. However, reliance on funding programs aimed at ad hoc collection of ephemeral disaster data also produces scattered results and incomplete data coverage. Similarly, the repurposing of existing datasets such as mail delivery data emerged as an ad hoc monitoring approach to measure displacement post-Katrina (Cutter et al. 2014). However, questions remain as to whether there are more effective ways to monitor disaster recovery, and the comparative strengths and weaknesses of the various methodologies.

Building support for long-term analysis of resilience at local, community, and regional scales is imperative. Lack of depth and breadth of empirical outcome measures linked to foundational theories of resilience exists across all disciplines. We may have a clear conceptual vision of resilience, but we lack connectivity between inputs and outcomes in the real world. Case studies identifying community resilience are largely descriptive and often fail to identify specific predictors of resilience or elucidate the mechanisms through which resilience is achieved. Building the scientific links between drivers of resilience and successful adaptation to disaster is critical, particularly given the increasing likelihood of climate-related disasters in the Gulf region (Colburn et al. 2016; National Climate Assessment 2018).

The Gulf Research Program is uniquely positioned to significantly advance the science and practice of community resilience using the Gulf of Mexico as its laboratory. Based on our review of over 250 data systems and datasets we offer the following suggestions as opportunities for investment. The

opportunities identified below could be used as standalone strategies or combined for added value. The ordering of the suggestions does not imply prioritization. Each suggestion links to one or more of the key messages based on our analysis.

1. Establish a social observatory for the Gulf of Mexico region.

This observatory would have three functions. The first function would be to mobilize existing networks of interdisciplinary research teams and interested stakeholders in co-developing mechanisms and opportunities for collaborative and coordinated work aimed at understanding the human dimensions of resilience drivers and outcomes. The second function would be to facilitate the development of panel and cohort studies that integrate data collection across all capitals. Such studies could help fill existing data gaps, measure and understand individual resilience, and address how individual resilience and drivers/outcomes link to community (or systems level) resilience. In addition to cohort studies, the observatory could work with local communities (defined by municipal and/or administrative boundaries) to define resilience measures from the bottom up and help implement data collection for their decision-making processes. The third function would be to curate and link data across all capitals associated with resilience and function as a data portal and/or regional data center. There are several examples of site-specific in-house centers (e.g., Census Research Data Centers) and distributive networks (e.g., NASA's Socioeconomic Data Archive Center, World Council on City Data Open Data Portal [open.dataforcities.org]) that could serve as models of integrated data centers. The establishment of a social observatory has been advocated for years by the hazards and disasters community and entities engaged in understanding human-environment interactions and data-curation and sharing (Peacock et al. 2008; Entwistle et al. 2017; NASEM 2019). This observatory is not imagined necessarily as a brick-and-mortar facility, but as a distributed effort among universities, non-profits, and other interested stakeholders with a lead coordinating entity in the Gulf region. NIH collaborative research networks (i.e. U19s) can serve as a good model. *(Recommendation addresses all key messages)*

2. Demonstrate to communities and stakeholders the benefits of community resilience and equip them with the tools necessary for its measurement.

GRP can support the innovative development and deployment of tools for monitoring resilience in local communities and promote the translation of resilience science into actionable practice through technical assistance hubs. Such efforts build local capacity and enable communities to understand trade-offs in decision-making and resource allocation, and will help them realize the dividends from resilience investments (Rodin 2014). Existing and new communities of practice (e.g., Climate and Resilience Community of Practice, Extension Disaster Education Network, Urban Sustainability Directors Network) should advocate for resilience monitoring as an integral part of community planning and performance metrics. In addition, communities that demonstrate a “whole community” approach and strive to achieve cross-capital linkages could serve as useful case studies and peer-learning opportunities to inform future efforts to “scale up” resilience planning across the region. Rather than just talking about resilience, this recommendation encourages communities to actively measure resilience, incorporate the metrics into routine governance structures, and conduct post-audits of programs and policies to see if they enhanced resilience as intended. The recommendation also supports the need for funding and providing technical assistance to communities as they try to implement these tools and strategies. *(Recommendation addresses key message 4)*

