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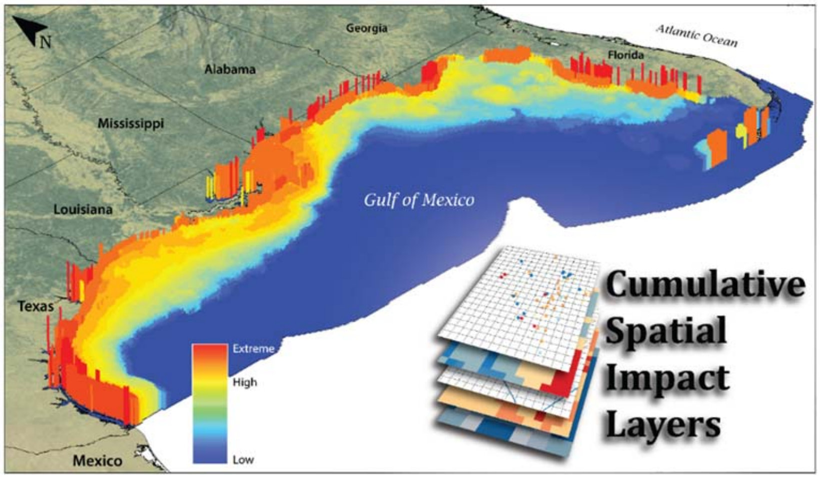

A Spatio-Temporal Approach to Analyze Broad Risks and Potential Impacts Associated with Uncontrolled Hydrocarbon Release Events in the Offshore Gulf of Mexico

19 February 2015

U.S. DEPARTMENT OF ENERGY

Office of Fossil Energy

NETL-TRS-2-2015

Disclaimer

Cover Illustration: Representative range of the cumulative estimated annual economic value per 4.77 x 4.77 km grid cell in the northwest region of the Gulf of Mexico based off activities related to oil and gas, commercial fishing, and tourism ocean use sectors. Specific estimated economic values are calculated in U.S. Dollars ($USD) for each grid cell, but are not shown in this figure for sensitivity reasons.

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A Spatio-Temporal Approach to Analyze Broad Risks and Potential Impacts Associated with Uncontrolled Hydrocarbon Release Events in the Offshore Gulf of Mexico

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Acronyms, Abbreviations, and Symbols

Term	Description
AAPA	American Association of Port Authorities
AIS	Automatic Identification System
BLOSOM	BLOwout and Spill Occurrence Model
BOEM	Bureau of Ocean Energy Management
CAGES	Comparative Assessment of Gulf Estuarine ecoSystems database
CFEV	Commercial fisheries economic value
CSILs	Cumulative spatial impact layers
DOE	Department of Energy
EEZ	Exclusive Economic Zone
EDX	Energy Data eXchange
EPA	Environmental Protection Agency
FSD	Fisheries Statistics Division
GDP	Gross domestic product
GIS	Geographic information service
GOM	Gulf of Mexico
GSMFC	Gulf States Marine Fisheries Commission
GOM IAM	Gulf of Mexico Integrated Assessment Model
HSMs	Habitat Suitability Models
IED	Inverse Euclidian Distance
MPAs	Marine Protected Areas
MSP	Marine spatial planning
MRIP	Marine Recreational Information Program
NETL	National Energy Technology Laboratory
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OBIS	Ocean Biogeographic Information System
OCS	Outer Continental Shelf
O&M	Operating and maintenance
ORD	Office of Research and Development
OSC	Oil Spill Commission
OSU	Oregon State University

Acronyms, Abbreviations, and Symbols

Term	Description
SEAMAP	Southeast Area Monitoring and Assessment Program
Semisub	Semisubmersible
SH	Species habitat
UNESCO	United Nations Educational, Scientific and Cultural Organization
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USD	United States Dollar
WMA	Wildlife management areas

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We also wish to thank the individuals and organizations who collect and provide publically data that was integral to this work. Without their efforts, this type of research would not be possible.

- Bureau of Ocean Energy Management (BOEM)
- Bureau of Transportation Statistics
- Entergy Corporation
- Florida Department of Parks and Recreational Areas
- Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute
- Google
- Gulf States Marine Fisheries Commission
- Hotelsbase
- Louisiana Department of Transportation and Development
- Louisiana Department of Wildlife and Fisheries
- National Atlas
- National Oceanic and Atmospheric Administration (NOAA)
- Noble Corporation
- Ocean Biogeographic Information System
- Oregon State University
- Rigzone
- Texas Parks and Wildlife Department
- Transocean
- U.S. Department of Interior, National Park Service
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

As hydrocarbon development in offshore settings pushes into deeper water and targets deeper subsurface resources, uncertainty and risks related to accessing and producing these resources can increase the potential for deleterious events. The work discussed here is part of an ongoing project that seeks to prevent future offshore spill events by quantifying and evaluating potential risks associated with exploration and production in the extreme offshore Gulf of Mexico (GOM) from the subsurface to the shore. In particular, this report focuses on efforts utilized by the Department of Energy's (DOE) National Energy Technology Laboratory (NETL) to develop spatial layers capable of supporting risk assessment predictions and research for the Gulf of Mexico.

After the BP Deepwater Horizon oil spill, the Federal Oil Spill Commission (OSC) identified significant gaps in the capabilities of current tools and technologies utilized to predict risks and quantify impacts associated with offshore hydrocarbon production, particularly in the GOM. The OSC also reported that our understanding of the environmental, economic, social impacts associated with an oil spill were inadequate (Graham et al., 2011).

In 2010, NETL researchers from the Office of Research and Development (ORD) initiated a research project focused on preventing offshore hydrocarbon spills in the GOM through the concatenation and analysis of publically available data along with new interpretations, analytical tools, and models. This report presents continued research efforts in support of NETL's development of the Gulf of Mexico Integrated Assessment Model (GOM IAM), a publically-available, open access coordination platform for independent, rapid-response, and science based predictions to assess risks and potential impacts associated with deep and ultra-deepwater drilling loss of control events in a variety of settings throughout the GOM. Building off previous NETL research (Graham et al., 2012) where spatial datasets related to the subsurface, wellbore, and water column systems were collected and integrated to support GOM IAM development, this report outlines a spatial approach that utilizes key spatial datasets representative of various social, economic, and environmental receptors interacting with the marine system to create cumulative spatial impacts layers (CSILs). CSILs provide a qualitative and quantitative representation of various receptors' spatial extent or economic value to help evaluate potential impacts and risks associated with various uncontrolled hydrocarbon release scenarios to better inform spill prevention efforts.

In this report, we have outlined the approach as well as provided a case study utilizing publically available, authoritative data representative of four major socio-economic ocean use sectors in the GOM: oil and gas industry, commercial transportation, commercial fisheries, and tourism. These datasets were analyzed and integrated to create CSILs, based off their spatial extent and estimated annual economic value to provide qualitative and quantitative results. These CSILs can then be integrated with the GOM IAM to assess potential risks and estimate broad impacts associated with hydrocarbon production and extraction throughout the GOM. These CSILs are anticipated to provide a unique Gulf-wide resource, and will be used in tandem with other GOM IAM products, including the BLOwout and Spill Occurrence Model (BLOSOM), which is a multi-component, integrated water column modeling system capable of simulating oil spills resulting from deep and ultra-deepwater blowouts in the GOM (Sim, 2013). Together, modeled oil spill scenarios from BLOSOM can be overlaid with the CSILs to assess potential economic and spatial impacts of an oil spill or blowout event, evaluate oil spill prevention methods, and

identify key technology gaps that may benefit from further research and development. Moreover, these CSILs can also be used to assist with oil spill prevention and response. The CSILs produced as a product of this effort will be made publically available through NETL's Energy Data eXchange (EDX; https://edx.netl.doe.gov/) and the GOM Geocube (https://edx.netl.doe.gov/gom-geocube/).

1. PROJECT MOTIVATION AND OVERVIEW

Recent natural and anthropogenic uncontrolled hydrocarbon release events, such as from Hurricanes Katrina and Rita and the BP Deepwater Horizon disaster, identified significant gaps in the ability of current tools and technology to predict risks associated with offshore hydrocarbon production as well as the capabilities to respond to deleterious events of varying scope, magnitude, and duration (Graham et al., 2011). Knowledge of these gaps along with industry's continued advance into new, unpredictable environments, particularly deep and ultra-deep water and subsurface environments, exemplifies the need for a comprehensive system-wide tool that integrates science based data to simulate the complexities of natural and engineered-natural systems to estimate potential risks and impacts. No publically available solutions are currently available that can incorporate subsurface reservoir, wellbore, and water column data and simulation tools to allow for spatial prediction in support of spill prevention and rapid response to unexpected hydrocarbon release events.

Instead, systems available tend to focus on single components (e.g., subsurface reservoir characteristics, or blowout characteristics, or surface spill characteristics, or oil weathering characteristics, or response options, etc.). Therefore, there is no integrated system available that captures the inherent complexities found in and between natural and engineered-natural systems that can heavily influence the behavior of an uncontrolled release event (Reed et al., 1999). Additionally, many of the integrated models available that are capable of combining multiple components tend to be proprietary and can require a significant investment to obtain access to the software and/or the underlying supporting data. Furthermore, a large range of datasets are utilized by these solutions as model inputs, including proprietary databases, field data collected by industry, and authoritative, open-source datasets provided mainly by federal and state governmental agencies and academia. However, these datasets are often dispersed amongst sources, varying in quantity and quality, and unavailable in a single location making it difficult to access data quickly when needed, such as during the response and recovery to any future offshore loss of control event.

To address these gaps, efforts are being taken at NETL to develop the Gulf of Mexico Integrated Assessment Model (GOM IAM), a publically-available, open access coordination platform that will allow for independent, rapid-response, and science based predictions of offshore hydrocarbon spills to assess risks and potential impacts associated with deep and ultra-deepwater drilling under various environmental conditions throughout the GOM. Since 2011, efforts have been focused on developing integrated component models for the reservoir, overburden, wellbore flow, and water column systems in deep (500–4,999 ft) and ultra-deep (>5,000 ft) water environments of the GOM (Rose et al., 2014). Additional work has also been done to collect, analyze, and interpret existing datasets to develop a geospatial database for the GOM and an online system that allows researchers from multiple organizations to coordinate and distribute the various datasets necessary to assess risks and impacts associated with offshore hydrocarbon development (Graham et al., 2012; Rose et al., 2014). The GOM IAM will be utilized to predict potential risks, highlight technology gaps, and improve our understanding of key systems and interactions associated with deep and ultra-deepwater offshore hydrocarbon development to improve oil spill prevention efforts, promote safer development and operations, as well as act as a baseline rapid response tool for any future uncontrolled hydrocarbon release events.

In order to effectively evaluate potential risks and identify technology gaps, as well as improve our understanding of natural and engineered-natural systems, a spatial approach was developed that concatenates data representative of key social, economic, and ecological receptors for a given region. This approach creates cumulative spatial impact layers (CSILs) that provide qualitative and quantitative estimates of key activities' spatial extent or economic value that can be used in combination with the results from different models, such as those produced from various GOM IAM tools, including the BLOwout and Spill Occurrence Model (BLOSOM), to identify broad spatial trends related to estimating risks and evaluating potential impacts associated with different modeled loss of control scenarios. The inherent flexibility of the CSIL approach presented here allows it to be quickly modified so that it can be applied in different geographic regions as well as natural and engineered-natural systems. The CSIL approach can also be performed utilizing spatial datasets that represent a diverse range of social, economic, and environmental factors to satisfy various analytical needs. To demonstrate the flexibility of this approach, a case study for the GOM is detailed to provide examples of datasets that can be used to represent the spatial extent or economic value of key socio-economic activities, identify useful analytical methods to determine spatial extent and quantify economic values, and, lastly, how datasets can be combined to create the final CSILs to identify key spatial trends and patterns related to potential impacts and can be utilized to evaluate risks associated with different loss of control scenarios.

2. DEVELOPING A SPATI- APPROACH

Lessons learned following the BP Deepwater Horizon oil spill highlighted the difficulties of managing ocean use sectors individually, leading to recommendations from the Federal Oil Spill Commission, the Interagency Ocean Policy Task Force, and Executive Order 13547 to utilize a marine spatial planning (MSP) framework when considering the activities of ocean use sectors (Graham et al., 2011; Interagency Ocean Policy Task Force, 2010; Obama, 2010). A MSP framework utilizes a more comprehensive, adaptive, integrated, and ecosystem-based approach to reduce potential conflicts amongst ocean users and estimate risks and evaluate potential impacts related to individual ocean use activities as well as the interactions between them (Interagency Ocean Policy Task Force, 2010; Obama, 2010; St Martin and Hall-Arber, 2008; Stelzenmüller et al., 2013; Stelzenmüller et al., 2008; White et al., 2012). Therefore, using a MSP framework, we developed a spatial approach that concatenates spatial data representative of key social, economic, and ecological receptors to provide a qualitative and quantitative estimate of their cumulative spatial extent or economic value for a given region of interest. To accomplish this, the CSIL approach utilizes four steps: (i) identifying key receptors, (ii) collecting data, (iii) analyzing data, and (iv) creating CSILs to evaluate the cumulative spatial extent and economic value of various receptors to help support oil spill prevention analysis efforts (Figure 1).

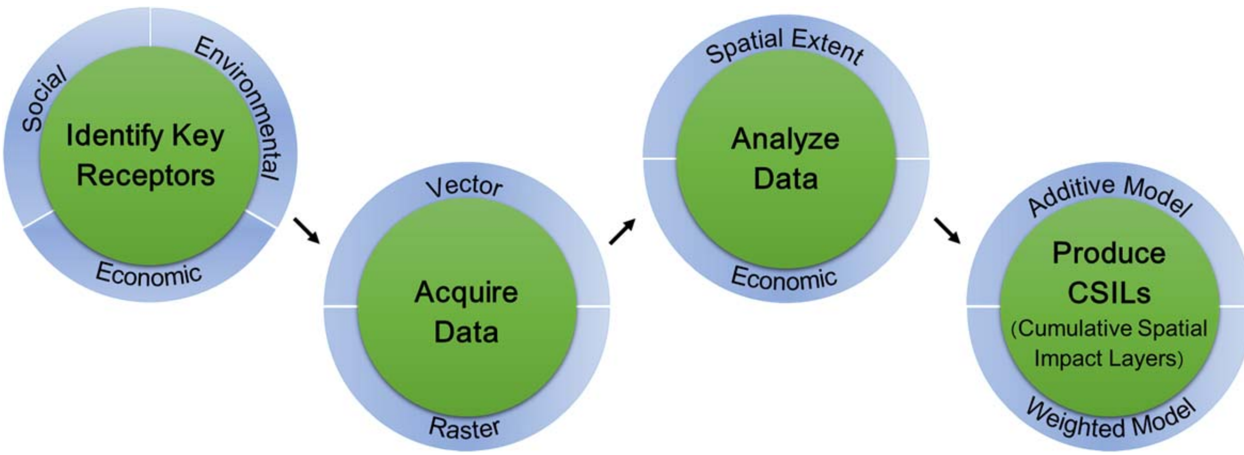

Figure 1: Workflow for NETL's CSIL approach.

