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Trends in oil and gas infrastructure, ecosystem function, and socioeconomic wellbeing in coastal Louisiana

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COASTAL LOUISIANA HAS A LONG HISTORY OF DYNAMIC AND RESILIENT HUMAN COMMUNITIES

Nettie Lou Bell with father William Thomas Bell and his crew at Gray #1 well, 1941; Children dropped off from school in front of their home in Hosston, Louisiana, 2014; Acy Cooper Jr. head of the shrimpers association in Venice LA, 2010.

BACKGROUND

Louisiana's coastal zone is home to highly productive ecosystems and human communities that are heavily reliant upon the region's abundant natural resources and associated industries.[1,2] This vital region supports infrastructure for the drilling, shipping, refining, and processing of oil and gas—on and off shore. Most of this occurs in Federal and state waters within the Gulf of Mexico.[3,4] Coastal Louisiana has a long history of resilient human communities that have had to adapt over time to changing environmental, economic, and social conditions. It is also a global hot spot for ecosystem and geological change, and multiple processes produce rapid subsidence and land loss of 42.9 km^2 per year (1985–2010 average), resulting in a highly dynamic human, economic, and ecosystem landscape.[5,6,7,8,9]

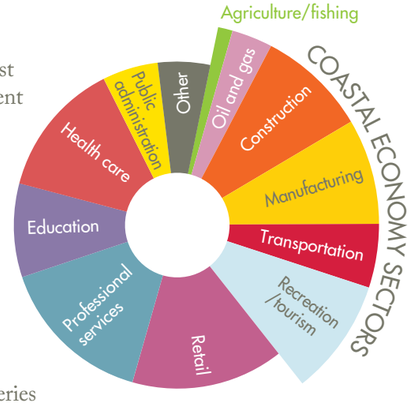
PROJECT AIM

Understanding historical changes in infrastructure density, ecosystem function, and socioeconomic wellbeing in coastal Louisiana can support better management and decision making. The objective of this project was to synthesize data from multiple sources to assess coastwide- and community-scale trends in a wide variety of infrastrucure development since the 1950s in coastal Louisiana. The next step was to quantify trends in socioeconomic wellbeing and ecosystem function related to fish and shellfish habitat over the same time period, assessing common trends between infrastructure development, ecosystem function, and socioeconomic wellbeing of communities.

EMPLOYMENT IN COASTAL LOUISIANA RELIES ON NATURAL RESOURCES

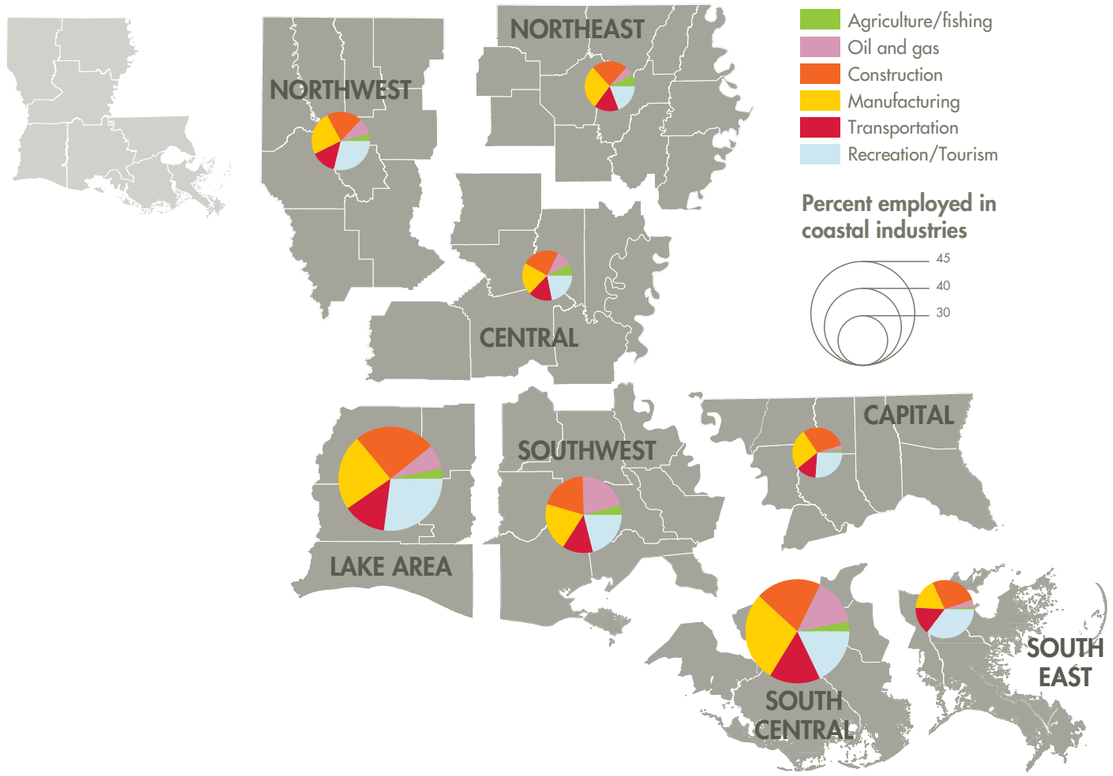
In Louisiana nearly 34 percent of all workers reside in coastal parishes—the greatest proportion of all the five Gulf of Mexico states.[10] A large portion of this employment centers on specific coastal economy sectors including: oil and gas production, commercial and recreational fisheries, marine construction, ship and boat manufacturing, tourism and recreation, and marine transportation.[11] The development of oil and gas has had a tremendous impact on the economic landscape of coastal Louisiana. In 2010, activities associated with the industry included oil and gas extraction, transportation, and refining; and directly employed nearly 65,000 workers throughout Louisiana. Additionally, for every new job created in the oil and gas industry, there are 3.4 additional jobs created in other sectors of the Louisiana economy.[12]

While it does not employ as many people as the oil and gas sector, Louisiana's fisheries sector remains a dominant economic driver in the state, especially for coastal citizens. Louisiana accounts for 21 percent of all commercial fish and shellfish landings in the lower 48 states, equivalent to 360 thousand metric tons, worth $234 million in 2010.[13] Marine sport fishing also represents an important source of jobs and earnings for many coastal communities. The economic impacts of recreational fishing in Louisiana exceeds $757 million annually and supports nearly eight thousand jobs.[13]