3. Incentivize researchers to integrate data across capitals and scales through demonstration projects.

Based on the review of the datasets and data systems, translating between scales is a major issue with integrating resilience across capitals. Innovations in geo-statistical downscaling (national to local),

systematic upscaling of local or regional data to national models, and dynamic downscaling (translating regionally nested modeled data into national profiles), may help increase the utility of many datasets that presently only use national samples as the unit of analysis. Investments in demonstration projects addressing cross-scalar and cross-capital challenges are needed. These demonstration projects should commit to transdisciplinary approaches (e.g., incorporating local knowledge communities as well as experts, engaging multiple disciplines, using diverse methods). They can take many forms, including: 1) short-term pilot studies; and/or 2) long-term longitudinal studies. Short-term studies should test the feasibility and validity of cross-capital data collection, integration, and analysis or proof of concept efforts to bridge differences in scale. Long-term studies should commit to using rigorous methods to monitor resilience predictors or drivers to real-world outcomes over extended periods of time (beyond a typical 3-year grant cycle). Locally-driven data collection and monitoring would help to underscore the need for community-relevant definitions of resilience (for whom, to what, where, and when) and to document the variability among places. *(Recommendation addresses key message 3)*

4. Support the use of innovative technology for resilience.

Numerous recent technological advances are also rapidly changing how human behaviors and experiences are measured, including big data analytics and wearable, connected technologies. These innovations have not yet been incorporated into traditional measures of community resilience but may offer unique opportunities to monitor and promote community responses to adversity. One example of innovative use of social networking data is the Social Connectedness Index, a measure of georeferenced friendship networks utilizing Facebook data (Bailey et al. 2018; Badger and Bui 2018). Employing big data and real-time data in resilience science is in its infancy, but offers the opportunity to address issues of scale, sampling, and data coverage. However, technological advances also introduce concerns about individual privacy, data ownership, equity, and the digital divide. As the demand for real-time data increases, these concerns will amplify, as will the demands on researchers to keep up with rapid technological changes and their implications especially for disadvantaged populations and communities. *(Recommendation addresses key message 5)*

5. Establish baseline measures of resilience for Gulf of Mexico communities as the first step towards monitoring resilience progress.

Critical baseline measures of resilience could be identified, and standardized monitoring systems developed, in select Gulf of Mexico communities. After implementation and evaluation, such methods and models could be customized for the local context with stakeholder input or scaled up across the region for mesoscale comparisons. The baseline indicators would not be exhaustive but could provide aspirational benchmarks against which communities can measure progress. At a minimum, such an effort would enable GRP to partially evaluate its own success and identify where more investment and interventions might be required to enhance community resilience. Consider using a minimum of two or three communities as pilots. *(Recommendation addresses key message 6)*

6. Create a living repository for evaluating longitudinal resilience datasets and data systems.

Such a “live” system would include the datasets analyzed here in the crosswalk matrix and be publicly available for viewing by anyone interested in pre-existing and longitudinal resilience data for the Gulf of Mexico region. The repository could be continuously updated with new datasets or data systems as they become available. Data producers could upload potential datasets for inclusion through a repository link, and a GRP-supported development team (or the social observatory) would evaluate them according to crosswalk and Pedigree Analysis procedures that have been established through this project. *(Recommendation addresses key messages 2 and 7)*

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APPENDIX 1

Table A-1 Highly Innovated Datasets Discarded for not Containing Longitudinal Data

Source/Repository	Database Name
Arizona State University	Sustainable Neighborhoods for Happiness Index
diversitydatakids.org	Childhood Opportunity Index
Equality of Opportunity Project	Effects of Neighborhoods on Intergenerational Mobility
	Geography of Intergenerational Mobility in the US
Facebook	Social Connectedness Index
FEMA	Emergency Management Performance Grants – V1
	Housing Assistance Renters – V1
	Hazard Mitigation Assistance Mitigated Properties – V1
Gallup	Well-Being Index
HHS	emPOWER
LSU Manship School of Mass Communication	Community Resilience Study - Flood
	Community Resilience Study - Race
Mississippi Department of Human Services	Monthly Statistical Report
Mississippi Development Authority	SNAPSHOT: Labor and Data
SitScape	Single Automated Business Exchange for Reporting (SABER)
StreetLight	StreetLight InSight
US Census Bureau; NSF's National Center for Science and Engineering Statistics	Annual Business Survey
US EPA	Smart Location Database
	US Human Well-Being Index
Waze	Traffic Data