In order to effectively evaluate risk and estimate potential impacts an understanding of the key social, economic, and ecological receptors for a user's region of interest will need to be determined. The vast number of potential receptors located throughout the water column and near-shore environments in diverse marine systems, such as oil and gas infrastructure, commercial transportation, biological communities, etc., can make identifying appropriate receptors for any region of interest difficult. To effectively identify receptors, researchers utilizing NETL's CSIL approach should focus on selecting receptors that have traditionally been affected by oil spills and are important to the social, economic, and/or ecological health or success of the region of interest (Aldy, 2011; Graham et al., 2011; National Oceanic and Atmospheric Administration, 2014; Nelson et al., 2014).

Once regional receptors have been evaluated and a subset of key receptors has been identified, spatial datasets will need to be collected to drive the analysis and creation of CSILs. The breadth of spatial data available to users related to each receptor will need to be evaluated to ensure they select the most appropriate, authoritative datasets. With NETL's CSIL approach, users can select any combination of spatial data formats, such as vector (i.e., points, lines, or polygons) and raster (e.g., DEMs, interpolated surfaces, satellite images, etc.) data, which either directly represent or can serve as a proxy for estimating the spatial extent and/or economic value of each identified receptor. In certain cases, the lack of spatial data may require users to relate tabular data or data from authoritative literature with data that has an appropriate spatial context. Also, users must ensure that the spatial data selected has the appropriate spatial and temporal resolution necessary for their analysis.

Next, these data will be analyzed to create appropriate spatial layers representative of each receptors cumulative spatial extent and/or economic value. This can be accomplished utilizing various spatial analytical tools, but will require a user to select the tools most appropriate for their data. Users might need to preform analyses that associate all their spatial data into a common coordinate system that is appropriate for their region of study (see Graham et al. (2012) and Romeo et al. (2015) for examples), combine related data for a receptor into a single dataset, convert vector data into raster data, sum spatial extents, and calculate economic values that can be associated with spatial data. A more detailed example of analyses that can be performed with the CSIL approach is detailed in a case study for the GOM within this paper (starting in Section 4).

Once data has been analyzed, CSILs for the spatial extent and/or economic value can be created. NETL's CSIL approach utilizes raster datasets (many of which are created in step 3, described above) as inputs for either an additive or weighted model to create CSILs that represent the cumulative spatial extent or economic value for a user's region of interest. This ability to select different models to create CSILs allows users to weigh or scale their analysis based off the sensitivity of their selected receptors to an oil spill, such as in relation to the sensitivity of a species based off its distribution (i.e., locomotive abilities, migration patterns, etc.), life stage (e.g., youth, juvenile, adult, mating/spawning seasons, etc.), as well as seasonal or temporal sensitivities such as factors relating to fishing pressures or tourism seasons. An additive model allows users to sum the spatial extent or economic value for each raster grid cell for all input layers to produce a CSIL where the scale will range from 0 to the maximum number of input receptors to represent spatial extent, or from the minimum to maximum summed value to represent economic values. Whereas a weighted model will multiply each input layer based off a weight value (e.g., 1–100, or 0.1–1.0, etc.) that will affluence the summation of the final CSIL, where greater values will be associated with heavier weighted receptors that a user has determined as more sensitive to the effects an oil spill than the other receptors utilized for their analysis. This final CSIL can then be utilized with oil spill model output to help quantify potential impacts, identify knowledge gaps, visualize locational and seasonal trends, evaluate oil spill response efforts, and compare different oil spill scenarios.

3. GULF OF MEXICO CASE STUDY

In order for the GOM IAM to effectively evaluate potential risks and identify technology gaps, as well as improve our understanding of natural and engineered-natural systems in the GOM, key social, economic, and ecological receptors needed to first be identified. With the vast number of potential receptors throughout the water column and near-shore environment of the GOM, such as oil and gas infrastructure, commercial transportation, biological communities, etc., all of the potential receptors were evaluated to identify a subset of key receptors in the GOM that have historically been affected by oil spills and blowouts and are important to the social, economic, and/or ecological health of the GOM region (Aldy, 2011; Graham et al., 2011; National Oceanic and Atmospheric Administration, 2013; Nelson et al., 2014). Using this information, we selected four major socio-economic ocean use sectors: i) oil and gas industry, ii) commercial transportation, iii) commercial fisheries, and iv) tourism to estimate their spatial distribution and annual economic value to provide qualitative and quantitative CSILs.

3.1 IDENTIFYING KEY RECEPTORS

To effectively estimate potential risks and impacts in the GOM associated with uncontrolled hydrocarbon release events, we first needed to identify ocean use sectors that are often receptors for a range of deleterious effects associated with loss of control events. Rather than collect information for every ocean use sector in the GOM to evaluate potential impacts and risk, we focused our efforts on common ocean use sectors within the GOM that significantly contribute to local jobs and the economy in all the Gulf States and are traditionally affected by oil spills (Aldy, 2011; Graham et al., 2011; National Oceanic and Atmospheric Administration, 2013). Furthermore, these sectors needed to have adequate authoritative spatial data available that represented various activities within each selected ocean use sector. Given these criteria, we focused our research efforts on potential receptors within the oil and gas, commercial transportation, commercial fishery, and tourism sectors of the GOM.

Within the GOM, the oil and gas industry is the largest contributing ocean use sector to the economy in terms of gross domestic product (GDP). In 2010, the oil and gas sector employed approximately 111,000 individuals and contributed $70.5 billion towards the GDP of the Gulf States (National Oceanic and Atmospheric Administration, 2013). Beyond the socio-economic importance of the oil and gas industry in the GOM, there are also significant costs associated with daily well operations; in some cases the average rig operating and maintenance costs can exceed $500,000 per day (Noble, 2013; Transocean, 2013). The economic loss associated with the shutdown of well operations, whether induced by natural or anthropogenic loss of control events has financial implications, in the multi-million to billion dollar range, just in out-of-service operating costs alone. Commercial transportation in the Gulf is also an important industry, as it spans numerous activities associated with shipping, such as port services, cargo handling and warehousing, ferries, pipeline transportation, manufacture of navigational equipment, and numerous import/export businesses. In 2010, the commercial transportation industry in the GOM employed approximately 83,000 individuals and contributed over $11 billion dollars to the overall GDP of the Gulf States (National Oceanic and Atmospheric Administration, 2013). Along with direct forms of employment and economic value, the ports in the Gulf are some of the busiest in the U.S., with seven of the top ten busiest ports in the U.S. and with the Port of Southern Louisiana (i.e., New Orleans) and Houston being the two busiest ports in the U.S. in terms of cargo volume, supporting additional indirect industries (American Association of Port Authorities, 2013; U.S. Environmental Protection Agency, 2012).

The two ocean use sectors that tend to draw the most attention as potential receptors to deleterious impacts from uncontrolled hydrocarbon loss events in the GOM, and throughout the world, are commercial fisheries and tourism. Commercial fishing activities within the GOM are not only a significant contributor to the local Gulf States economy, but also a critical socio-economic sector. According to the National Oceanic and Atmospheric Administration (NOAA) (2011), the Gulf States (Texas (TX), Louisiana (LA), Mississippi (MS), Alabama (AL), and Florida (FL)) landed 1.8 billion pounds of finfish and shellfish in 2011, earning approximately $818 million dollars in total landings revenue. Additionally, the entire Gulf seafood industry generated over $18.8 billion dollars in 2011 (National Oceanic and Atmospheric Administration, 2011). Tourism based activities within the GOM contributed 11% or $10.9 billion to the overall GDP of the Gulf States in 2010. In addition, the tourism industry in the GOM employs 50.6% of the people (271,000) working in the various ocean sectors of the Gulf States (National Oceanic and Atmospheric Administration, 2013). Recreational fishing, another popular tourist activity, is another major contributor to the economy of the Gulf States. A report following the BP Deepwater Horizon oil spill estimated that an average of 106,703 recreational fishing trips were taken per day in the GOM, generating approximately $9 million dollars per day (Gentner, 2010).

Events during the BP Deepwater Horizon oil spill demonstrated the range of effects an uncontrolled hydrocarbon release event can have on these four socio-economic ocean use sectors. For example, impacts to the entire oil and gas industry mainly resulted from the federal moratorium put into place on all deep and ultra-deep drilling activities in the GOM (Gentner, 2010). Other effects included the precautionary shutdown of the nearby Nakika crude oil pipeline due to concerns over potential damage to the pipeline from debris from the Deepwater Horizon rig (Aldy, 2011). Concerns within commercial transportation focused on the potential adverse effects of the BP Deepwater Horizon oil spill on shipping, including concerns over potential delays as well as possible contamination from vessels into inland waters that were not previously affected by the oil spill (Aldy, 2011; Bureau of Transportation Statistics, 2010). As a result the U.S. Coast Guard established additional procedures for inspection and cleaning vessel hulls to prevent oil from being spread by vessels (Aldy, 2011). Following the BP Deepwater Horizon oil spill, there were immediate health concerns about the safety of fisheries within the Gulf, which resulted in the closures of state and federal waters throughout the GOM to commercial fishing activities. Concerns over the safety of consuming seafood from the GOM had significant effects on local fishermen, as well as the processing facilities, seafood distributors, and restaurants across the region (Graham et al., 2011). Businesses also related to tourism activities, including hotels and recreational fishing charters, were also significantly impacted by concern over the safety of oil-exposed regions and seafood, resulting in the cancellation of reservations and loss of revenue for those businesses, even in areas that were never affected by the oil spill (Graham et al., 2011). The wide-spread effects on the oil and gas industry, commercial transportation, commercial fishing, and tourism demonstrated during the BP Deepwater Horizon oil spill, as well as the significant contribution from these ocean use sectors to local jobs and the economy in all the Gulf States, demonstrate the importance of better understanding the spatial extent of these four ocean use sectors throughout the Gulf to help better estimate and predict potential risks and impacts associated with continued hydrocarbon exploration and production in the GOM.

3.2 COLLECTING REPRESENTATIVE DATA SOURCES

This study utilized publically available, authoritative datasets for our analyses. Data collection for this project has been ongoing since 2011 (Graham et al., 2012). The datasets outlined below served as proxies for various ocean use activities within the oil and gas, commercial transportation, and commercial fishery, and tourism sectors in the GOM. Datasets collected and utilized in this study include a mix of vectors (i.e., points, lines, or polygons) and rasters (i.e., continuous surfaces).

3.2.1 Oil and Gas Industry

To evaluate potential impacts to oil and gas industry, infrastructure data was collected for platforms, boreholes, and pipelines in the GOM from the Bureau of Ocean Energy Management (BOEM) and the Marine Cadastre project. BOEM is responsible for the development of the Outer Continental Shelf (OCS) leasing program which oversees assessments of the oil, gas and other mineral resource potential, inventories oil and gas reserves, and develops production projections for the U.S. They provide a complete and up-to-date database regarding the infrastructure in the GOM and the U.S. Additional datasets related to the oil and gas industry were provided by BOEM and NOAA, along with additional state and federal partners, on the Marine Cadastre, a project that integrates marine information systems that provide geographic information to the public (National Oceanic and Atmospheric Association and Bureau of Ocean Energy Management, 2013). These datasets were utilized as proxies for estimating the spatial extent of oil and gas related activities within the GOM. However, our search efforts were unable to identify any spatially explicit information relating to economic values. Instead we utilized industry reports to provide economic data that could be associated with the oil and gas infrastructure layers used to estimate the spatial extent of oil and gas activities in the GOM.

3.2.2 Commercial Transportation

The dominant source of data related to the spatial extent of commercial transportation activities are collected by the Automatic Identification System (AIS), an onboard navigation system which records and transmits the location and characteristics of vessels in U.S. and international waters. Within the U.S., AIS data are collected and maintained by the U.S. Coast Guard and other commercial vendors. AIS data, which can serve as a proxy for estimating commercial transportation activities, was made available by the U.S. Coast Guard on Marine Cadastre for commercial vessels from 2009–2011 in monthly time steps (National Oceanic and Atmospheric Association and Bureau of Ocean Energy Management, 2013). Information such as location, time, ship type, speed, length, beam, and draught was extracted from the raw data using the AIS data handler and data analysis tool packaged for a desktop geographic information service (GIS) software, ArcGIS (Esri, 2012), provided by Marine Cadastre. These data were used to estimate commercial vessel density and provide a proxy for the spatial extent of commercial transportation activities throughout the GOM. Given the limitation of spatial datasets related to commercial transportation activities in the Gulf, we were unable to identify any spatially explicit information relating to economic values and find a method capable of linking economic data from industry sources with the AIS commercial vessel density layer used to estimate the spatial extent of commercial transportation activities in the GOM.

3.2.3 Commercial Fisheries

To evaluate commercial fishing related activities throughout the GOM, most of the representative spatial layers were downloaded from various NOAA websites, but there was a lack of spatially-explicit data representing commercial fishing activities throughout the Gulf. Therefore, for the purpose of this report we considered the spatial extent of commercial fishing activities in the GOM to be equivalent to the areas of federal waters where commercial fishing activities are permitted, the U.S. Exclusive Economic Zone (EEZ) (National Oceanic and Atmospheric Association and Bureau of Ocean Energy Management, 2013). However, the EEZ covers large areas within the GOM and fails to delineate any areas from which commercial fishing has been restricted, such as Marine Protected Areas (MPAs) (National Oceanic and Atmospheric Association and Bureau of Ocean Energy Management, 2013). Therefore, for analyzing the spatial extent of commercial fishing activities in the GOM, we utilized MPA boundaries to refine our commercial fishing layer, represented by the EEZ boundary, and remove areas where commercial fishing is prohibited in the GOM. Datasets related to the location of critical ports and processing plants (U.S. Army Corps of Engineers, 2010) for commercial fish species, focusing primarily on brown shrimp, white shrimp, and Gulf menhaden since they represent approximately 60% of the total commercial landings in the GOM (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2012), were also used to analyze the spatial extent of commercial fishing activities in the GOM.

Given the coarse spatial resolution of spatial layers available and lack of spatially explicit economic data related to commercial fishing activities throughout the GOM, our analyses to estimate economic values with commercial fishing were supplemented by research from Oregon State University (OSU). OSU researchers utilized species occurrence and environmental data from the Gulf States Marine Fisheries Commission (GSMFC) Southeast Area Monitoring and Assessment Program (SEAMAP) for brown shrimp, white shrimp, and Gulf menhaden (Gulf States Marine Fisheries Commission, 1983–2010) to create Habitat Suitability Models (HSMs) for all three species using Maxent modeling software (version 3.3.3k; available at http://www.cs.princeton.edu/~schapire/maxent/). The HSMs for all three species were correlated with commercial fishery landings values from 1990–2011 (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2012). Major U.S. ports for brown and white shrimp as well as major processing plants for Gulf menhaden were used in the economic analysis as well to estimate the economic value associated with commercial fishing activities in the GOM.

3.2.4 Tourism

Tourism, as a major industry in the GOM drawing visitors to the region due to the abundance of natural resources, temperate climate, and miles of shoreline, can be associated with numerous activities. To evaluate the possible impact on tourism related activities, we focused on identifying datasets related to the hotel industry, recreational fishing, and recreation areas, such as national and state parks, wildlife refuges, and preservation areas to serve as proxies for identifying the spatial extent and economic value of tourism based activities in the GOM.