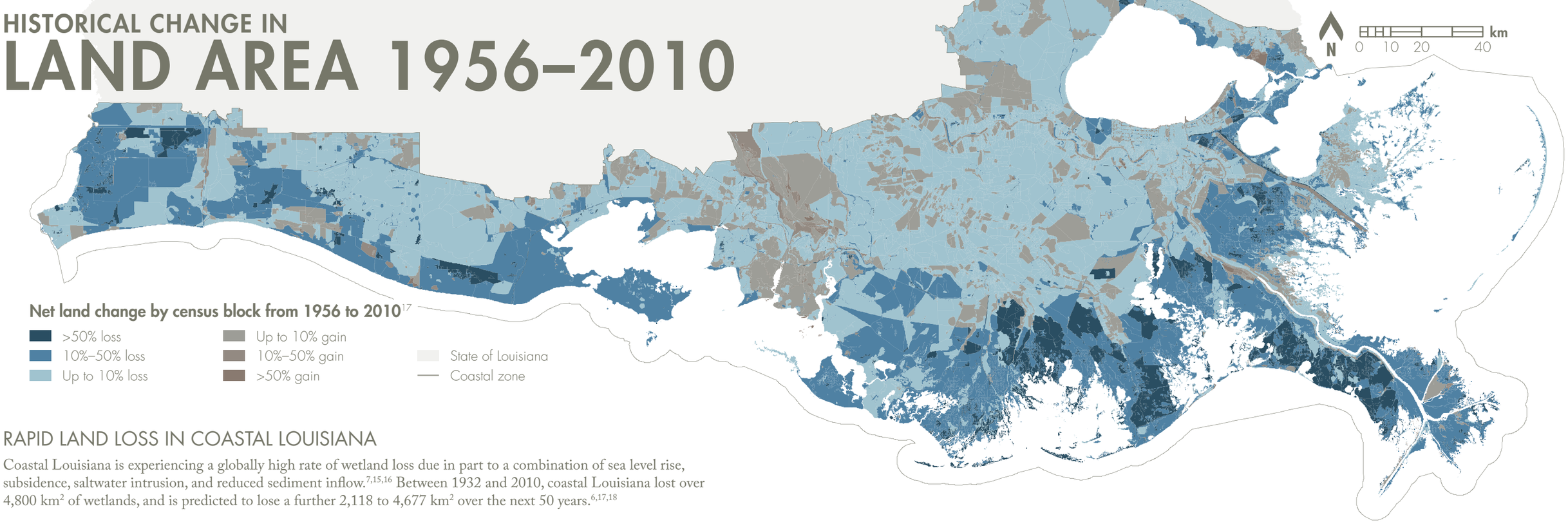


The Coastal Economy Sector represents 36.1% of the 1.95 million people employed across Louisiana.[14]

Regional coastal economy sector employment across Louisiana



HISTORICAL CHANGE IN LAND AREA 1956–2010



RAPID LAND LOSS IN COASTAL LOUISIANA

Coastal Louisiana is experiencing a globally high rate of wetland loss due in part to a combination of sea level rise, subsidence, saltwater intrusion, and reduced sediment inflow.[7,15,16] Between 1932 and 2010, coastal Louisiana lost over 4,800 km^2 of wetlands, and is predicted to lose a further 2,118 to 4,677 km^2 over the next 50 years.[6,17,18]

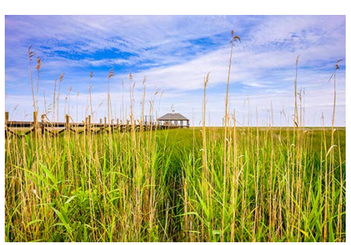
COASTAL LOUISIANA HAS ABUNDANT ECONOMIC, SOCIETAL, & ECOLOGICAL RESOURCES

Economic

Many of the economic activities of coastal Louisiana are strongly dependent on the Gulf of Mexico and based on renewable and non-renewable natural resources.[19] Six intertwined economic segments comprise the coastal economy sector: oil and gas production, commercial and recreational fisheries, marine construction, ship and boat manufacturing, tourism and recreation, and marine transportation.[20] These industries are largely immovable and based on local resources.

Societal

Coastal Louisiana is home to a wide range of cultural groups that have proven resilient to extreme weather events through strong family, ethnic, and religious ties.[21] A number of these ethnic and social groups, including Native American, Acadian, Isleño, African American, and Vietnamese, reside in the coastal parishes and are supported by livelihoods based on the abundant renewable and non-renewable natural resources of the region.



Ecological

Coastal Louisiana contains approximately 37% of all estuarine marshes in the contiguous United States, which provide valuable ecosystem services including: water use and regulation, fisheries production, alligator production, carbon sequestration, recreation, wave attenuation, and surge reduction.[17,22,23] However, dependence of fish and other ecosystem resources varies with physical marsh structure.[24,25,26]

THESE RESOURCES ARE THREATENED BY COASTAL LAND LOSS

Economic

The economic value of Louisiana's resources is sensitive to natural and human-induced changes, including fluctuating global economic conditions, environmental stress, climate change impacts, coastal habitat destruction, and increasing social and economic pressures.[19] Shoreline erosion and coastal land loss also threaten the onshore infrastructure that supports the oil and gas industry, including the extensive network of pipelines that cross the coastal zone.[27]