APPENDIX 2

Table A-2 Key Concepts and Proxy Variables Identified in Resilience Meta-Analyses

Concept	Operationalized	Proxy Variable examples	Studies
Community	Assets/functions	Community services; potable water, wastewater treatment	Cutter 2016; ISO 37123
	Aspirations/goals	Hope, belonging, working together	Cutter 2016; Patel et al. 2017
	Attributes	Support families and kids	Cutter 2016
	Networks	Connectedness (social networks, kinship networks) Cohesion (shared values, trust)	Patel et al. 2017
	Preparedness	Disaster training and response skills, plans for disaster response	BRIC 2015; Patel et al. 2017
	Vulnerability	Poverty, homeless, seniors, complete secondary school	ISO 37120; ISO 37123
Economic	Employment	Employment rate, working age structure, skills, labor markets, informal employment	Sharifi 2016; ISO 37123
	Security	Individual/community savings, insurance, social welfare, contingency funds	Sharifi 2016; Beccari 2016; ISO 37123
	Dynamism	Inward and green economy investments, diverse economic structure, locally-owned businesses, business size	Sharifi 2016; BRIC 2015
	Wealth	GDP per capita, GINI index, per capita income, income inequality (race & gender) homeownership, median household income	Beccari 2016; Cutter 2016; BRIC 2015; Sharifi 2016

Longitudinal Data and Systems for Resilience

	Disaster Impacts	Historic losses, essential services with business continuity plan; insured high risk properties; ratio value insured properties to total value at risk	ISO 37123
Education	Education equality	Population with more than high school, racial differences in high school education	Cutter 2016; BRIC 2015; Beccari 2016
	Emergency preparedness	Schools teaching disaster risk reduction, population trained	ISO 37123; BRIC 2015
Emergency Management and Response	Attributes and Capacities	Experience, loss causing events, response time from initial emergency call, number of firefighters or police officers	Cutter 2016; ISO 37123; Sharifi 2016
	Assets	Shelters and capacity, evacuation routes, waste disposal sites for debris/rubble, shelter options (vacant rentals, hotels/motels, public schools)	Cutter 2016; BRIC 2015; ISO 37123
	Risk or crisis communication	Provision of up-to-date information, accurate threat information, specialized and reliable communication technology	Patel et al. 2017; Cutter 2016; ISO 37123
	Disaster exposure	Flood frequency, area covered by hazard maps, land in high risk zones	Beccari 2016; ISO 37123
Environment	Natural assets	Impervious surfaces, biodiversity, heat/cold extremes, air quality, heat island, land for agriculture, public outdoor recreation space	Cutter 2016; Sharifi 2016; ISO 37123; BRIC 2015; ISO 37120; Beccari 2016
	Energy	Source of electricity supply, electrical capacity as percentage of peak demand, energy use	ISO 37123; BRIC 2015; ISO 37120

Longitudinal Data and Systems for Resilience

	Resource management	Protection of wetlands and watersheds, erosion protection, availability of resources, ecosystem restoration, compliance with environmental policies, fairness in distribution	Sharifi 2016; ISO 37123; Beccari 2016; Patel et al. 2017
	Resource use	Water consumption, water loss	ISO 37120
Governance	Municipal Finance	Municipal expenditures for services, green/blue infrastructure, emergency services. Debt service ratio, own revenue source	ISO 37123; ISO 37120
	Disaster planning	Frequency of disaster plan updates, continuity plans, electronic data backups, public meetings risk and resilience; departments integrating results of risk assessments	ISO 37123
	Public Engagement and Leadership	Local leadership, community empowerment, participation in planning processes	Patel et al. 2017
Health and Health Care	Services	High quality care, emergency response capabilities, wait times in emergency room	Patel et al. 2017; ISO 37123
	Functioning	Physical, psychological, clinical distress, adverse mental health outcomes	Patel et al. 2017; Sharifi 2016; BRIC 2015
	Attributes and Capacities	Population with health insurance, children fully immunized	ISO 37123; ISO 37120; BRIC 2015
	Assets	Health care facilities, physicians, hospital beds, mental health practitioners, nurses	ISO 37123; ISO 37120; BRIC 2015; Beccari 2016