3.2.4.1 Hotels

Estimating the spatial extent and economic value for the hotel industry in the Gulf was based off hotel data collected from Hotelsbase (2013), an open source application which contains contributed data on hotels from all over the world. Hotelsbase's databases were queried to select hotels within 3 km of the GOM shoreline, since literature from previous oil spill impacts indicated that tourism activities, including the hotel industry, within close proximity of the shoreline were more negatively affected from an oil spill than activities located further away (Restrepo et al., 1982). Queries from Hotelsbase on Gulf State hotels, motels, resorts, and condos provided details on hotel names, location, average room rate, total number of rooms, and average star ratings, which ranged from 1 to 5 stars, for each record. Additionally, 79 randomly selected hotels (based off state and star rating) were contacted for brief phone interviews to acquire additional information that was not provided from Hotelbase. Out of the 79 contacted, 65 answered the following questions:

1. During which months are the hotel's busy and off seasons?
2. What is the hotel's occupancy rate during the busy and off season?

Additionally, 30 of the randomly selected hotels interviewed were asked the additional question of:

1. How many rooms are in the hotel? (due to errors in the hotel data from Hotelsbase)

Information from the Hotelsbase database query, along with the supplemental information provided from phone interviews (n = 30) on the number of rooms per hotels (detailed in Appendix C) were used to calculate monthly occupancy percentages for each hotel based off the state and star rating. Economic data, also provided from Hotelsbase, were used to spatially associate economic values with hotels around the Gulf States.

3.2.4.2 Recreational Fishing

To estimate the spatial extent and economic value of recreational fishing activities in the GOM, data on the number of anglers and estimated recreational trip expenditures were collected from numerous sources. Species occurrence databases, such as the Southeast Area Monitoring and Assessment Program (SEAMAP) database (Gulf States Marine Fisheries Commission, 1983-2010), the Comparative Assessment of Gulf Estuarine ecoSystems (CAGES) (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2013a), and the Ocean Biogeographic Information System (OBIS) (2013), were used as proxies for the spatial extent of recreational fishing activities. Economic values were estimated from data on the number of angler trips and associated trip expenditure was collected from the Gulf States Marine Fisheries Commission (GSMFC) (2009), and NOAA National Marine Fisheries Service (NMFS) (2009), and NOAA Fisheries Statistics Division (FSD) (2013b). Additional information on recreational fishing activities in the Gulf was obtained from the Marine Recreational Information Program (MRIP) carried out by NOAA FSD (2013b). The program conducts in person and over the phone interviews with recreational fishermen. The data collected from the interviews were used to statistically estimate the total catch, total number of anglers, and relative location of recreational fishing activities across the GOM in a given two month time period. The MRIP survey data, estimated annual recreational fishing expenditure data, and recreational fishing density provides the datasets necessary to spatially estimate the amount spent on recreational fishing in the GOM.

3.2.4.3 Recreational Areas

Uniform to the selection process for the hotel data, parks and wilderness conservation and preservation areas that were within 3 km of the shoreline were used as a proxy for estimating the spatial extent of tourism based activities in the GOM. Locational data on the National Parks was acquired from the National Park Service for 2002–2013 (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2013a). Geospatial data of state park boundaries was available from the appropriate state agency, except for Alabama (Florida Department of Parks and Recreational Areas, 2011; Louisiana Department of Transportation and Development, 2007; Mississippi Site Selection Center, 2013; Texas Parks and Wildlife Department, 2011). To obtain information for state parks in Alabama, points were obtained for Alabama state parks using Google API web services (available online at https://developers.google.com/). Points were transformed into polygons to identify additional state parks areas that were not provided in the other datasets. Geospatial data on the location of wildlife refuges and preservation areas were found through the U.S. Fish & Wildlife Service Geospatial Services search engine (2013) and the National Atlas (2005). Additional wilderness management areas specific to Louisiana, which were not already included in the previous datasets collected were added from the Louisiana Department of Wildlife and Fisheries (2006). A detailed map on the location of all recreational areas used for the analyses is available in Appendix D. Spatially explicit economic information was not obtained for any of the recreational areas due to its lack of availability and therefore, recreational areas will not be factored into the proxy for economic value of tourism related activities for the GOM.

3.3 ANALYZING DATA

Once necessary datasets were collected, differences in spatial formats, spatial and temporal extents, and spatial resolutions needed to be rectified for each activity within the ocean use sector, to provide a common framework for the spatial analytical techniques utilized to calculate both the cumulative spatial extent and estimated annual economic value for each of our selected ocean use sectors. To ensure compatibility across all our analyses, all created rasters were set to a resolution of approximately 4.77 x 4.77 km, which was the coarsest spatial resolution from all our datasets, to reduce uncertainty and improve accuracy of our analyses and any produced spatial layers.

3.3.1 Oil and Gas Industry

3.3.1.1 Estimating Spatial Extent

The oil and gas industry ocean use layers were created using data related to oil and gas platforms, wells, and pipelines from BOEM and the Marine Cadastre (Table 1). Each infrastructure shapefile (Figure 2A, 2B, 2C) were converted into a presence-absence rasters, where a value of 1 indicates the presence of an infrastructure activity and 0 indicates the absence of any infrastructure activity. Once a presence-absence raster was created for oil and gas platforms, wells, and pipelines, an unweighted, additive model was used in ArcGIS (Esri, 2012) to combine all presence-absence rasters, to produce a cumulative oil and gas layer that represents the number of ocean use activities within each 4.77 x 4.77 km grid cell (Figure 2D).

Table 1: List of datasets, data sources, and URLs utilized as proxies to identify the spatial extent of oil and gas related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
Oil and Gas Platforms	Bureau of Ocean Energy Management (BOEM)	http://data.boem.gov/homepg/data_center/platform/platform.asp http://www.marinecadastre.gov/data/default.aspx
Oil and Gas Wells	BOEM	http://data.boem.gov/homepg/data_center/well/well.asp http://www.marinecadastre.gov/data/default.aspx
Pipelines	BOEM	http://data.boem.gov/homepg/data_center/pipeline/pipeline.asp http://www.marinecadastre.gov/data/default.aspx

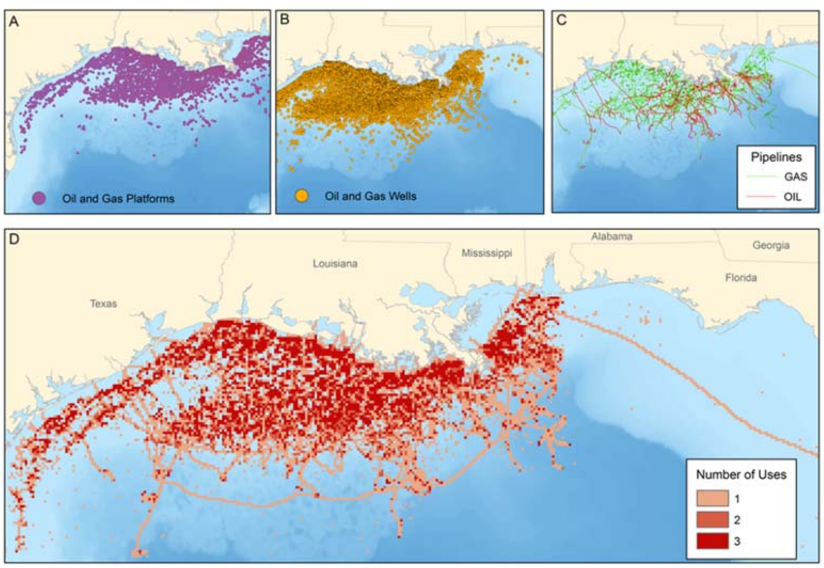

Figure 2: Location of present-day key oil and gas infrastructure in the Gulf of Mexico; Oil and Gas Platforms (A), Oil and Gas Wells (B), and Pipelines (C). Cumulative number of oil and gas ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico (D).

3.3.1.2 Estimating Annual Economic Value

Due to the lack of spatially explicit economic data associated with the oil and gas industry, we utilized industry sources to estimate the daily operating and maintenance (O&M) cost of semi-submersible (or semisub) drilling units in the GOM to relate economic values with the location of oil and gas platforms in the GOM (Table 2) (Rigzone, 1999). Furthermore, the lack of information from the oil and gas platform layer, we assigned approximate economic values to each platform in the GOM based off water depth, since daily O&M costs increase as water depth increase (Table 2).

Table 2: List of datasets, data sources, and URLs utilized as proxies to estimate the annual economic value of oil and gas related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
Oil and Gas Platforms	Bureau of Ocean Energy Management (BOEM)	http://data.boem.gov/homepg/data_center/platform/platform.asp http://www.marinecadastre.gov/data/default.aspx
Daily Operating and Maintenance Costs for Semi-submersible Drilling Units	Rigzone	http://www.rigzone.com/data/dayrates/

The oil and gas platform shapefile, which contains the location of oil and gas platforms in the GOM, was split into three separate layers based off water depth and each platform within the layer was assigned an economic value based off the average daily O&M cost (Table 3). The three layers were then merged and point statistics were run using ArcGIS (Esri, 2012) using a 3-km square search radius to aggregate all platforms and calculate a total economic value for each 4.77 x 4.77 km grid cell. Since these economic values now assigned to each grid cell represented an estimated daily O&M cost, each grid cell value was multiplied by 365 to calculate the annual daily O&M cost per grid cell to represent the estimated annual economic value, in U.S. Dollars ($USD) of oil and gas related activities in the GOM (Figure 3).

Table 3: Breakdown of daily operating and maintenance costs for semi-submersible (a.k.a. semisub) rigs based off water depth (Rigzone, 1999)

Floating Rigs	Average Day Rate
Semisub < 1,500 ft water depth	$281,000
Semisub 1,500–4,000 ft water depth	$317,000
Semisub 4,000 ft + water depth	$438,000

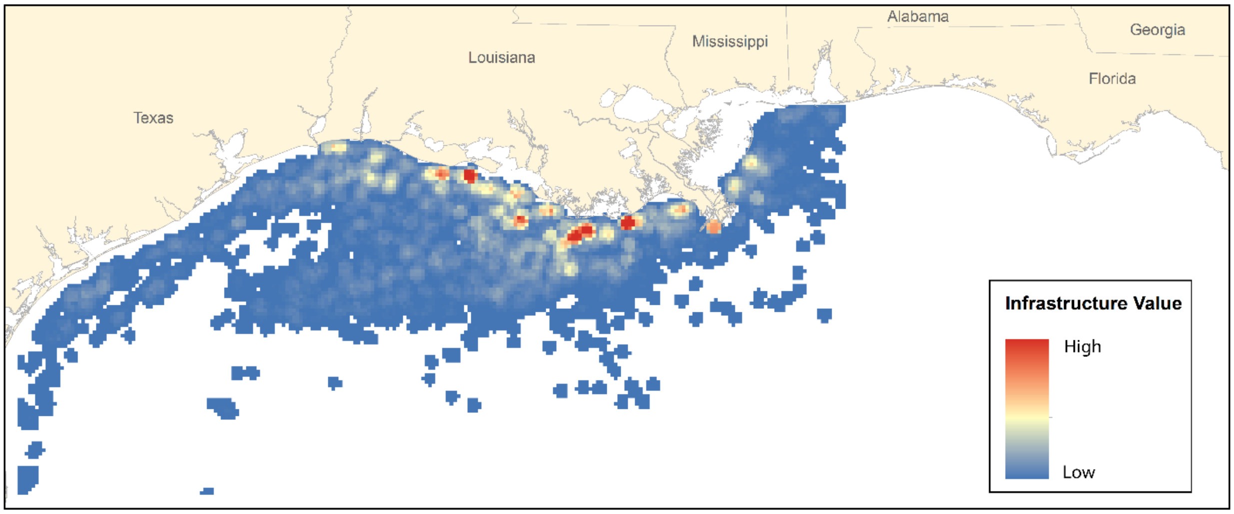

Figure 3: Representative range of the estimated annual economic value of oil and gas ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico. Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

3.3.2 Commercial Transportation

3.3.2.1 Estimating Spatial Extent

Using AIS data as a proxy for commercial transportation activities in the GOM (Table 4), point based ship track locations for each month of the year were downloaded in a file geodatabase from Marine Cadastre. The ship track points were connected in 24-hour time stamps for each month of the year using the Track Builder tool in ArcGIS (Esri, 2012) to create a series of polyline shapefiles for each month. These monthly polyline shapefiles were then merged to create an annual ship track polyline shapefile, which was used to create a vessel density raster, based off the annual number of commercial vessels observed per 4.77 x 4.77 km grid cell throughout the GOM. This layer is used to represent the overall spatial extent of commercial transportation ocean use activities throughout the GOM (Figure 4). A presence-absence raster was also created from the vessel density raster, where a value of 1 indicates the presence of the activity and 0 indicates the absence of the activity, for use in later analyses.

Table 4: List of the dataset, data source, and URL utilized as a proxy to identify the spatial extent of commercial transportation related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
2009–2011 AIS Data	U.S. Coast Guard (USCG)	http://www.marinecadastre.gov/AIS/default.aspx

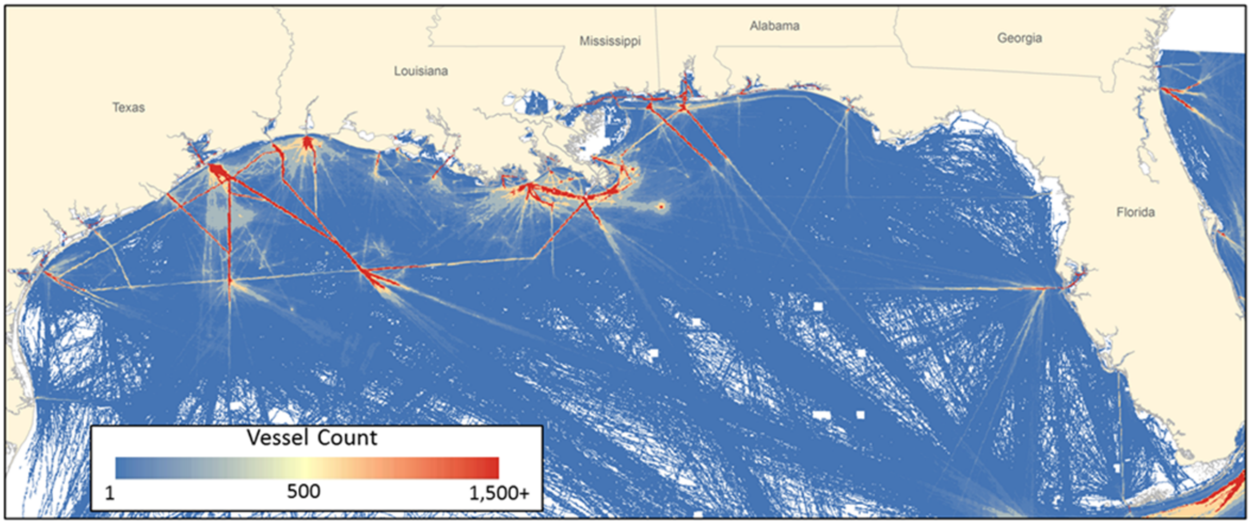

Figure 4: Annual density of commercial vessels per 4.77 x 4.77 km grid cell in the Gulf of Mexico.

3.3.2.2 Estimating Annual Economic Value

Economic costs associated with ship track lines have not yet been established for this research, due to problems associating economic values with specific ship track lines since most of the publically available datasets were not spatially exclusive. In order to evaluate the economic impact of an uncontrolled release event to commercial transportation in the Gulf, additional information would need to be collected to provide means for estimating economic values associated with spatially explicit commercial transportation activities. At a minimum, however, the overall spatial extent layer representing commercial transportation ocean use activities throughout the GOM (Figure 4) allows for the assessment of the number of vessels impacted on a daily basis for a given region based on hypothetical or actual hydrocarbon spill occurrences.