Societal

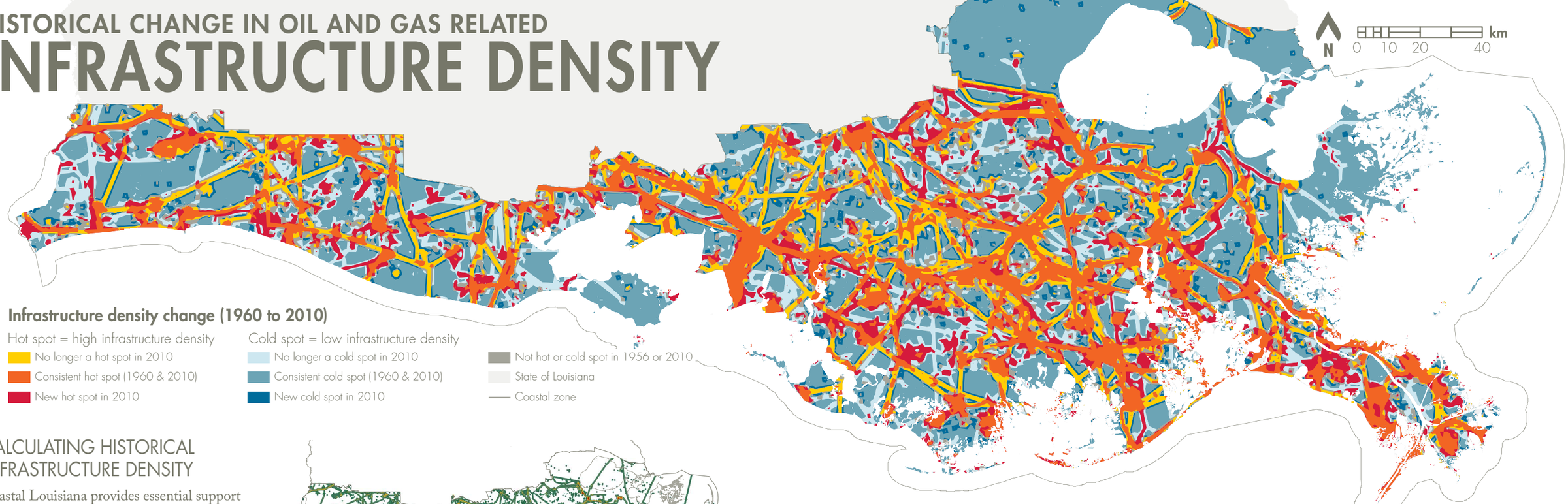
As coastal land is lost, communities become increasingly vulnerable to storm surge, coastal flooding, tropical weather events, hurricanes, storms, and frontal systems. Residents living in this changing environment will be forced to either adapt or relocate away from these high risk areas. Those who choose to remain, or who lack the means to relocate, may additionally face increasing economic threats, as rising insurance rates potentially make living in coastal areas unaffordable.[28]

Ecological

The high rate of marsh loss in coastal Louisiana is not spatially uniform, involving changes in the structure, configuration, and spatial distribution of the vegetation.[29] Habitat fragmentation—the breaking apart of continuous habitat into smaller patches—directly impacts the species utilizing the habitat.[30] Responses to fragmentation vary by species as some may linearly increase or decrease while others exhibit more complex patterns.[31]

HISTORICAL CHANGE IN OIL AND GAS RELATED

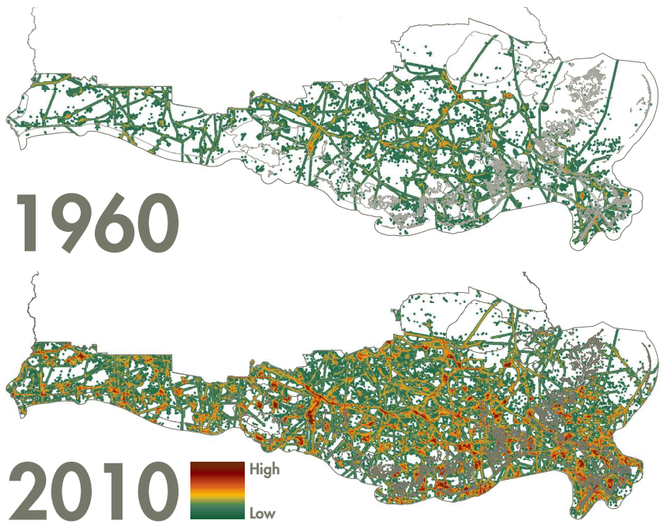
INFRASTRUCTURE DENSITY



CALCULATING HISTORICAL INFRASTRUCTURE DENSITY

Coastal Louisiana provides essential support to nearly one-third of crude oil and one-fifth of natural gas produced in the United States.[27] Although most of this production occurs in the Gulf of Mexico, the extraction and processing of oil and gas requires an expansive network of onshore infrastructure, including: gas processing plants, refineries, petrochemical plants, as well as a vast assortment of pipelines that transport the product to and from these facilities. Although not included in the current analysis, there is also extensive infrastructure from associated industry such as platform fabrication, boat building, ship manufacturing, and pipe coating. This development has fostered economic growth and employment opportunities for coastal residents, while providing potential additional stressors to the wetlands and coastal ecosytems.[32]

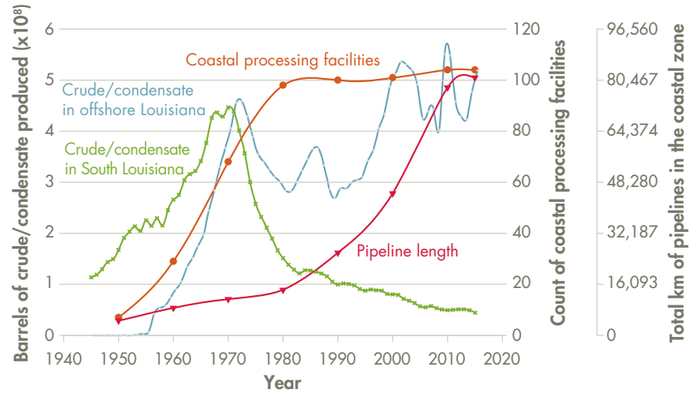
The weighted infrastructure density surface was derived using the spatial location of infrastructure and a series of influence zones based upon the type of facility and the products being stored or processed there.[33,34] Application of this 'hazardousness of place model' showed an intensification of oil and gas development in the coastal zone since the 1960s as production shifted from onshore to offshore, and since the 1990s into the deepwater Gulf of Mexico.[35]



Combined oil and gas related infrastructure density in 1960 and 2010.