Longitudinal Data and Systems for Resilience

Infrastructure	Assets	Internet service, emergency management buildings, government/institutional buildings, bridges, water infrastructure, ICT, transportation	BRIC 2015; Cutter 2016
	Robustness and Redundancy	Redundancy of critical infrastructure facilities, spatial distribution, consolidation of critical utilities, collaboration among utilities	Sharifi 2016
	Efficiency	Regular monitor and maintenance critical infrastructure, retrofit, refurbishment	Sharifi 2016
	Housing Quality	Conform to building codes, deaths from residential fires, not mobile homes, vulnerable to high-risk hazards, housing age	ISO 13723; BRIC 2015
	Urban Design and Land Use	Development density, street connectivity, public spaces, green/blue infrastructure, visual quality, passive lighting, heating, and cooling	Sharifi 2016; Ostadtaghizadeh et al. 2015
	Quality of Services	Electrical interruptions, transportation fatalities, high capacity public transportation	ISO 37120; ISO 37123
Institutional	Emergency Services (capacity)[s1]	Warning, evacuation, response, planning, recovery planning, training	Ostadtaghizadeh et al. 2015; Cutter 2016; BRIC 2015; Sharifi 2016; ISO 37123
	Mitigation	Mitigation spending, crop insurance, mitigation plans, FEMA Flood insurance coverage	Cutter 2016; BRIC 2015
	Jurisdictional distance and fragmentation	Distance from state capital, county seat, number of special governing districts	BRIC 2015

Longitudinal Data and Systems for Resilience

	Leadership	Strong leadership, stability, transparency	Sharifi 2016
	Participation and Collaboration	Multi-stakeholder planning and decision making, decentralized responsibilities, MOU with other communities	Sharifi 2016
	Management	Manage resources (funds, staff), skilled personnel, redundant capacity in personnel	Sharifi 2016
	Regulations and Enforcement	Availability and enforcement of policing, crime, building codes, zoning laws, manage informal settlements	Sharifi 2016
	Civic Education and Training	Demand management for education, drills and exercises, information dissemination, civic responsibility, voter participation	Sharifi 2016; Patel et al. 2017; ISO 37120
Social	Connectedness	Belonging to community, place attachment, proximity to urban area, community bonds	BRIC 2015; Cutter 2016; Sharifi 2016,
	Social structure	Population composition, demographics, language, mobility, diverse skills	Sharifi 2016; Ostadtaghizadeh et al. 2015; Beccari 2016
	Social/cultural capital	Civic organizations, religious ties and affiliations,	Ostadtaghizadeh et al. 2015; Cutter 2016; BRIC 2015
	Community bonds, social support, social institutions	Volunteerism and civic engagement in social networks, collective memories, trust, shared assets; social safety net mechanisms neighborhoods with open neighborhood association meetings	Sharifi 2016; ISO 37123

Longitudinal Data and Systems for Resilience

	Equity and diversity	Gender norms, ethnic equality, culturally diverse, fair access to basic needs and services	Sharifi 2016
	Knowledge	Learn from the past; indigenous knowledge and traditions	Sharifi 2016
	Local culture	Respect local cultures, positive behavioral norms, historic/cultural preservation	Sharifi 2016
	Language competency	Proficiency in speaking English	BRIC 2015
	Food security	Population served by city food reserves; population living at distances from grocery stores	BRIC 2015; ISO 37123
	Social conditions	Spatial segregation, population at risk to hazards, crime prevention and reduction	ISO 37123; Sharifi 2016