3.3.3 Commercial Fisheries

3.3.3.1 Estimating Spatial Extent

To estimate the spatial extent of commercial fishing related activities in the GOM, layers representing the total area in the GOM available to commercial fishing (based on the EEZ), major ports, and location of MPAs were utilized (Table 5). All three of these layers were converted into presence-absence rasters, where a value of 1 indicates the presence of the activity and 0 indicates the absence of the activity. Once a presence-absence raster was created for commercial fishing areas, major ports and processing plants, and MPAs, an unweighted, additive model was used in ArcGIS (Esri, 2012) to combine the presence-absence rasters for commercial fishing areas, processing plants, and ports, to produce a cumulative commercial fishing layer that represents the number of ocean use activities within each 4.77 x 4.77 km grid cell. A presence-absence raster designating MPAs that are restricted to commercial fishing within the GOM was subtracted from the additive model raster to create a final raster layer that outlines the cumulative ocean use related to commercial fishing activities in the GOM (Figure 5).

Table 5: List of datasets, data sources, and URLs utilized as proxies to identify the spatial extent of commercial fishing related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
200NM Exclusive Economic Zone (EEZ) and Maritime Boundaries	National Oceanic and Atmospheric Administration (NOAA) National Ocean Service; NOAA Office of Coast Survey	http://www.marinecadastre.gov/data/default.aspx
Marine Protected Area (MPA) Inventory	National Marine Protected Areas Center; NOAA; U.S. Department of the Interior	http://www.marinecadastre.gov/data/default.aspx
Brown Shrimp Ports	U.S. Army Corps of Engineers (USACE)	http://www.navigationdatacenter.us/ports/ports.asp
Gulf Menhaden Processing Plants	NOAA National Marine Fisheries Service (NMFS); USACE	http://www.st.nmfs.noaa.gov/Assets/commercial/market-news/Menhaden_Forecast_Report-2013.pdf http://www.navigationdatacenter.us/ports/ports.asp

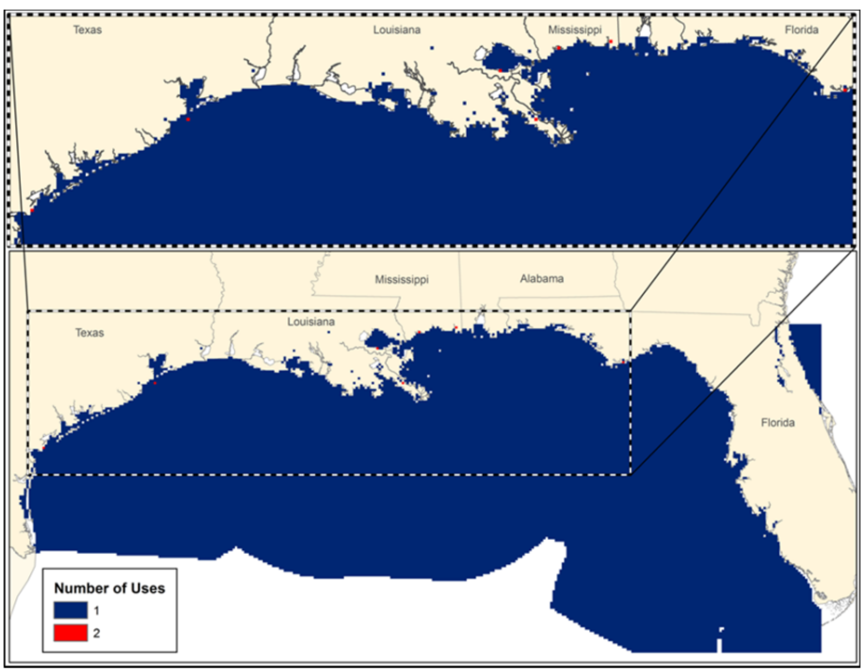

Figure 5: Cumulative number of commercial fishing ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico.

3.3.3.2 Estimating Annual Economic Value

Due to a lack of high spatial data resolution associated with commercial species, we sought additional datasets that would improve the accuracy of our analysis. Spatial layers representing the spatial distribution and occurrence of three dominant commercial fishery species (brown shrimp, white shrimp, and Gulf menhaden) as well as spatial layers representing cost-distance from major ports and processing plants and commercial landings values for all three species were utilized to estimate the annual economic value of commercial fishing ocean use activities in the Gulf of Mexico (Table 6).

Table 6: List of datasets, data sources, and URLs utilized as proxies to estimate the annual economic value of commercial fishing related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
Brown Shrimp Ports	U.S. Army Corps of Engineers (USACE)	http://www.navigationdatacenter.us/ports/ports.asp
Gulf Menhaden Processing Plants	National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS); USACE	http://www.st.nmfs.noaa.gov/Assets/commercial/market-news/Menhaden_Forecast_Report-2013.pdf http://www.navigationdatacenter.us/ports/ports.asp
Southeast Area Monitoring and Assessment Program (SEAMAP)	Gulf States Marine Fisheries Commission (GSMFC)	http://www.gsmfc.org/default.php?p=sm_ov.htm
Commercial Fishery Landings (1990–2011)	NOAA NMFS Office of Science and Technology	http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index

Final products from Habitat Suitability Models (HSMs) provided by Oregon State University (OSU) represented the spatial distribution and occurrence of three target species: brown shrimp, white shrimp, and Gulf menhaden throughout the GOM. The spatial distribution and occurrence for each of the three target species was estimated based on data obtained from the SEAMAP database. Each HSM produced a species habitat (SH) layer that was scaled from 0 to 1, with 0 representing no suitable habitat for that species in a 4.77 km^2 area and 1 representing suitable habitat for that species within the entire 4.77 km^2 area. Representative layers for major ports and processing plants for all three target species were created using Inverse Euclidean Distance tool in ArcGIS (Esri, 2012) which scaled the layers from 0 to 1, where larger values represented areas closest ports and processing plants. To calculate commercial fishing economic values per month ($CFEV_{month}$), the Inverse Euclidean Distance (*IED*) layers for ports and processing plants were raised using a transformative parameter, *t*, to better represent the distribution of commercial landings across state and federal waters. The species habitat (*SH*) layers and *IED* layers were then combined with the monthly averages of commercial landings values

($AVGLandingsValue_{month}$; in $USD) to estimate monthly CFEV values across the GOM (Equation 1).

$$CFEV_{month} = \frac{[IED^t \times SH]}{\sum[IED^t \times SH]} AVGLandingsValue_{month} \quad (1)$$

where $t = 3$. The resulting monthly economic rasters contained an estimated monthly economic value for each 4.77 x 4.77 km grid cell for each species: brown shrimp, white shrimp, and Gulf menhaden, were multiplied to estimate the annual economic value for each species; and then all three layers were summed using an unweighted, additive model in ArcGIS (Esri, 2012) to estimate the annual economic value of commercial fisheries ($USD) throughout the GOM (Figure 6).

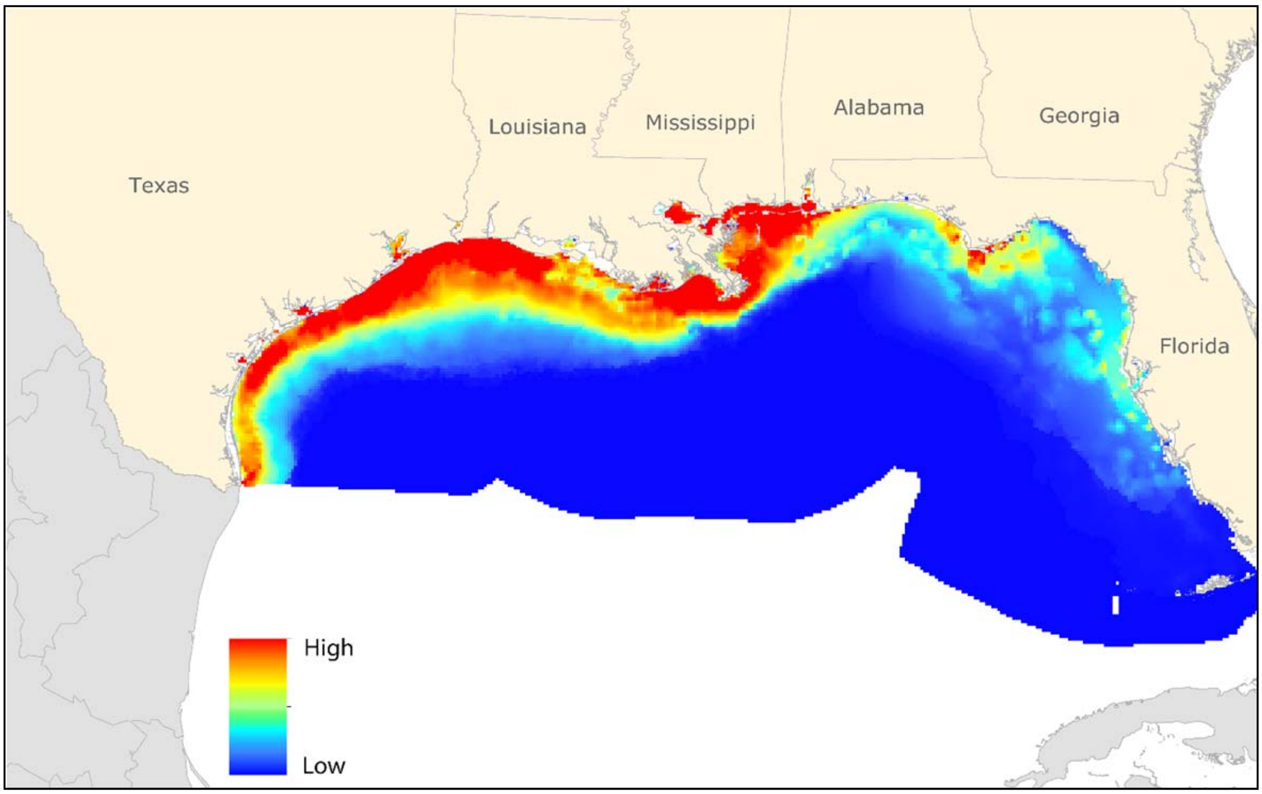

Figure 6: Representative range of the estimated annual economic value of commercial fishing ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico. Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

3.3.4 Tourism

3.3.4.1 Estimating Spatial Extent

Tourism ocean use was determined by combining the proxy data collected from the hotel industry, recreational fishing, and recreational areas across the GOM (Table 7). All three of these representative layers were converted into presence-absence rasters, where a value of 1 indicates the presence of the activity and 0 indicates the absence of the activity. Once all the presence-absence rasters were created representing the spatial extent of each tourism activity throughout the GOM, they were combined using an unweighted, additive model in ArcGIS (Esri, 2012) to produce a final cumulative tourism layer that represents the number of ocean use activities within each 4.77 x 4.77 km grid cell throughout the GOM (Figure 7).

Table 7: List of datasets, data sources, and URLs utilized as proxies to identify the spatial extent of tourism related ocean uses in the Gulf of Mexico.

Dataset	Data Source	URL(s)
Hotelsbase	Hotelsbase	http://hotelsbase.org/
Additional Hotel Info	Personal Communication	See Appendix C
Southeast Area Monitoring and Assessment Program (SEAMAP)	Gulf States Marine Fisheries Commission (GSMFC)	http://www.gsmfc.org/default.php?p=sm_ov.htm#:content@10:links@11 http://www.gsmfc.org/default.php?p=sm_ov.htm
Comparative Assessment of Gulf Estuarine ecoSystems (CAGES)	National Oceanic and Atmospheric Administration (NOAA) Environmental Research Division	http://barataria.tamu.edu/erddap/info/index.html?page=1&itemsPerPage=1000 http://barataria.tamu.edu/erddap/index.html
Marine Species Observation Database	Ocean Biogeographic Information System (OBIS)	http://www.iobis.org/
Current Administrative Boundaries of National Park System Units	U.S. Department of the Interior National Parks Service	https://irma.nps.gov/
Florida State Park Boundaries	Florida Department of Parks and Recreational Areas	http://www.dep.state.fl.us/gis/datadir.htm
Louisiana State Parks	Louisiana Department of Transportation and Development	http://lagic.lsu.edu/data/losco/state_parks_ldotd_2007_faq.html#what
Wildlife Management Areas (WMAs) and Refuges	Louisiana Department of Wildlife and Fisheries	http://lagic.lsu.edu/data/losco/wma_refuge_ldwf_2006_faq.html#what.1

Table 7: List of datasets, data sources, and URLs utilized as proxies to identify the spatial extent of tourism related ocean uses in the Gulf of Mexico, continued.

Dataset	Data Source	URL(s)
Mississippi State Parks	Entergy Corporation; Mississippi Site Selection Center	http://www.mississippisiteselection.com/gis-data-download.aspx
parkpy (Texas State Park Boundaries)	Texas Parks and Wildlife Department	http://www.tpwd.state.tx.us/landwater/land/maps/gis/data_downloads/
Alabama State Park Boundaries	Google API query	https://developers.google.com/
National Wildlife Refuge System (NWRS) Boundary Data	U.S. Fish and Wildlife Service	http://www.fws.gov/gis/data/national/#NWRS%20BOUNDARY
Wilderness Preservation System Areas	Bureau of Land Management; U.S. Fish and Wildlife Service; U.S. Department of Agriculture Forest Service; U.S. National Park Service	http://www.nationalatlas.gov/maplayers.html?openChapters=chpbound#chpbound http://www.nationalatlas.gov/mld/wildrnp.html

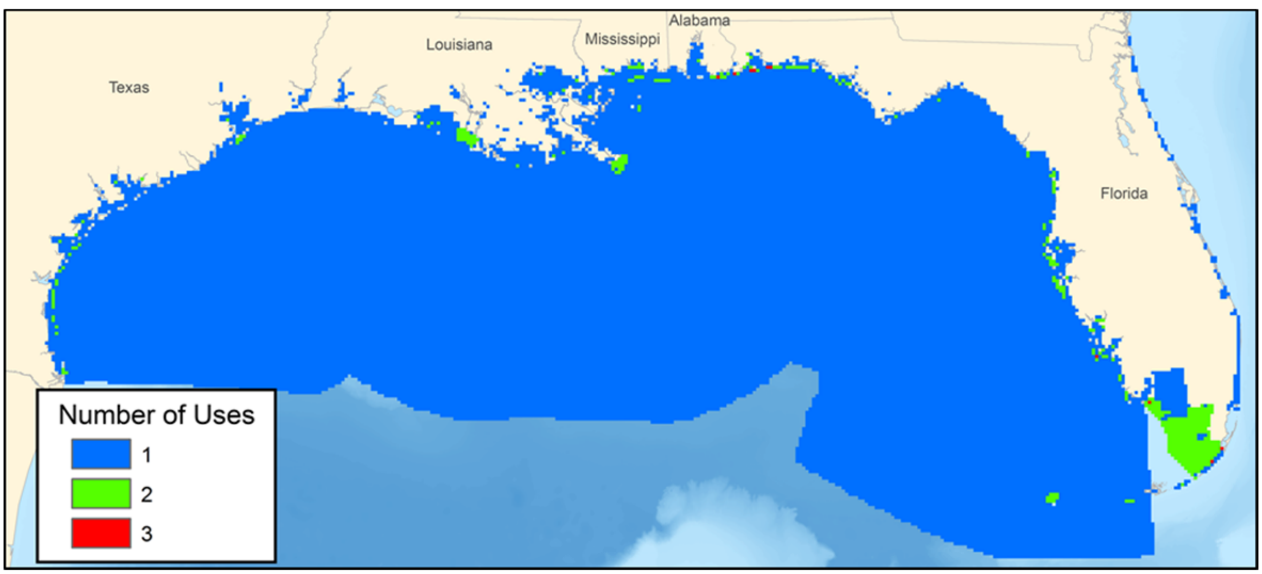

Figure 7: Cumulative number of tourism ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico.