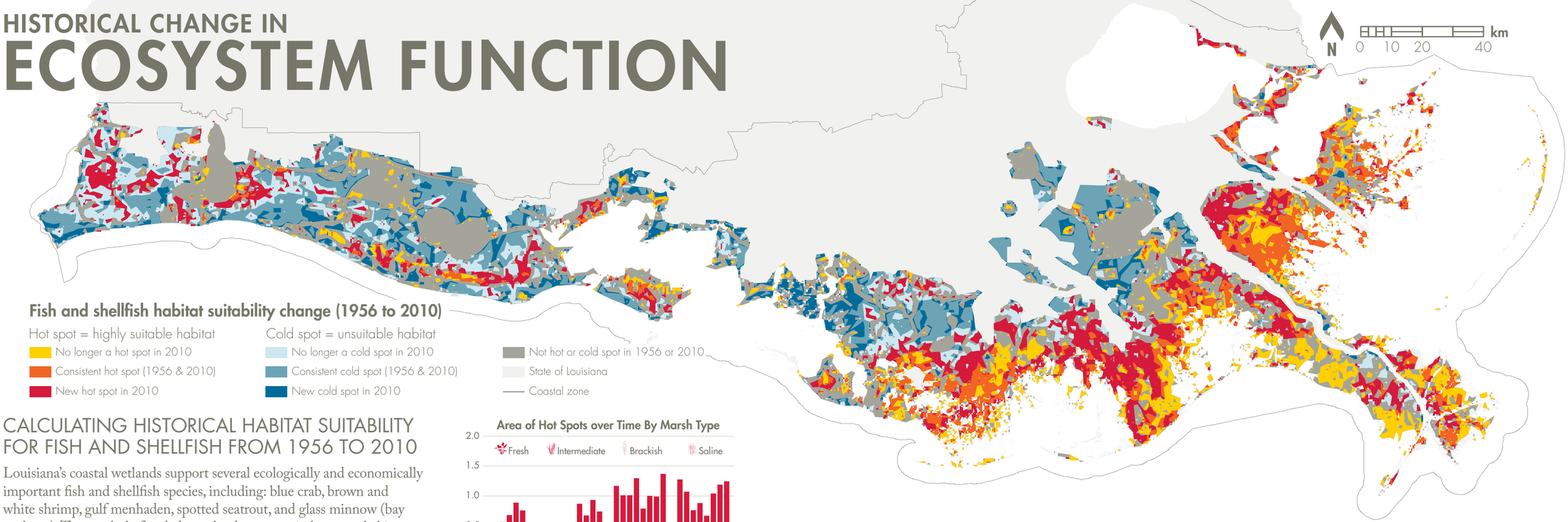
LINKING HISTORICAL INFRASTRUCTURE DENSITY

Despite the logistical challenges associated with drilling in Louisiana's coastal zone, the success of exploratory operations in south Louisiana led to increasing well outputs throughout the twentieth century until 1969, when Louisiana oil production peaked and reserves began to decline. Demand for petroleum and petroleum products, however, continued to increase and producers began drilling in areas previously considered economically infeasible, moving from the coastal marshes further offshore on the Outer Continental Shelf.[4] Following a drop in production, deepwater development in the Gulf of Mexico led to a rebound in activity during the 1990s. While the number of oil and gas processing facilities has remained relatively stable since then, the miles of pipeline to transport product from the extraction sites to the processing facilities has steadily increased.



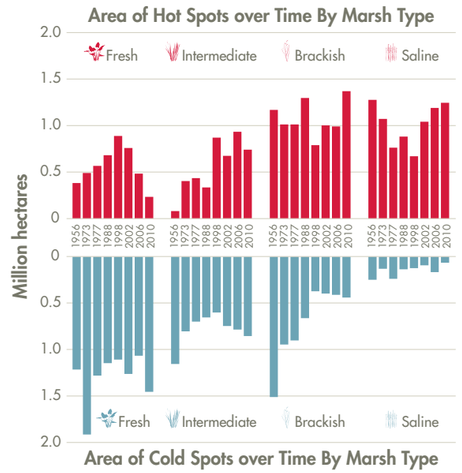
Growth of oil and gas infrastructure including the number of coastal processing facilities and miles of pipelines from 1940 to 2016.

HISTORICAL CHANGE IN ECOSYSTEM FUNCTION



CALCULATING HISTORICAL HABITAT SUITABILITY FOR FISH AND SHELLFISH FROM 1956 TO 2010

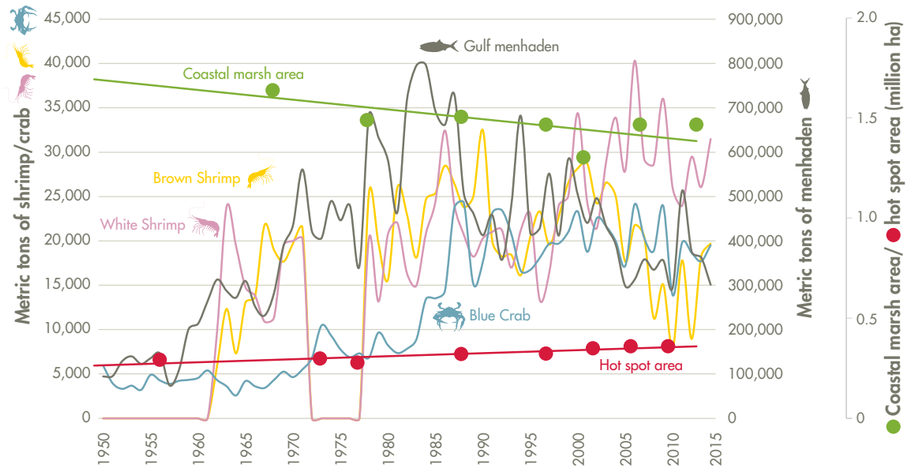
Louisiana's coastal wetlands support several ecologically and economically important fish and shellfish species, including: blue crab, brown and white shrimp, gulf menhaden, spotted seatrout, and glass minnow (bay anchovy). The regularly flooded marsh edges are a vital nursery habitat for these species, providing predation refuge from larger animals and high abundance of prey.[24,25,26] The ratio of land to water influences the utility of marsh in supporting fish and shellfish species. Areas with 25–80% land are most suitable for juvenile fish and shellfish.[36] When applied to coastal land maps from 1956 to 2010, saline and brackish marshes (>5 ppt) had the highest suitability (most hot spots), while fresh and intermediate marshes had the lowest suitability (most cold spots). Loss of hot spots between 1956 and 2010 across the Mississippi River Delta reflect the conversion of marsh habitats to open water during that period. Newly developed hot spots reveal increasing marsh fragmentation coastwide. As a result, even though total wetland area has declined rapidly since 1956, habitat ideal for fish and shellfish (hot spots) has remained steady or shown a slight increase (see graph on page 11).



Area of hot spots and cold spots for fish and shellfish habitat suitability, from 1956 through 2010 for coastal Louisiana, for four marsh salinity types.

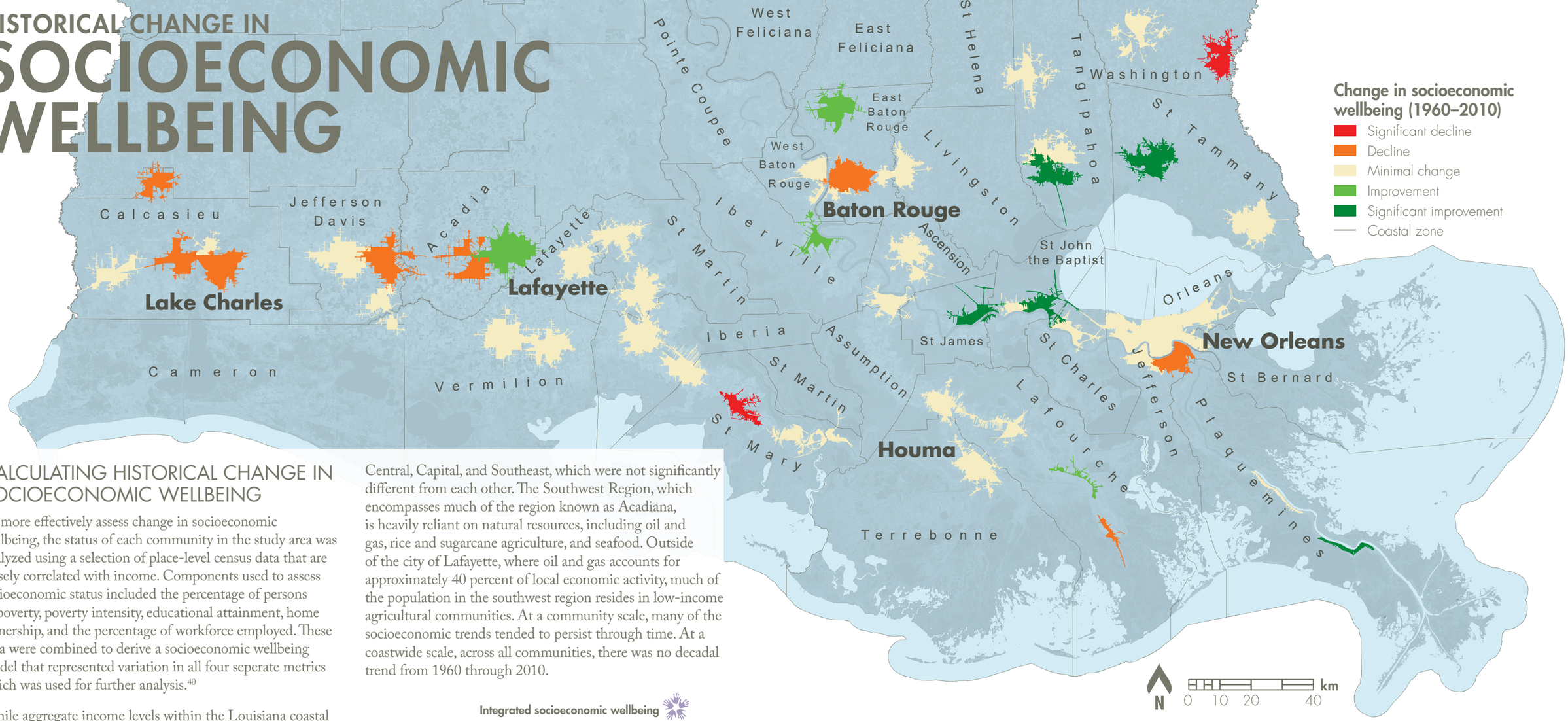
LINKING HABITAT SUITABILITY TO FISHERIES LANDINGS

Louisiana's commercial fishery is dominated by estuarine-dependent species, such as gulf menhaden, brown shrimp, white shrimp, and blue crab. Gulf menhaden make up the bulk of all landings. The apparent decline in that fishery in the 1990s was largely due to changes in fishing regulation, and therefore fishing effort, rather than changes in fish abundance.[37] Fishery yields in Louisiana, for all species combined, have remained relatively stable since the 1950s, despite extensive wetland loss.[38] The process of marsh loss starts with increased marsh fragmentation which provides increased access to habitat for fish and shellfish and trophic exchanges with the flooded marsh.[39] As a result, fragmentation has potentially balanced the effects of land loss by providing suitable habitat to support maintained total landings of fish and shellfish over the past decades in coastal Louisiana.



Landings data for Louisiana of four key fisheries species relevant to the hot spot analysis, from 1950 through 2014, compared with the area of coastal marsh and the area of hot spots (million hectares).

HISTORICAL CHANGE IN SOCIOECONOMIC WELLBEING



CALCULATING HISTORICAL CHANGE IN SOCIOECONOMIC WELLBEING

To more effectively assess change in socioeconomic wellbeing, the status of each community in the study area was analyzed using a selection of place-level census data that are closely correlated with income. Components used to assess socioeconomic status included the percentage of persons in poverty, poverty intensity, educational attainment, home ownership, and the percentage of workforce employed. These data were combined to derive a socioeconomic wellbeing model that represented variation in all four seperate metrics which was used for further analysis.[40]

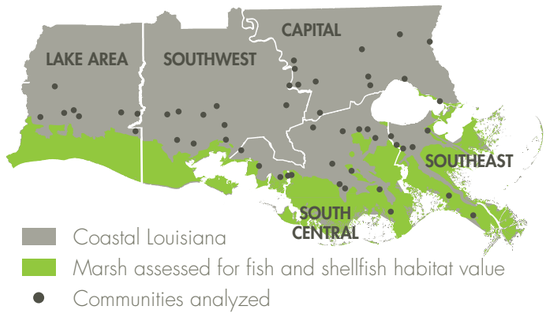
While aggregate income levels within the Louisiana coastal zone may not correlate to either oil and gas intensity or industrial composition, oil and gas development has been shown to provide a source of economic stability and growth for coastal communities, effectively mitigating the loss of onshore production in the last quarter of the twentieth century.[41] Despite the fact that oil and gas extraction wages are two and a half times larger than the average wage earned by a Louisiana worker,[12] the coastal parishes of Louisiana do not seem to be any worse off or any better off than the rest of the state in terms of personal income growth, when examined over time.[12,41]

COASTAL REGIONS SHOW DIFFERENT SOCIOECONOMIC STATUS

Analysis of the integrated socioeconomic wellbeing index showed significant differences between coastal regions in Louisiana: Southwest was lower than Lake Area, South Central, Capital, and Southeast, which were not significantly different from each other. The Southwest Region, which encompasses much of the region known as Acadiana, is heavily reliant on natural resources, including oil and gas, rice and sugarcane agriculture, and seafood. Outside of the city of Lafayette, where oil and gas accounts for approximately 40 percent of local economic activity, much of the population in the southwest region resides in low-income agricultural communities. At a community scale, many of the socioeconomic trends tended to persist through time. At a coastwide scale, across all communities, there was no decadal trend from 1960 through 2010.