3.3.4.2 Estimating Annual Economic Value

In order to estimate the annual economic value associated with tourism activities in the GOM, we needed to integrate economic value with spatial layers representing the hotel industry and recreational fishing activities in the GOM (Table 8).

Table 8: List of datasets, data sources, and URLs utilized as proxies to estimate the annual economic value of tourism related ocean uses in the Gulf of Mexico

Dataset	Data Source	URL(s)
Hotelsbase	Hotelsbase	http://hotelsbase.org/
Additional Hotel Info	L. Romeo, Personal Communication (2013)	See Appendix C
Marine Recreational Fishery Catch and Effort Estimates	Gulf States Marine Fisheries Commission (GSMFC)	http://www.gsmfc.org/#:content@10:links@13
Fisheries Economics of the U.S. (2009) for recreational fishing economic value estimates	National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)	http://www.st.nmfs.noaa.gov/st5/publication/fisheries_economics_2009.html
Marine Recreational Information Program (MRIP)	NOAA's Fisheries Statistics Division	http://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/data-downloads/index http://www.st.nmfs.noaa.gov/recreational-fisheries/index# https://www.st.nmfs.noaa.gov/mrip/aboutus/index.html

Baseline monthly economic values were calculated for each hotel based on the number of rooms sold. To calculate monthly economic values based on rooms sold required additional data on each hotel's occupancy percentage per season, and on the occurrence and duration of each state's busy and off-season. Monthly occupancy percentages were generalized for each hotel by state and star rating. Data on the number of rooms per hotels from Hotelsbase and the supplemental information from the interviewed hotels (n = 30), identified a statistically significant linear relationship between the number of rooms per hotel and the star rating, R = 0.8688 (Figure 8). Therefore, this positive correlation between the star rating and the number of rooms was used to fill in hotel records missing information about the number of rooms based on their star rating.

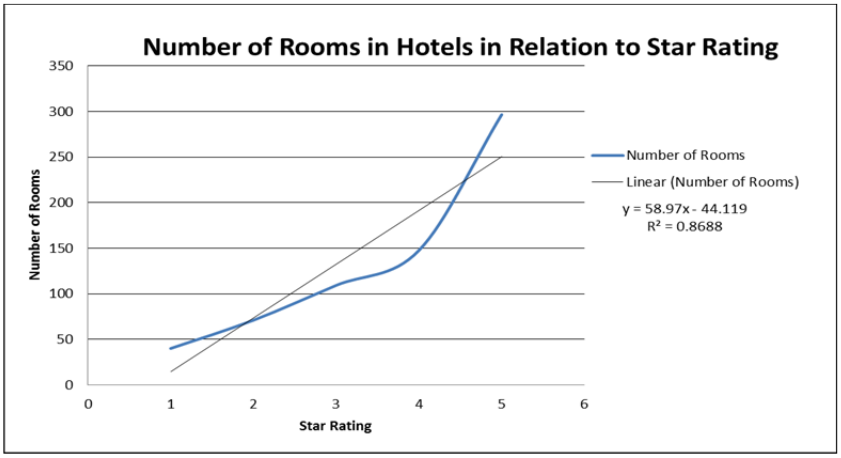

Figure 8: Relationship between the number of rooms and the star rating for hotels across the Gulf of Mexico (Hotelsbase, 2013; Romeo, 2013).

From this combination of data acquired from Hotelsbase and phone interviews, we were able to use each hotel's monthly occupancy rate, number of rooms, room rates, and the number of days per month, to calculate a monthly economic value for the hotels (*Value*; Equation 2).

$$Value = MOP \text{ x } N_{rooms} \text{ x } C_r \text{ x } N_{days} \quad (2)$$

Where *MOP* is the monthly occupancy percentage, N_{rooms} is the total number of rooms, C_r is the cost per room, and N_{days} is the number of days in the month. Point data representing the monthly economic value per hotel were processed using a Python script (version 2.7.2; see Appendix F for python code) and converted into rasters using the Point Statistics tool in ArcGIS (Esri, 2012) which aggregated all hotels within a 3-km square radius of each other to calculate a total economic value for each 4.77 x 4.77 km grid cell (see Appendix C for the annual economic map per state for tourism using income generated from hotel rooms sold as a proxy).

Estimated economic values associated with recreational fishing were created using effort data, trip expenditure data, and the density of recreational fish within each of the Gulf States recreational fishing areas. Using recreational fish species occurrence data, a density surface for the entire GOM was created (Equation 1). The number of angler trips was compiled from 2000–2009 by wave (a wave is equivalent to a 2 month period) for each state with available data (Appendix E). Once compiled, the total number of recreational fishing trips for each Gulf State was calculated by adding the totals from each wave. Using the total annual trips for the GOM, a percentage of the total annual recreational trips (*P*) were calculated for each Gulf State by dividing the number of trips taken for each state by the total number of trips taken annually (Equation 3).

$$P = \frac{N_{Rec}/N_{total}}{2} \quad (3)$$

Where N_{Rec} is the number of recreational fishing trips in a wave, N_{total} is the total annual trips taken. The data from total annual trip expenditures (Appendix E) for each state was then used to calculate the economic value of recreational fishing for each month. The annual trip expenditure (A) for each GOM state was multiplied by the percent of trips taken during each of the respective waves in each GOM state (Equation 4). This gave the trip expenditure scaled to the percentage of trips taken during each wave (X).

$$X = {}^{(P \times A)}/_{2} \tag{4}$$

Cost surfaces were created using the aforementioned data. Water boundaries were used to clip the recreational fishing density layer between state waters and federal waters. Multiplying the density surface by the state trip expenditure per month produced a cost surface scaled by the density of recreational fishing species in those waters (Equation 5).

$$E_{surface} = X \times p_{RecFish} \tag{5}$$

Where $E_{Surface}$ is the economic raster surface, and $p_{RecFish}$ is the density of recreational fish species. After the creation of estimated economic value rasters for hotels and recreational fishing, the monthly rasters were integrated using an unweighted, additive model to create a cumulative estimated annual economic value raster ($USD) for all activities used to represent the tourism ocean use sector in the GOM (Figure 9).

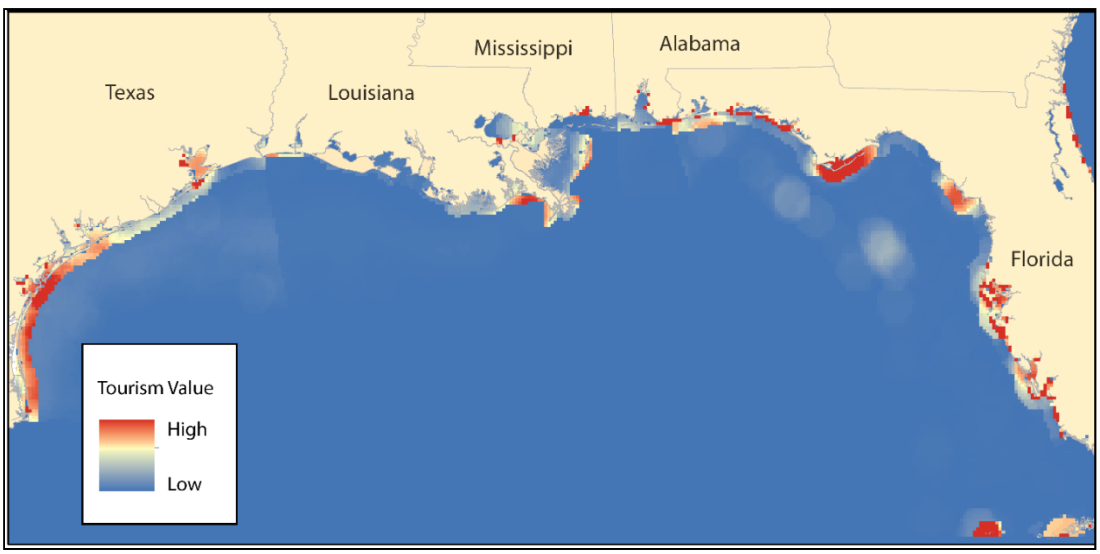

Figure 9: Representative range of the estimated annual economic value of tourism ocean use activities per 4.77 x 4.77 km grid cell in the Gulf of Mexico. Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

3.4 DEVELOPING CUMULATIVE SPATIAL IMPACT LAYERS

In order to understand broad spatial trends and patterns associated with risk and potential impacts from uncontrolled hydrocarbon release events in the GOM, we created CSILs that allow us to estimate the number of ocean use sectors and activities affected by an oil spill as well as estimate the cumulative economic impact an oil spill could have on these four major socio-economic sectors in the GOM.

3.4.1 Cumulative Spatial Extent

After the ocean use rasters representing different activities within the oil and gas industry, commercial transportation, commercial fishing, and tourism ocean use sectors were created, a cumulative ocean use raster was created using an unweighted, additive model to sum the spatial extent (or footprint) for the spatial layers that served as proxies for the oil and gas industry, commercial transportation, commercial fishing, and tourism (Figure 10).

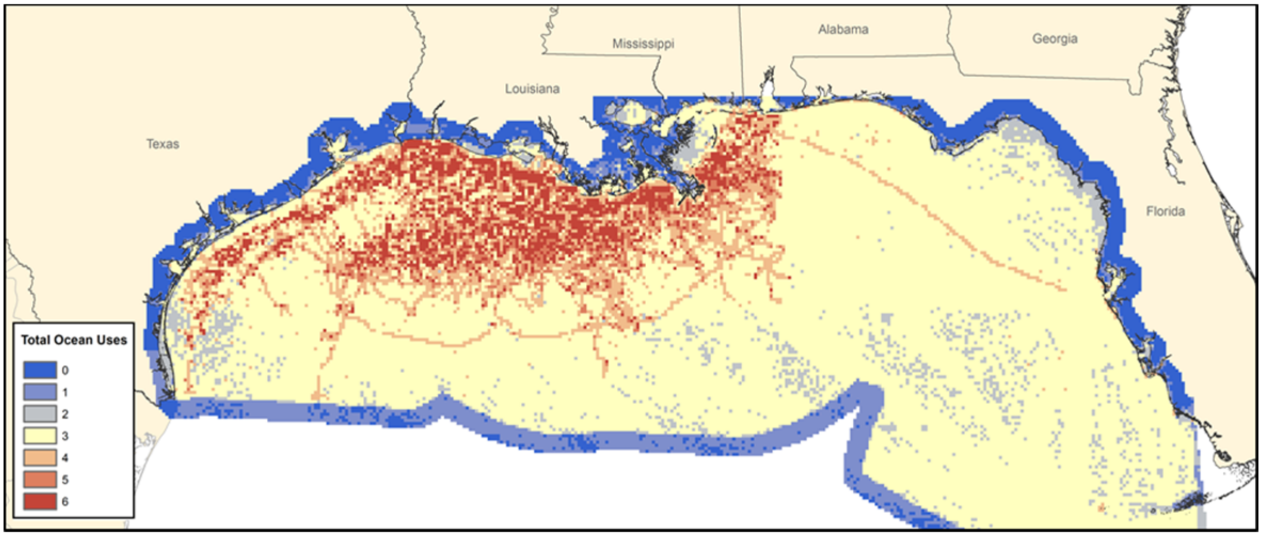

Figure 10: Cumulative number of ocean use activities related to the oil and gas industry, commercial transportation, commercial fishing, and tourism ocean use sectors per 4.77 x 4.77 km grid cell in the Gulf of Mexico.

3.4.2 Cumulative Estimated Annual Economic Value

To estimate the cumulative estimated annual economic value for the oil and gas industry, commercial fishing, and tourism ocean use sectors in the GOM we utilized an unweighted, additive model in ArcGIS (Esri, 2012) to sum each ocean use sector's estimated annual economic value to create a cumulative estimated annual economic value ($USD) for the GOM (Figure 11). Economic values related to commercial transportation in the GOM, as discussed in Section 3.3.2.2 above, were not included in the cumulative estimated annual economic value layer (Figure 11) due to the lack of economic information available to characterize this resource.

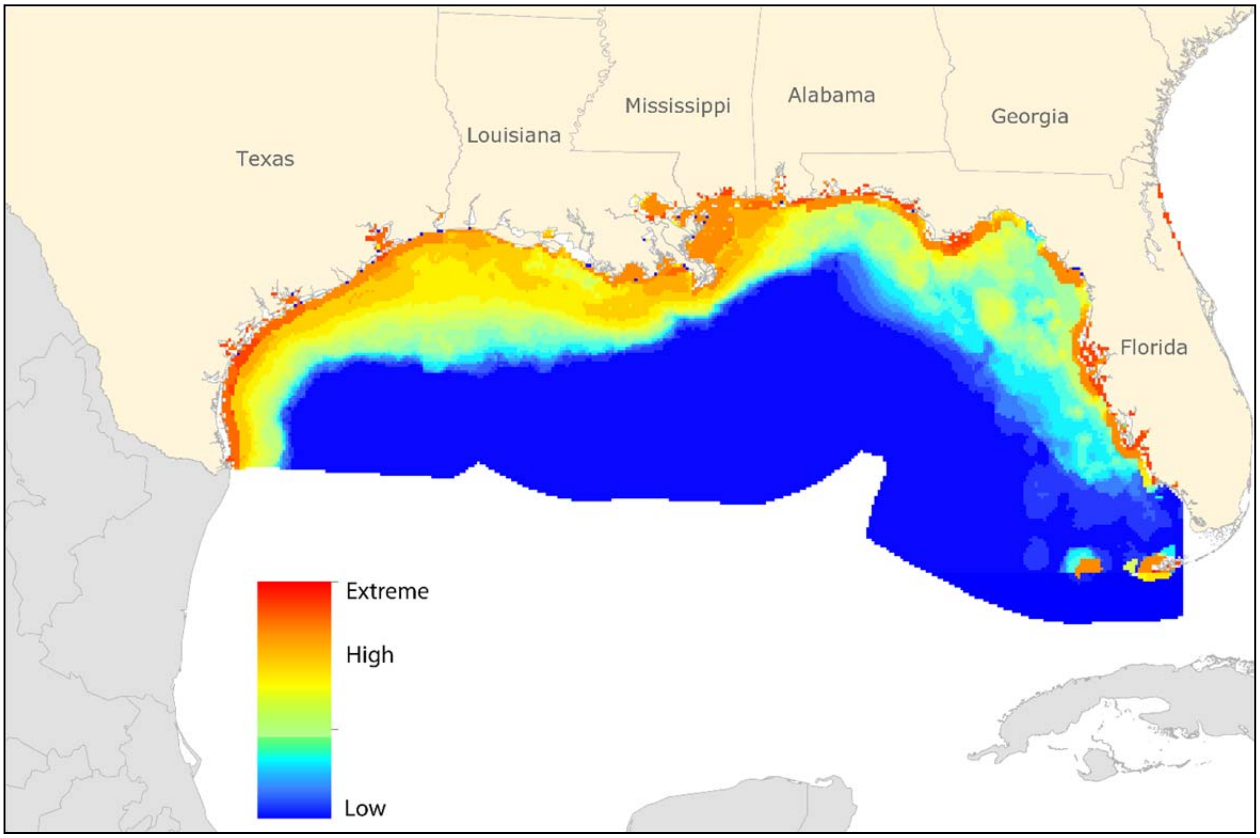

Figure 11: Representative range of the cumulative estimated annual economic value per 4.77 x 4.77 km grid cell in the Gulf of Mexico based off various activities related to the oil and gas, commercial fishing, and tourism ocean use sectors. Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

4. NEXT STEPS

With the completion of the CSILs representing ocean uses and estimated annual economic value, our next steps are to (i) make the spatial layers for each ocean use sector as well as the CSILs publically available via NETL's Energy Data eXchange (EDX; https://edx.netl.doe.gov/), and (ii) to begin utilizing the CSILs with preliminary, hypothetical hydrocarbon spill modeling scenarios at different representative locations throughout the GOM to evaluate broad spatial trends and patterns of potential risks and impacts associated with uncontrolled hydrocarbon release scenarios. As previously noted, a caveat of current modeling solutions is the use of various datasets which are often dispersed amongst sources or are difficult to obtain quickly when the need arises. NETL's EDX is an online system capable of providing timely access to energy related data and information from both publically available resources as well as data products from NETL-affiliated research. Datasets collected for the GOM IAM, including the datasets utilized and produced as part of this report, are available on EDX to ensure efficient and timely access to key information in support of energy research and assessments.