Average integrated socioeconomic wellbeing for each region (normalized scores: +1SD = above average, and -1SD = below average).

METHOD TO DETERMINE COMMUNITY ANALYSIS AREA



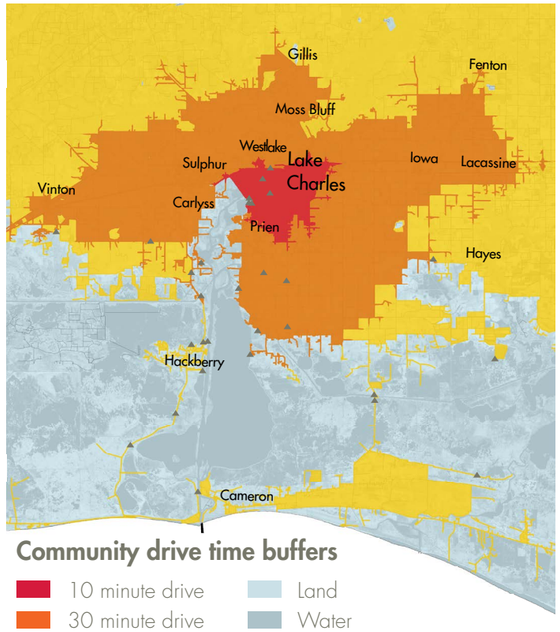
Area of coastal marsh assessed for fish and shellfish habitat value, and coastal communities included in the study.

LINKING COMMUNITIES TO RESOURCES

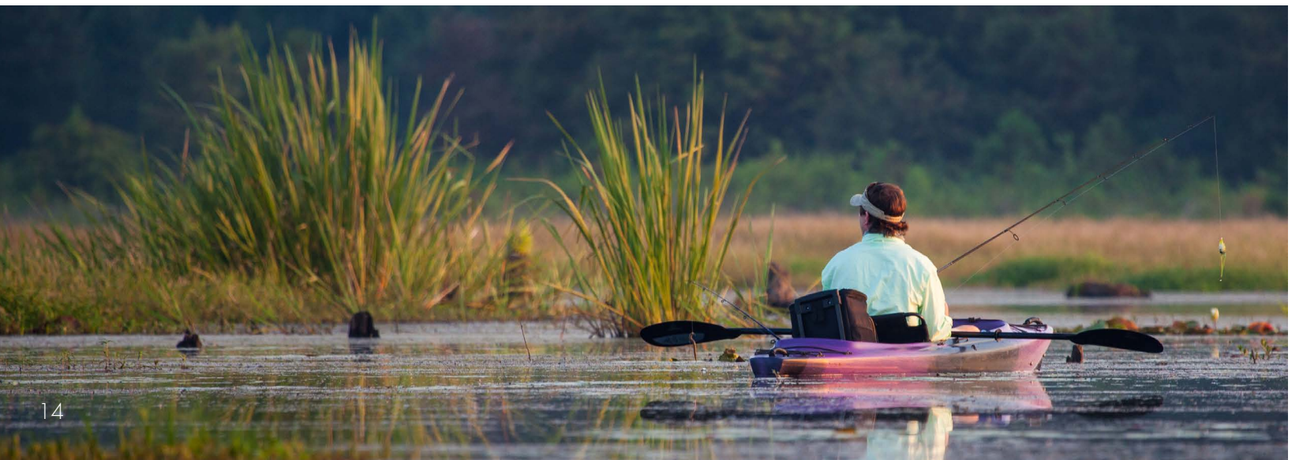
As can be seen in the above map, most of the larger coastal communities within southern Louisiana with a continuous census data record are not located within the area of saline, brackish, intermediate, or fresh marsh. However, many people from those communities still use the fish and shellfish resources supported by coastal marshes for commercial or recreational purposes. Habitat suitability was calculated in the area identified above for each decade from 1960 through 2010. An approach was then developed to link ecosystem function (in terms of potential support for fish and shellfish) of the coastal marshes to each community.

DEFINING COMMUNITY EXTENT BY DRIVE TIMES

Communities are dynamic and often extend beyond the administrative boundaries of the place itself. Some residents live outside that boundary and reach inward for goods and services. Others reach outward for employment or recreation, extending the community well beyond administrative boundaries. In this research, the boundary of each community consists of the administrative core and those areas within a 10 minute drive time buffer. This buffer was extended out to 30 minutes to account for commuting distances for work and 90 minutes to account for recreational activities, including hunting and fishing.



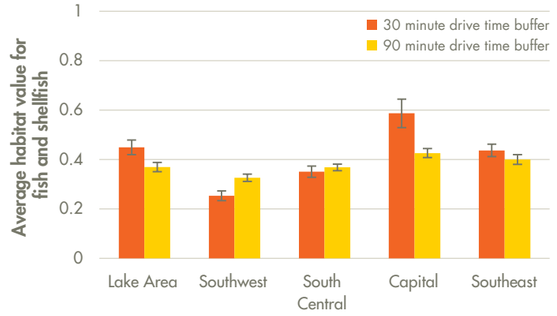
Example of drive time buffers from Lake Charles community.



LINKAGES IN ECOSYSTEM FUNCTION

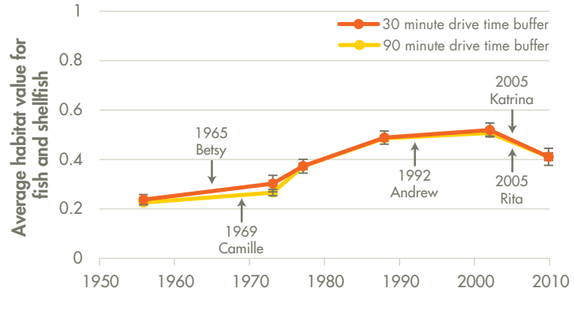
ECOSYSTEM FUNCTION VARIES ACROSS COASTAL LOUISIANA

Average habitat value for fish and shellfish within a 90 minute drive time from communities were more similar than within a 30 minute drive time, reflecting that 90 minute drive buffers are larger and therefore have greater overlap. Communities within the Capital region and the north shore of Lake Pontchartrain had access to areas with the highest potential for supporting fish and shellfish, while the Southwest region had the lowest. This can be seen in the map showing change in hot spots of habitat suitability (see map on pages 10 and 11).



ECOSYSTEM FUNCTION INCREASED FROM 1960 TILL 1990, DECLINING IN 2010

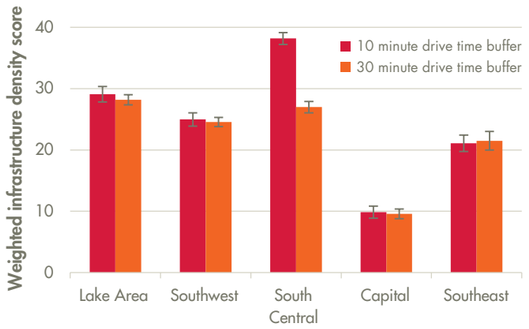
Across the five coastal regions of Louisiana, habitat suitability for fish and shellfish accessible within a 30 or 90 minute drive from communities increased from 1960, levelled after 1990, and declined after 2000, a period that included two major hurricanes. Fragmentation of intermediate and brackish marshes has been measured to be higher after 2005, and fragmentation is positively correlated to rate of land loss in subsequent years.[42] Both loss and fragmentation of marsh influence habitat suitability for fish and shellfish.



LINKAGES IN INFRASTRUCTURE DENSITY

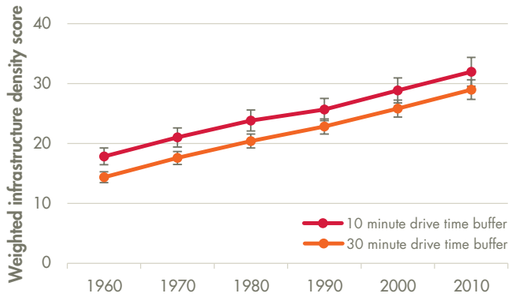
INFRASTRUCTURE DENSITY VARIES ACROSS COASTAL REGIONS

The Capital region, including the north shore of Lake Pontchartrain, has significantly less industrial infrastructure density within both a 10 and 30 minute drive of communities than all other Louisiana coastal regions. Southeast, Southwest, and Lake Area all had moderate industrial infrastructure density and South Central communities the highest density of oil and gas related infrastructure.



COASTWIDE INFRASTRUCTURE DENSITY INCREASED FROM 1960 THROUGH 2010

Density of oil and gas related industrial infrastructure increased in all regions of the Louisiana coast from 1960 through 2010. The rate of increase within each region was related to the total infrastructure density, with greatest increases in those regions with highest overall infrastructure density.

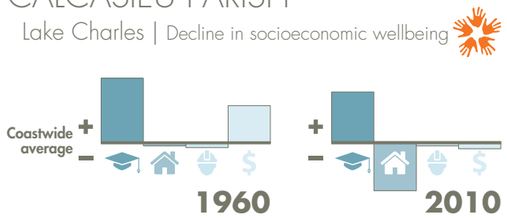


LINKAGES BETWEEN INFRASTRUCTURE DENSITY, ECOSYSTEM FUNCTION, AND SOCIOECONOMIC WELLBEING

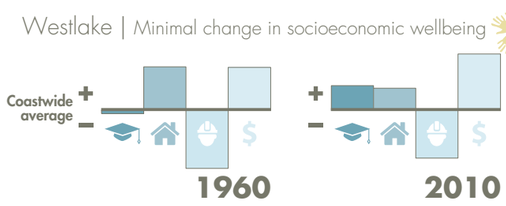
After analyzing data from 53 communities with a continuous census data record over six decades, socioeconomic wellbeing was found to increase with increasing distance from the coast. Communities that had a higher density of oil and gas infrastructure within the community boundary (10 minute drive time from community) had higher socioeconomic wellbeing; and communities that had a higher potential for supporting fish and shellfish within a regular commute (30 minute drive time from community), had higher socioeconomic wellbeing.

CALCASIEU PARISH

Lake Charles | Decline in socioeconomic wellbeing

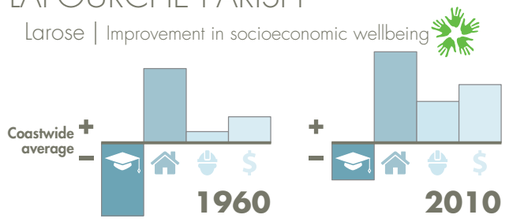


Westlake | Minimal change in socioeconomic wellbeing

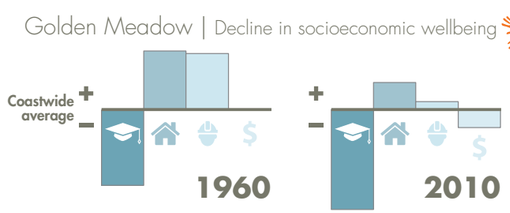


LAFOURCHE PARISH

Larose | Improvement in socioeconomic wellbeing



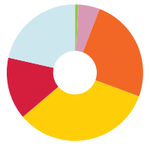
Golden Meadow | Decline in socioeconomic wellbeing



Education Property ownership Employment Poverty alleviation

With the growth of the offshore oil and gas industry, the refineries and liquefied natural gas facilities in Calcasieu Parish increased capacity to process the increasing amounts of crude brought onshore. Despite the presence of a large petroleum refining cluster, economic wellbeing has generally declined in many communities in Calcasieu Parish. This decline is related to increasing poverty levels and a drop in home ownership rates. These reductions are somewhat offset by high educational attainment levels, particularly in the urban core of Lake Charles, Westlake, and Sulphur.