Some of the example datasets that can be used to create cumulative ocean uses and estimate economic values are available through EDX and can be added to the EDXtool, the GOM Geocube, which is a customizable, web mapping application that allows users to access spatial datasets relevant to energy research in the GOM (https://edx.netl.doe.gov/gom-geocube). The GOM Geocube is intended to fill the data resource gaps identified following recent uncontrolled loss events in the GOM (e.g. Hurricane Katrina, BP Deepwater Horizon blowout) by providing a single location where users can access relevant spatial datasets, visualize datasets without needing access to additional software, and easily upload or download datasets needed for additional custom analyses.

Another future step for this research is to evaluate the efficacy of our CSILs to predict broad spatial trends and patterns associated with modeled scenarios of uncontrolled release events in the GOM. Efforts are ongoing in the GOM IAM team to combine the cumulative spatial impact layers with outputs from one of the GOM IAM component models. The BLOwout and Spill Occurrence Model (BLOSOM) is a multi-component, integrated water column modeling system capable of simulating oil spills resulting from deep and ultra-deepwater blowouts in the GOM (Sim, 2013). Capable of producing spatially explicit oil spill extents that identify the spatial distribution of oil, BLOSOM scenarios will be overlapped with the CSILs to identify broad trends and patterns that can be utilized to predict areas in the GOM with greater risks of potential impacts as well as estimate the potential effect on the Gulf economy. Furthermore, testing different uncontrolled release events with BLOSOM, such as location, time of occurrence, and duration of the blowout when overlapped with the CSILs might assist with the identification of spatio-temporal variability associated with risks to these various ocean use sectors. These and other modeling results from the GOM IAM effort are expected to result in the identification of technology and knowledge gaps, as well as potentially bolster planning and leasing processes for future hydrocarbon exploration and development in the GOM, as well as provide additional baseline information that can be used to improve response models and efforts.

5. SUMMARY

NETL's recognition of technology gaps following recent uncontrolled hydrocarbon release events led to on-going research efforts to develop additional technologies that will improve the prediction of risks associated with offshore hydrocarbon production in the GOM and as well as serve as a baseline rapid-response tool to help respond to future deleterious events. Ultimately, results from the GOM IAM evaluations are expected to help identify technology and knowledge gaps that will help prevent future hydrocarbon spill events associated with the deep and ultra-deepwater GOM. This paper describes our efforts in support of the GOM IAM to provide CSILs that can be used to analyze potential broad spatial risks and impacts associated with modeled uncontrolled release events in the GOM. The approach for developing the CSILs demonstrated here is intended to both support ongoing research under the GOM IAM effort and serves as a basis for future updates to the approach to improve the quality and accuracy of the CSILs. The current CSILs provide NETL the ability to concatenate layers with outputs from the GOM IAM models to demonstrate their strength and efficacy at estimating potential impacts or risks in relation to hydrocarbon spill events. In addition, the availability of these analyses on resources such as EDX and the GOM Geocube will strengthen the range of solutions available to help predict potential risks and impacts and respond to any future deleterious events associated with uncontrolled hydrocarbon release events in the GOM. Together, this combination of science based prediction tools, spatial layers, and online resources results in a unique Gulf-wide resource, accessible to federal and state, industry, and academia collaborators. The approach demonstrated in this study and the CSILs produced to date will be used to support assessments of the *in situ* system, identify technology gaps, and model loss of control scenarios from the subsurface to the shore to assess risks and potential impacts to various ocean uses, while offering baseline information to assist with any future response needs.

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APPENDIX A –DATA SOURCES AND WEBSITES

Table A-1: List of all data sources used as proxies to estimate the spatial extent and annual economic value for oil and gas, commercial transportation, commercial fisheries, and tourism related ocean uses in the Gulf of Mexico

Data Source	Dataset(s)	URL(s)
American Association of Port Authorities (AAPA)	Commercial Transportation Economic data	http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=900&navItemNumber=551
Bureau of Ocean Energy Management (BOEM)	Oil and Gas Platforms Oil and Gas Wells Pipelines	http://data.boem.gov
Entergy Corporation and the Mississippi Site Selection Center	State Park Boundaries	http://www.mississippisiteselection.com/gis-data-download.aspx
Florida Department of Parks and Recreational Areas	State Park Boundaries	http://www.dep.state.fl.us/gis/datadir.htm
Google	State Park Boundaries	https://developers.google.com/
Gulf States Marine Fisheries Commission	SEAMAP	http://www.gsmfc.org
Hotelsbase	Hotels	http://www.hotelsbase.org/
Intergovernmental Oceanographic Commission of UNESCO	Ocean Biogeographic Information System (OBIS)	http://www.iobis.org/
Louisiana Department of Transportation and Development	State Park Boundaries	http://lagic.lsu.edu/data/losco/state_parks_ldotd_2007_faq.html#what
Louisiana Department of Wildlife and Fisheries	Wilderness Management Areas	http://lagic.lsu.edu/data/losco/wma_refuge_ldwf_2006_faq.html#what.1
Marine Cadastre (NOAA and BOEM)	Oil and Gas Platforms Oil and Gas Wells Pipelines Commercial Transportation (AIS) U.S. Ports	http://www.marinecadastre.gov/
National Atlas of the U.S.	Wilderness Management Areas	http://www.nationalatlas.gov

Table A-1: Continued

Data Source	Dataset(s)	URL(s)
National Oceanic and Atmospheric Administration (NOAA)	Marine Protected Areas Commercial Fisheries Economic data	http://marineprotectedareas.noaa.gov/dataanalysis/mpainventory/ http://www.csc.noaa.gov/digitalcoast/data/enow http://www.st.nmfs.noaa.gov/Assets/economics/documents/feus/2011/FEUS2011%20-%20Gulf%20of%20Mexico.pdf
NOAA Environmental Research Division	Comparative Assessment of Gulf Estuarine ecoSystems (CAGES)	http://barataria.tamu.edu/erddap/info/CAGES_Texas_Trawls_Lengths_IOOS_Standard/index.html
NOAA Fisheries Statistics Division	Marine Recreational Information Program (MRIP)	http://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/data-downloads/index
NOAA National Marine Fisheries Service	Economic Commercial Landings Data Gulf Menhaden Processing Plants	http://www.st.nmfs.noaa.gov/st1/commercial/index.html http://www.st.nmfs.noaa.gov/st1/market_news/menhaden_forecast_2012.pdf
Noble Corporation	Oil and Gas Industry Economic data	http://phx.corporate-ir.net/phoenix.zhtml?c=98046&p=irol-reportsOther
Rigzone	Oil and Gas Industry Economic data	http://www.rigzone.com/data/dayrates/
Texas Parks and Wildlife Department	State Park Boundaries	http://www.tpwd.state.tx.us/landwater/land/maps/gis/data_downloads/
Transocean	Oil and Gas Industry Economic data	http://www.deepwater.com/fw/main/Fleet_Update_Report-58.html
U.S. Coast Guard	Commercial Transportation (AIS)	http://www.marinecadastre.gov/AIS/default.aspx http://www.uscg.mil/acquisition/nais/
U.S. Department of Interior, National Park Service	National Park Boundaries	https://irma.nps.gov/
U.S. Environmental Protection Agency	Commercial Transportation Economic data	http://www.epa.gov/gmpo/about/facts.html
U.S. Fish & Wildlife Service	Wilderness Management Areas	http://www.fws.gov/gis/data/national/#NWRS%20BOUNDARY

APPENDIX B – GULF ECONOMIC INFORMATION

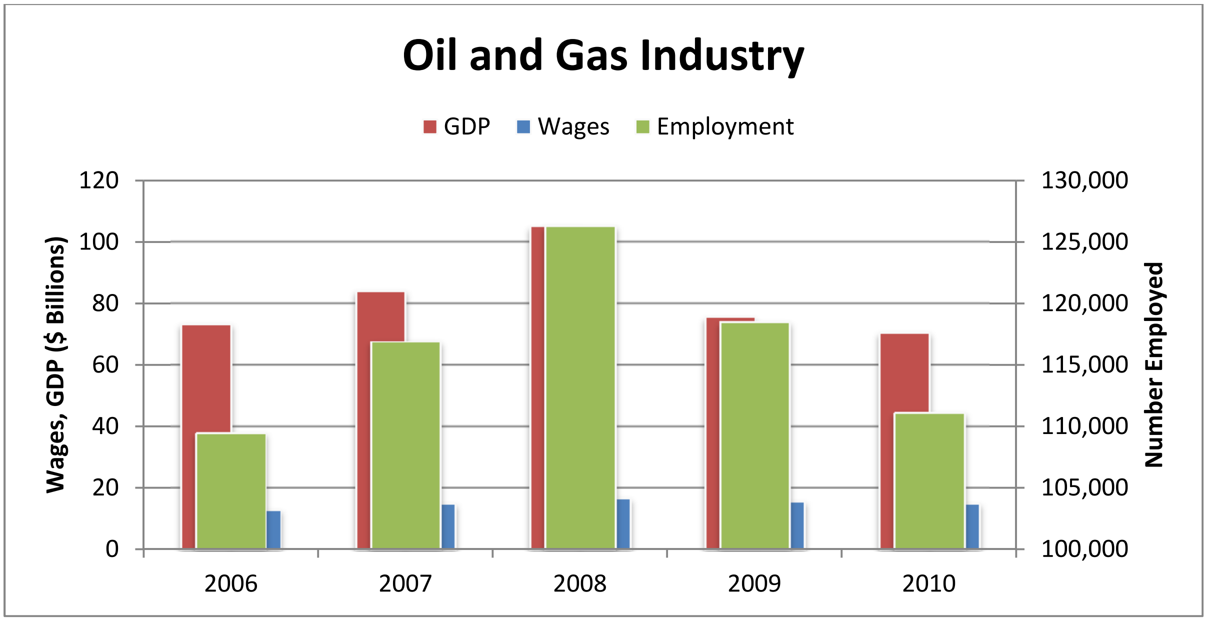

Figure B-1. Annual economic contribution from oil and gas activities within the Gulf of Mexico. The left axis represents the total contribution to the gross domestic product (GDP) and total wages paid to employees. The right axis represents the total number of people employed by the oil and gas sector (National Oceanic and Atmospheric Administration, 2013).

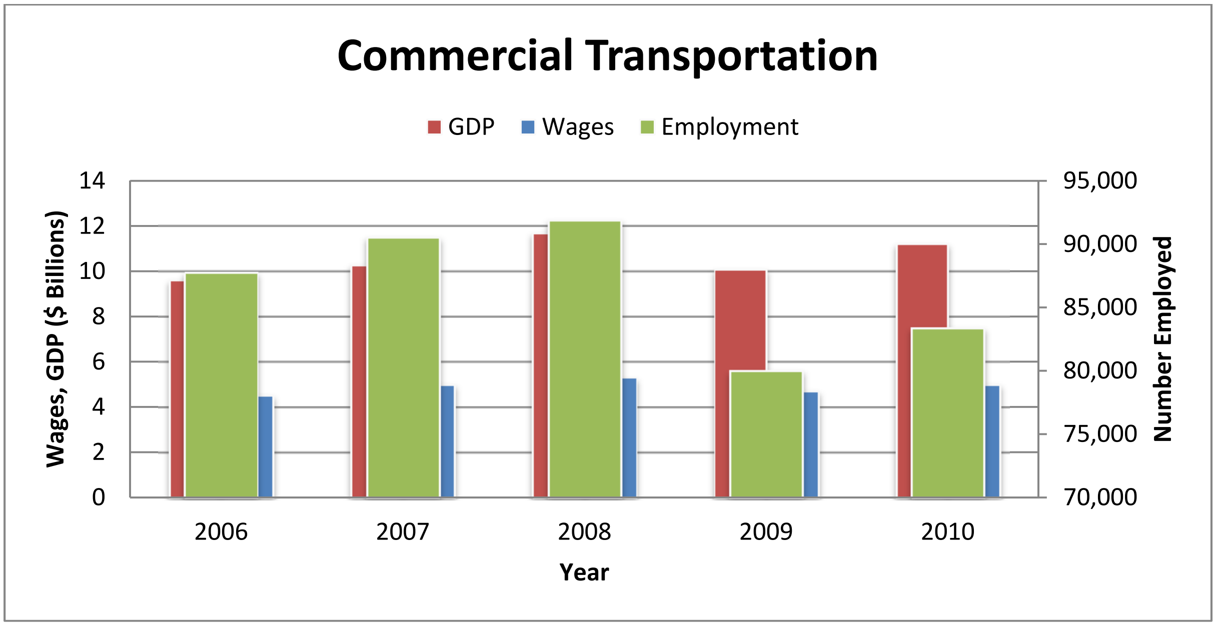

Figure B-2. Annual economic contribution from commercial transportation activities within the Gulf of Mexico. The left axis represents the total contribution to the gross domestic product (GDP) and total wages paid to employees. The right axis represents the total number of people employed in the commercial transportation sector (National Oceanic and Atmospheric Administration, 2013).

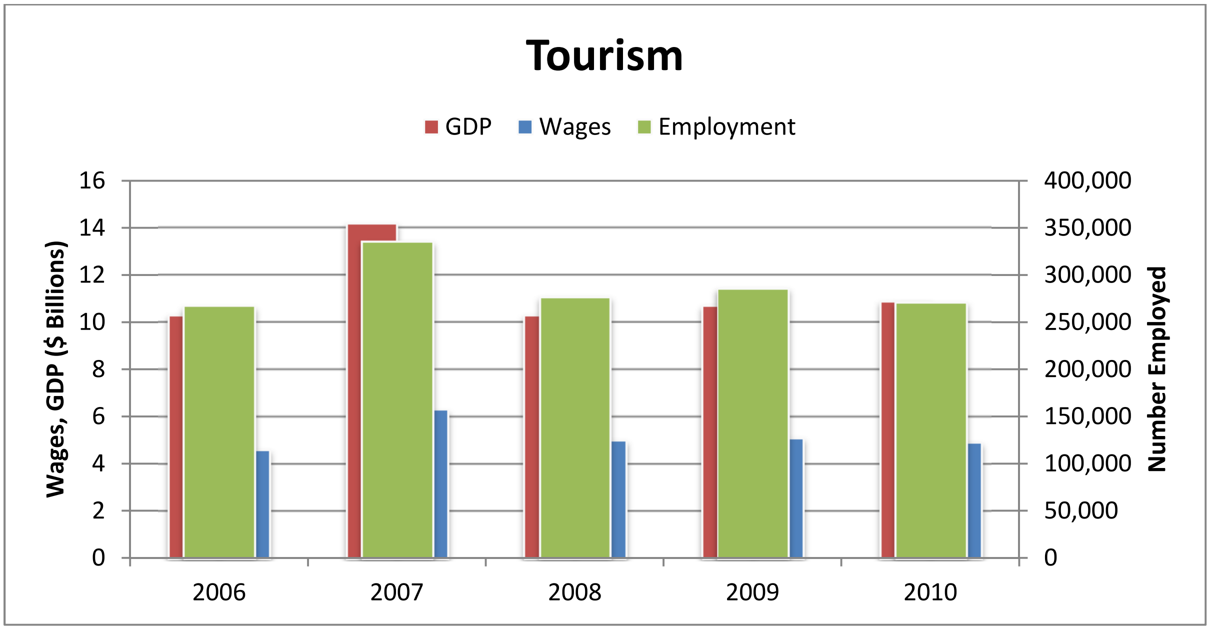

Figure B-3. Annual economic contribution from tourism activities within the Gulf of Mexico. The left axis represents the total contribution to the gross domestic product (GDP) and total wages paid to employees. The right axis represents the total number of people employed by the ocean tourism sector (National Oceanic and Atmospheric Administration, 2013).

APPENDIX C – GULF OF MEXICO HOTELS

Table C-1: Additional information collected via phone interviews from hotels (n=30) to provide additional data for our estimation of the annual economic value in the Gulf of Mexico contributed from the hotel industry (Romeo, 2013)

Number	Hotel Name	Rating	Number of Rooms
1	Adobe Hacienda Motel	1	15
2	Helen Apartments & Motel	1	16
3	Island Time in Hollywood	1	7
4	Seven Js Motel	1	21
5	Motel 6 Destin	1	131
6	La Mer Motel	1	11
7	Hampton Inn & Suites Clearwater / St. Petersburg - Ulmerton Road	2	128
8	Sun Viking Lodge	2	96
9	Belmont Inn and Suites Port Richey	2	80
10	Sunrider Beach Resort	2	17
11	Econo Lodge Fort Pierce	2	60
12	Ocean East Resort Club Ormond Beach	2	114
13	La Quinta Inn & Suites Panama City Beach	3	84
14	Marriott New Orleans Metairie at Lakeway	3	220
15	Four Points by Sheraton New Orleans Airport	3	220
16	Clarion Hotel Port Canaveral Merritt Island	3	128
17	Value Place Fort Walton Beach	3	121
18	Riptide Hotel	3	21
19	Marriott Beach Resort Marco Island	4	724
20	Longboat Key Club & Resort	4	221
21	Ocean Lodge Saint Simons Island	4	15
22	Intercontinental Hotel Tampa	4	323
23	Residence Inn Delray Beach	4	131
24	Casa Marina A Waldorf Astoria Resort	4	311
25	Don Cesar Beach Resort Saint Pete Beach	5	387
26	The Ritz-Carlton Sarasota	5	297
27	Ritz-Carlton South Beach	5	375
28	Charleston Place Hotel	5	440
29	The Ritz Carlton Fort Lauderdale	5	195
30	Cinnamon Beach at Ocean Hammock Beach Resort	5	325

Table C-2: List of the busy and off season months, based off each state, as identified during the phone interview with an additional 30 hotels (Romeo, 2013)

State Tourism Seasonality by Month		
State	**Busy Months**	**Off Months**
Texas	May, June, July, August, September	January, February, March, April, October, November, December
Louisiana	February, March, April, May, September, October, November	January, June, July, August, December
Mississippi	March, April, May, June, July, August, September, October	January, February, November, December
Alabama	March, April, May, June, July, August, September, October, November	January, February, December
Florida	January, February, March, April	May, June, July, August, September, October, November, December

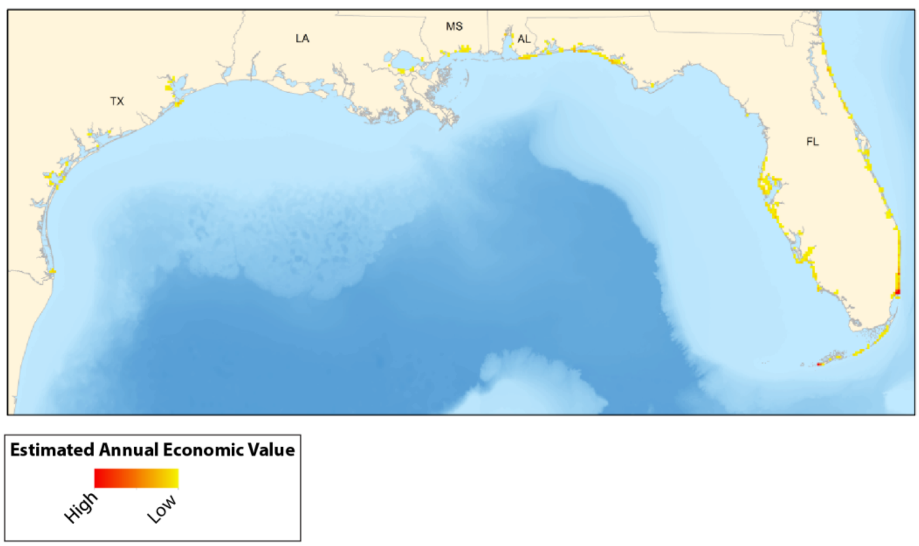

Figure C-1: Estimated Annual Economic Value from hotel related activities from all the Gulf States, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

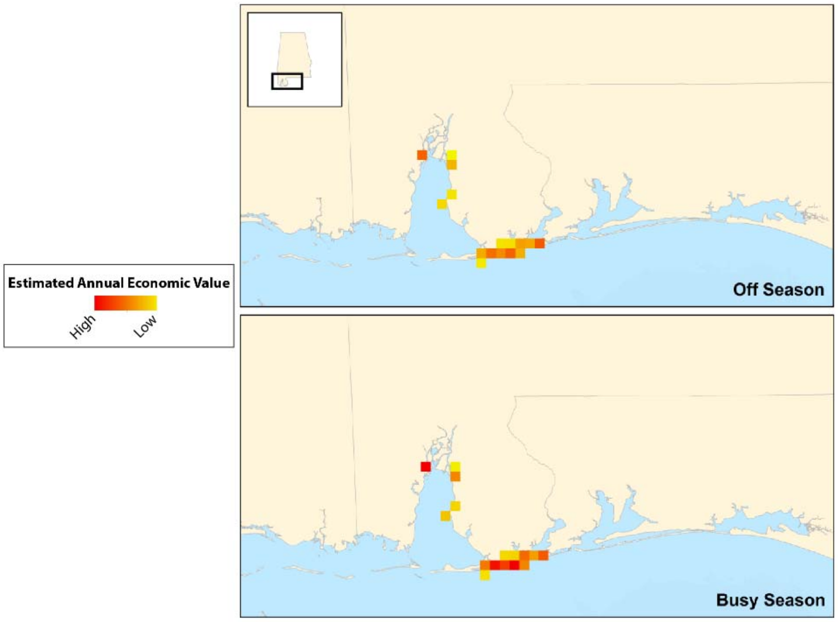

Figure C-2: Estimated Seasonal Economic Value from hotel related activities for Alabama, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1) based off the identified off and busy season months (see Table C-2). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

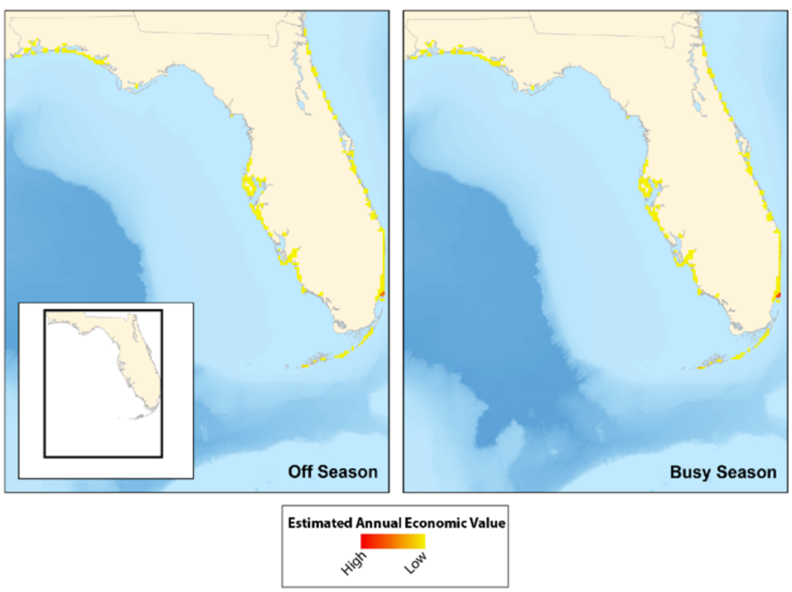

Figure C-3: Estimated Seasonal Economic Value from hotel related activities for Florida, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1) based off the identified off and busy season months (see Table C-2). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

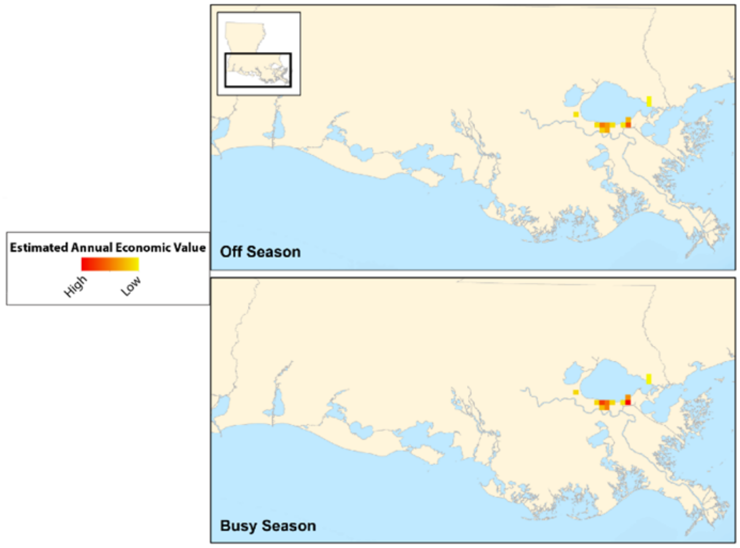

Figure C-4: Estimated Seasonal Economic Value from hotel related activities for Louisiana, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1) based off the identified off and busy season months (see Table C-2). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

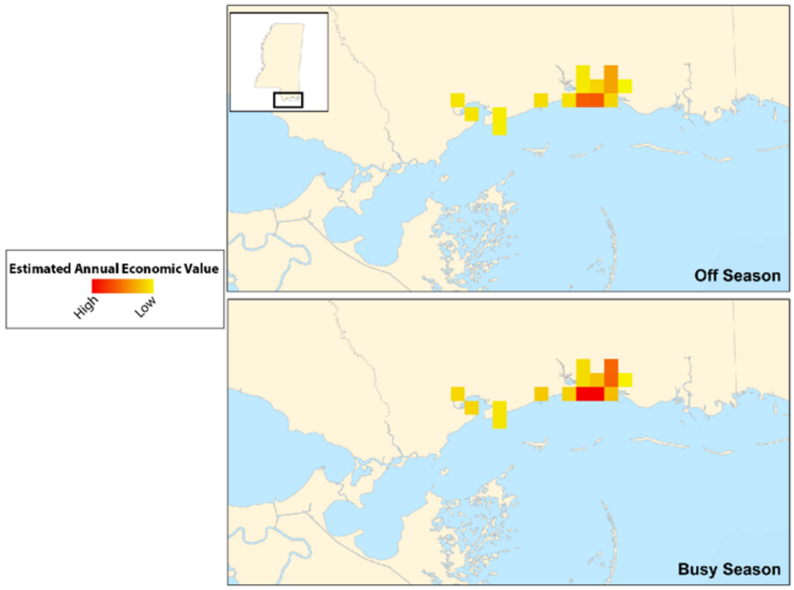

Figure C-5: Estimated Seasonal Economic Value from hotel related activities for Mississippi, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1) based off the identified off and busy season months (see Table C-2). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

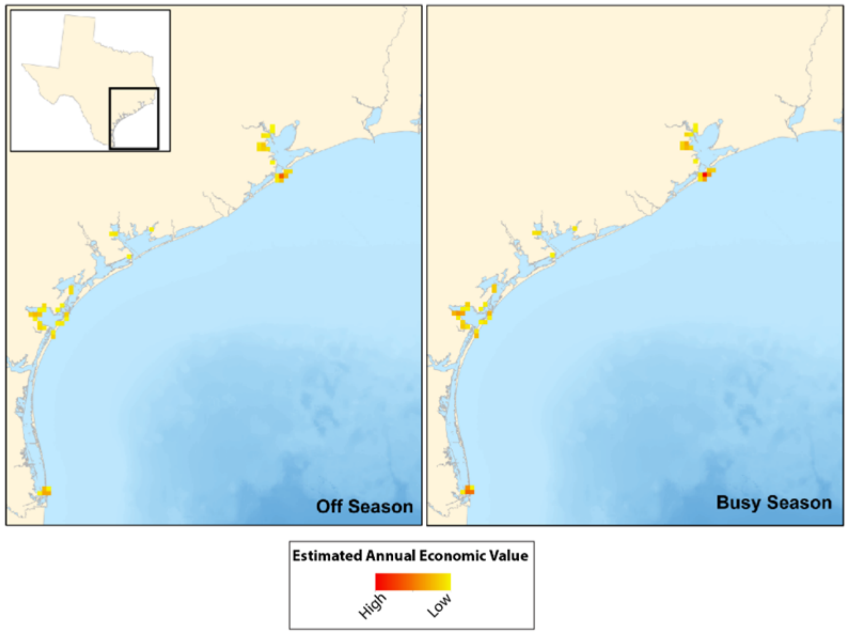

Figure C-6: Estimated Seasonal Economic Value from hotel related activities for Texas, calculated based off hotel information collected from Hotelsbase (2013) and additional phone interviews (see Table C-1) based off the identified off and busy season months (see Table C-2). Specific estimated economic values are calculated in $USD for each grid cell, but are not shown in this figure for sensitivity reasons.