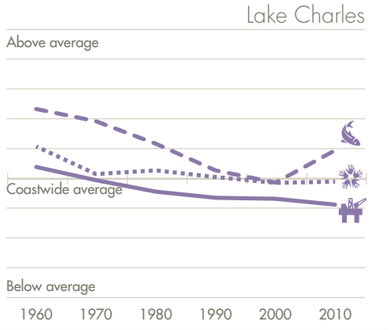
Lafourche Parish is the principal land-based supply center for the majority of the offshore oil and gas activity occurring in the Gulf of Mexico—the communities along Bayou Lafourche are home to the workers employed on the rigs, in shipbuilding, and in the transportation of supplies and workers offshore. Both Larose and Golden Meadow have relatively low levels of educational attainment but relatively high levels of home ownership. Larose, however, located at the junction of Bayou Lafourche and the Gulf Intracoastal Waterway, is home to more coastal economy-based industries, leading to lower levels of poverty.



LAKE CHARLES

Urban refinery based

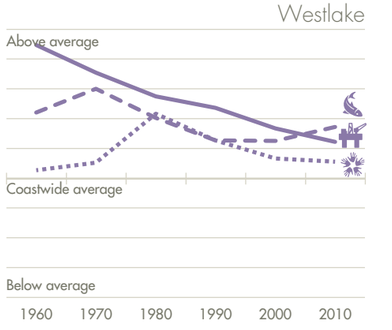
Although the density of oil and gas infrastructure in Lake Charles is below the coastwide average, petroleum refining and liquefied natural gas processing (classified as manufacturing industries) remains the dominant industry in the region. Socioeconomic wellbeing in Lake Charles has decreased slightly since 1960 as increasing levels of poverty and dropping levels of home ownership are offset by high levels of educational attainment and the high level of taxes paid by the petroleum extracting, refining, and pipeline industries in Calcasieu Parish.



WESTLAKE

Urban refinery based

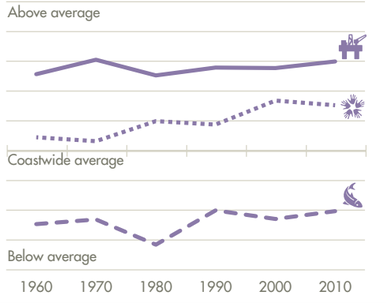
Over 55 percent of the Westlake's coastal employment consists of petroleum refining and manufacturing. With the expansion of offshore oil and gas production, Westlake experienced an uptick in socioeconomic wellbeing, followed by a readjustment and decline to levels slightly higher than those found in 1960. Despite above average levels of unemployment, Westlake tends to have relatively high levels of educational attainment and home ownership along with low poverty levels.



LAROSE

Offshore oil and gas development

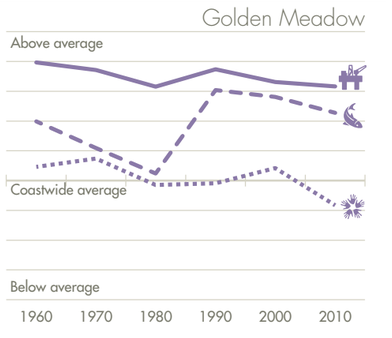
Larose is home to several large shipyards that employ a large number of residents. Despite the fact that education attainment levels have remained significantly below the coastwide average, high levels of employment have led to an overall increase in socioeconomic wellbeing, as poverty levels have fallen and home ownership rates have increased.



GOLDEN MEADOW

Offshore oil and gas development

Golden Meadow has a much smaller manufacturing base than other communities located further up Bayou Lafourche, with the community much more heavily dependent on oilfield work and water transportation. This has led to employment levels only slightly higher than that of other coastal communities but also higher levels of poverty. Between 2000 and 2010, Golden Meadow experienced a drop in socioeconomic wellbeing, likely due in part to the combination of Hurricane Katrina, the Deepwater Horizon disaster, and the collapse of oil prices.



Employment by sector

Agriculture/fishing
Oil and gas
Construction
Manufacturing
Transportation
Recreation/Tourism

Infrastructure within 10 minutes
Habitat suitability within 30 minutes
Socioeconomic scale

CONCLUSIONS

1. Oil and gas related coastal infrastructure density rapidly expanded between 1960 and 2010, reflecting the shift from predominantly onshore and nearshore extraction to offshore and deepwater Outer Continental Shelf extraction.

2. While the shift to offshore and deepwater extraction did not result in the construction of new large refining centers, existing facilities expanded capacity and there was growth in smaller coastal gas processing facilities and pipelines needed to transport product to the refining centers.

3. Infrastructure density was lowest, on average, across communities in Louisiana's Capital region, which includes those communities on the north shore of Lake Pontchartrain. Infrastructure density was highest in the South Central region of Louisiana, which includes Lafourche and Terrebonne Parishes, the center of Louisiana's offshore oil support industry, and has shown a consistent increase from 1960 through 2010.

4. Across the Mississippi Delta, as coastal marshes have fragmented and then become open water over the last six decades, hot spots for fish and shellfish habitat have migrated north (inland).

5. Estimated suitability of habitat for fish and shellfish varied across all coastal regions, increasing coastwide from 1960 through 2000, showing a significant decline in 2010. This period included major hurricanes, a major oil spill, and high Mississippi River flow events, but may indicate declining resilience of the coast to maintain suitable habitat for fish and shellfish.

6. Socioeconomic wellbeing has remained fairly constant through time on a coastwide basis, although regional- and community-scale differences are apparent. While the causes of these differences cannot be determined, an examination of the data identified a correlation between levels of socioeconomic wellbeing and close proximity (within a 10 minute drive) to areas with high industrial development. In addition, socioeconomic wellbeing within communities was positively correlated to a moderate proximity to areas of habitat with high potential for supporting fish and shellfish (within a 30 minute drive).

7. Many oil- and gas-dependent communities, particularly those that support the offshore industry, tend to have relatively low levels of poverty and unemployment, although they often have lower levels of educational attainment, suggesting that many residents may choose to work the oil fields at the expense of completing school. In more industrialized urban areas, this process appears reversed, with higher poverty levels and unemployment, despite the presence of large petroleum refining industries.

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