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APPENDIX D – RECREATIONAL AREAS

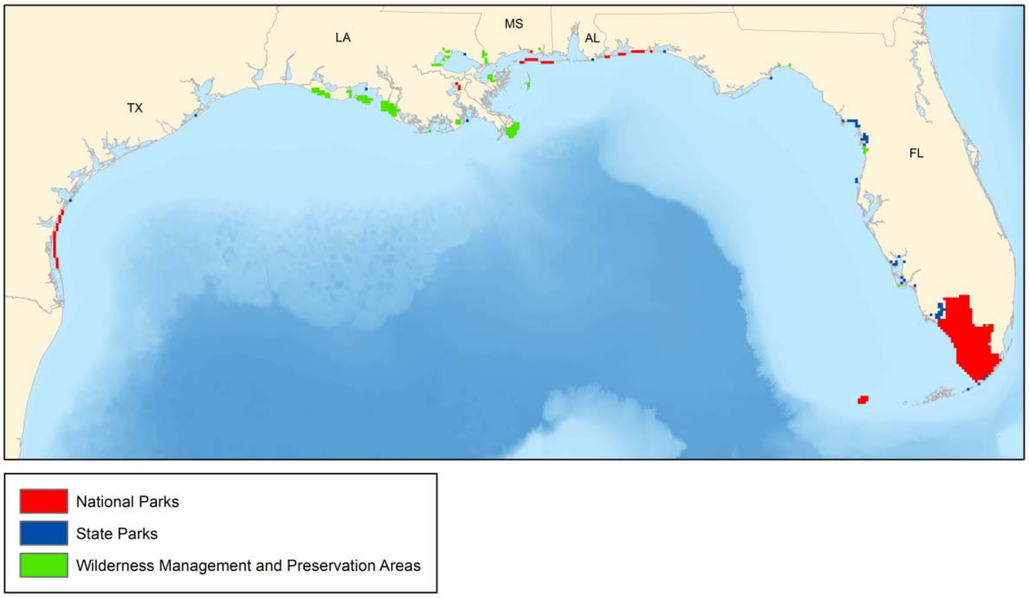

Figure D-1. Location of recreational areas, including national parks, state parks, and wilderness management and preservation areas, used to estimate the cumulative spatial extent of tourism ocean use activities in the Gulf of Mexico (Florida Department of Parks and Recreational Areas, 2011; Louisiana Department of Transportation and Development, 2007; Louisiana Department of Wildlife and Fisheries, 2006; Mississippi Site Selection Center, 2013; National Atlas of the United States, 2005; Texas Parks and Wildlife Department, 2011; U.S. Department of Interior National Park Service, 2013; U.S. Fish and Wildlife Service, 2013).

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APPENDIX E - RECREATIONAL FISHING

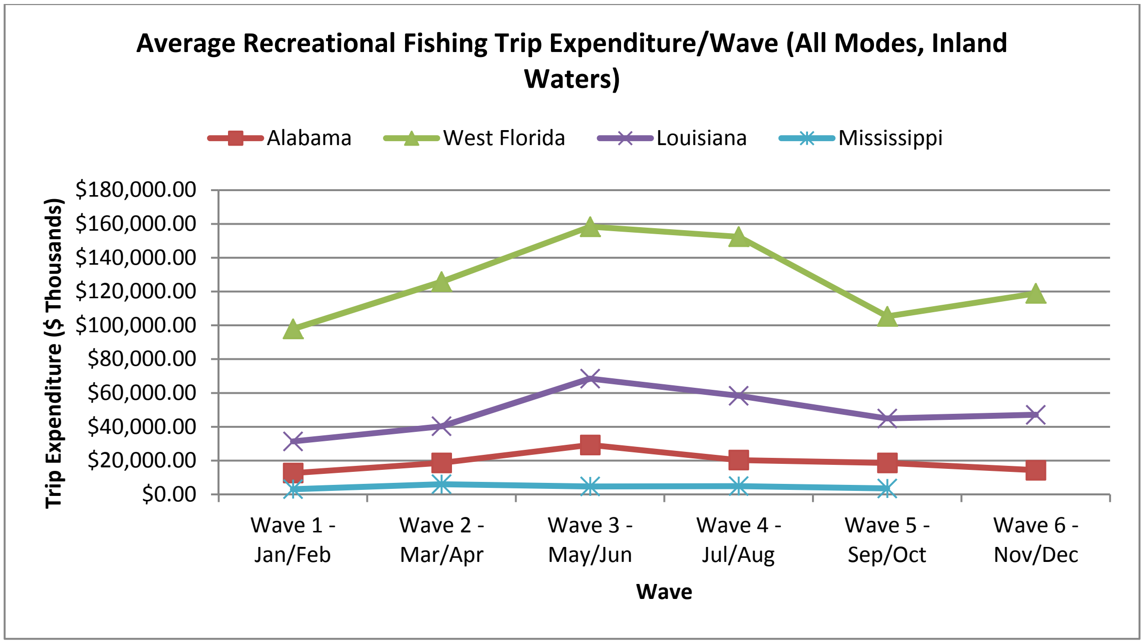

Figure E-1: Average recreational fishing trip expenditure for two month wave periods within inland waters (within 3 nautical miles from the shoreline) for all the Gulf States except Texas. Data was averaged from 2006–2009 for each two month wave period to estimate the average recreational fishing expenditure (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2009).

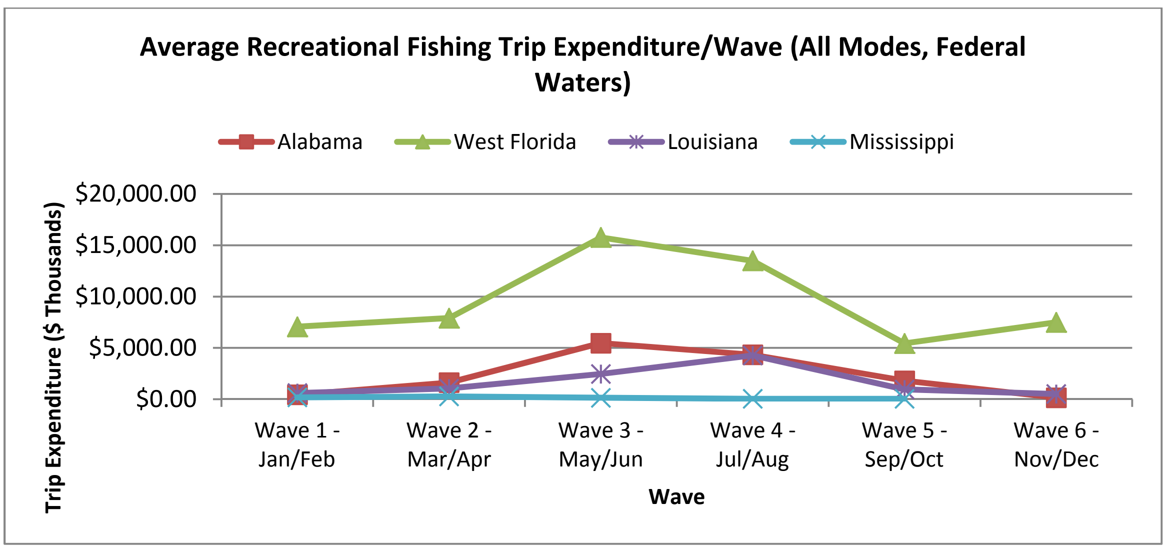

Figure E-2: Average recreational fishing trip expenditure for two month wave periods within federal waters (3 nautical miles and beyond from the shoreline) for all the Gulf States except Texas. Data was averaged from 2006–2009 for each two month wave period to estimate the average recreational fishing expenditure (National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2009).

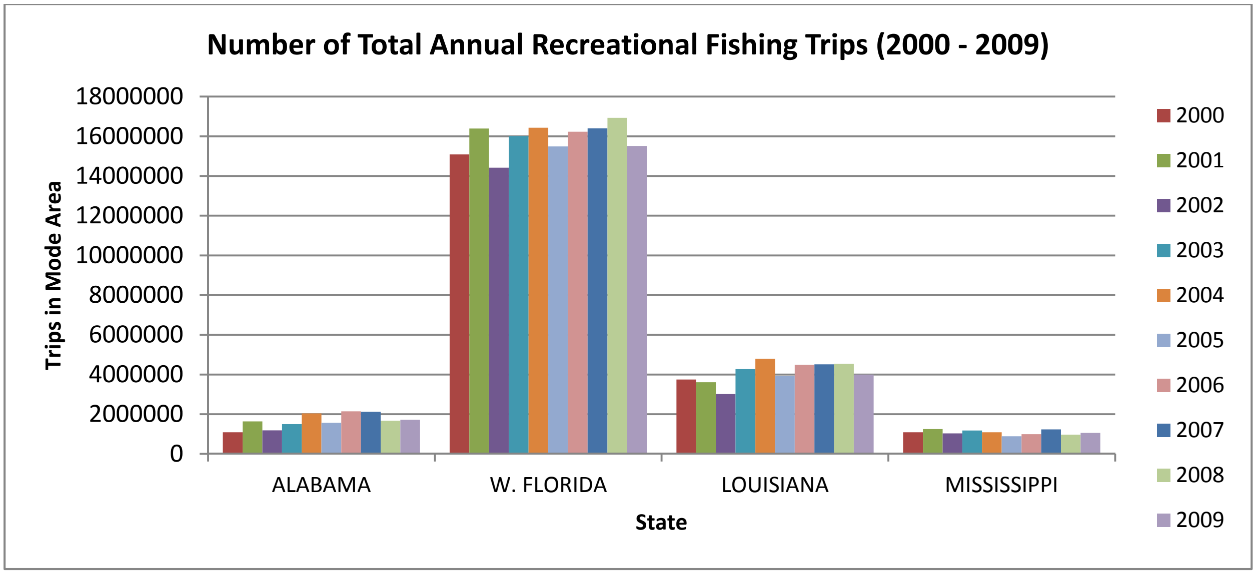

Figure E-3: Total number of annual recreational fishing trips taken from 2000–2009 for all Gulf States except Texas (Gulf States Marine Fisheries Commission, 2009).

APPENDIX F – PYTHON CODE INDEX

Provided below is the python code used to analyze the monthly economic value of hotels throughout the Gulf of Mexico to estimate the annual economic value of the hotel industry located within 3 km of the Gulf of Mexico shoreline.

```
-------------------------------------------------------------------------------------
Processes geospatial data from vector points into a raster with monetary values per
cell
'''
Call Script for Hotel Data Processing Function
National Energy Technology Laboratory for Department of Energy\
Created by Lucy Romeo, Summer 2013


Purpose of the Script: Processes geospatial data from vector points into a raster
with monetary values per cell


Input:
        - Monthly hotel point shapefiles with associated monetary values (days in
        month * room number * room rate * occupancy percentage)
                -> 12 files total, all previously projected into GOMalbers projection
                (see Graham et al., 2012 for details)
Outputs:
         - 3km buffer surrounding each hotel point
        - Point Statistics raster surrounding points with a 1km resolution and a 3km
        circle search radius, using sum of the EconVal field
        - Rasters with monetary values ranging max sum to 0 value per cell (no null
        values) - this will be the Relative Tourism Value (RTV) raster for the tourism
        model
         - Resampled point statistics based on uniform extent for model inputs
'''


# Import needed functions and libraries
import os
import hotelDataProcessing


# Set variable to class with previously defined processing script
TheInterface = hotelDataProcessing.ArcInterface()


# Set folder paths for inputs and outputs
```

```
FolderPath = "E:/NETL/GIS_Tourism/gisdata/"

# Input folder
InputFolder = "E:/NETL/GIS_Tourism/gisdata/Points_prj/"

# Output folders
BufferFolder = FolderPath + "Buffer_3km/"
PointStatFolder = FolderPath + "PointStats/"
EconRasters = FolderPath + "EconRasters/"
RasterFiller = FolderPath + "RasterFiller2.tif"

#Resampling Extent
ResampleExtent = FolderPath + "gomextenteez2/"

TheList = os.listdir(InputFolder)

# Create a list (n=12) of each of the point files
PointList = []

# Append only the files ending with an extension of .shp into the list
for TheFile in TheList:
  # Split file names and extensions
  TheFileName, TheFileExtension = os.path.splitext(TheFile)
  # Define full file path
  FullPath = TheFileName + TheFileExtension
  # Append all .shp files into point list
  if (TheFileExtension == ".shp"):
    PointList.append(FullPath)

# While loop to call function one point file at a time
p = 0
while p < len(PointList):
  MonthlyPoints = PointList[p]
  # Call function within class to process each point file
  InputShapefile = TheInterface.ProcessShapefile(MonthlyPoints, FolderPath,
InputFolder, BufferFolder, PointStatFolder, RasterFiller, EconRasters,
ResampleExtent)
```

```
  print ("Processing complete - Shapefile #:" + format(p))
  p += 1


'''
```

Processing Script for Hotel Data Processing Function

```
hotelDataProcessing - a Class containing several arcpy functions to process the hotel
point data into monthly economic value rasters
Created by Lucy Romeo


Purpose of Classes
 - Run inputs through ArcInterface class containing functions
 - ProcessShapefile function will process each shapefile and create multiple outputs


1. __init__
 - Initializes the class
 - Input of "self" is the standard input parameter for the function
2. ProcessShapefile function
 - Processes each shapefile, resulting in multiple outputs
 - Inputs:
  - self - standard input parameter for the function within a class
  - FileName - name of shapefile to be processed
  - InputFolder - where the FileName is located
  - FillRaster - raster of area with all zero values
  - BufferFolder - location for the output buffered shapefile
  - PointStatFolder - location for the output point statistics raster
  - EconRasters - location for the output point statistics raster containing no
          zeros
 - Outputs:
  - 3 kilometer buffered polygons around each hotel point
  - Point Statistics raster showing the sum of the economic values in the cells
       using a 3km circle radius at a 1 km resolution, map units
    - Point Statistics raster with no null values which will be used an a tourism
     proxy in the final model
  - Resampled point statistics based on uniform extent for model inputs
'''
```

```
# Import needed packages
import arcpy
from arcpy import env
from arcpy.sa import *
arcpy.env.overwriteOutput = True

arcpy.CheckOutExtension("Spatial")

# Create ArcInterface class
class ArcInterface:
  # Create initializing function
  def __init___(self):
    # Function to retrieve license
    arcpy.CheckOutExtension("spatial")
  # Create function to process shapefiles
  def ProcessShapefile(self, FileName, FolderPath, InputFolder, BufferFolder,
PointStatFolder, FillRaster, EconRasters, ResampleExtent):

    # Define buffer inputs
       HotelPoints = InputFolder+FileName

       FileName_Rewrite = FileName[0:10]
       BufferOutput = BufferFolder+FileName_Rewrite+"_3km.shp"
       Distance = "3000 Meters" # all within a set distance from the coast line
       sideType = "FULL"
       endType = "ROUND"
       dissolveType = "NONE"
       dissolveField = "#"

    # Create a 3km buffer around each point

arcpy.Buffer_analysis(HotelPoints,BufferOutput,Distance,sideType,endType,dissolveType
,dissolveField)

       # Define Point Statistics raster inputs
       PointStatsRaster = PointStatFolder+FileName_Rewrite+".tif"
    field = "EconValue"
```

```
        cellSize = 1000 #1 kilometer

        neighborhood = NbrCircle(3000, "MAP") #3 kilometer search radius based on
distance to coast


    # Check out Spatial Analyst extension

        arcpy.CheckOutExtension("Spatial")


    # Create Point Statistics raster

    outPointStatistics = PointStatistics(HotelPoints, field, cellSize, neighborhood,
"SUM")

        outPointStatistics.save(PointStatsRaster)


        # Resample raster to match extent for model input

        outputRaster_resample = EconRasters + FileName_Rewrite + ".tif"

        arcpy.env.snapRaster = ResampleExtent

        samplingMethod = "BILINEAR"

        cellSize_resample = "4778.303115 4778.303115" #New cell sized based on defined
extent from ResampleExtent file

        arcpy.Resample_management(PointStatsRaster,outputRaster_resample,cellSize_resa
mple,samplingMethod)

        print format(FileName_Rewrite)+"tif completed!"

-------------------------------------------------------------------------------------
```

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