Offshore petroleum platforms and dissolved oxygen in the northern Gulf of Mexico

Derek G. Bolser

Term Paper for Geographic Information Systems in Water Resources, Fall 2016

Key words: Gulf of Mexico, hypoxia, offshore petroleum platforms, explosive severance

Introduction

The northern Gulf of Mexico is a highly productive and dynamic area due to the influence of the Mississippi River and its tributaries. The high levels of productivity in the region support some of the most important fisheries in the United States, with the Gulf of Mexico providing about 15% of domestic fishing revenue (National Marine Fisheries Service 2014). Louisiana has historically made the largest contribution to fisheries among the gulf states, contributing 65.6% of total catch and 38.6% of total revenue from 1950-1996 (Chesney et al. 2000).

Areas with low dissolved oxygen, or hypoxic ‘dead zones’, are known to occur in the northern Gulf of Mexico, particularly in waters offshore of Louisiana. Nutrient and freshwater inputs from the Mississippi River cause eutrophication and stratification, and thus hypoxia (Bianchi et al. 2010). These conditions are most commonly observed in the summer months, and typically persist until water becomes adequately mixed by extreme weather events (Rabalais and Wiseman 2002). Hypoxia is defined by dissolved oxygen levels below 2 mg/L, which is not enough to sustain most marine organisms. Mobile organisms must relocate or perish, leaving these zones mostly devoid of life.

Offshore petroleum platforms have proven to be some of the most vital habitat for reef-associated organisms in the Gulf of Mexico. Indeed, they are colonized by a variety of taxa almost immediately after installation (Gallaway and Lewbel 1982). With 7,225 platforms present in the Gulf of Mexico as of October 2016, there are ample opportunities for such colonization. Some of the marine organisms found on offshore petroleum platforms support recreationally and/or commercially important fisheries that are crucial to the economic well-being of coastal communities in the United States. A few of these species, such as the red snapper (*Lutjanus campechanus*), are valuable enough to be managed on the federal level.

Legally, offshore petroleum platforms are temporary structures that must eventually be removed. One way to remove these platforms is known as explosive severance; essentially the detonation of the platform’s supporting structure. This procedure has been used in the Gulf of Mexico since the 1950s, but was not regulated until 1986 (Kaiser and Pulsipher 2003). The number of platforms removed by explosive severance has steadily risen since the development of the technique, and currently about 200 platforms are removed by explosive severance per year. As one can imagine, these sudden explosions have a great effect on the communities of organisms present on platforms. Most of the regulations associated with explosive severance are directed towards protecting marine mammals and sea turtles, the ‘charismatic’ species, but they are not the only groups of organisms impacted. In the case of red snapper, explosive severance was estimated to kill 71% of fish present (Gitshlag et al. 2003). With an estimated 68% of the entire age 2 population of red snapper in the western Gulf of Mexico residing on offshore petroleum platforms (Gallaway et al. 2009), explosive severance could be having a great impact on this valuable species. Further work is needed to determine the effect of explosive severance on other fishes associated with offshore petroleum platforms, but it is likely that these fishes will be similarly impacted.

Objective

The objective of this project is to serve as a proof-of-concept study to map offshore petroleum platform distribution within historical hypoxic zones on the continental shelf offshore of Louisiana, USA, and quantify the area of dissolved oxygen classes within the range of available data. If dissolved oxygen data can be obtained in real-time, a future map of dissolved oxygen and offshore petroleum platforms similar to these historical maps could be used to better plan explosive severance and minimize its ecological and economic impacts. Ideally, this map would be used to ensure that explosive severance would occur only when an offshore petroleum platform falls within a hypoxic zone. Even if there are not enough platforms in hypoxic zones to meet demolition demands, this map could be used to better assess the impacts of explosive severance, thus improving stock assessments and fisheries management, or simply to plan fishing excursions.

Methods.

Data

Hypoxia data was obtained from the Louisiana Department of Wildlife and Fisheries (LDWF) via the National Oceanic and Atmospheric Administration (NOAA) (http://www.ncddc.noaa.gov/hypoxia/). Hypoxic zones in the northern Gulf of Mexico have been cooperatively monitored since 1985, with participation from the LDWF, NOAA, United States Geological Survey (USGS), and the Louisiana Universities Marine Consortium. Researchers collected these data during June and July of each year.

Offshore petroleum platform location data was obtained from the Bureau of Safety and Environmental Enforcement (BSEE) (https://www.data.bsee.gov/homepg/data_center/platform/platform.asp).

ArcGIS procedure

ArcGIS Pro version 1.3 was used in this project. Dissolved oxygen data was imported directly from NOAA. Symbology was adjusted upon importing to achieve desired contour lines and color scheme. Platform location data was downloaded from BSEE and manipulated in Microsoft Excel before importing. Platform points were mapped to show the distribution of platforms throughout the Gulf of Mexico (fig. 1). Platform points were then transformed to raster data using the feature to raster tool. The extract by mask tool could then be used with the newly transformed platform raster data. This tool was employed to select only the platforms that fell within the range of the dissolved oxygen data. The resulting platform raster data was then transformed back to points with the raster to point tool. To ensure that the raster calculator tool would work properly, the spatial join tool was used with platform points as the target feature and minimum O_2 value specified from the dissolved oxygen data. When the spatially joined layer was generated, the raster calculator tool could be used to generate the hypoxic, near-hypoxic, and not hypoxic classes. The hypoxic class was defined as “spatial join layer” <= 2.0. The not hypoxic class was defined as “spatial join layer” > 5.0. The near-hypoxic class consisted of the remaining platforms. Attribute tables were used to obtain the number of platforms in each class. Symbology was adjusted so that platforms were colored to represent the dissolved oxygen value they were associated with. This was validated by overlaying newly classified platform points on top of the dissolved oxygen map (figs. 4, 7)

For dissolved oxygen data, the add geometry attributes tool was used to calculate the area of the polygons formed by the dissolved oxygen contour lines. The polygons were grouped into classes and areas were summed to obtain a total area for each class. A table was generated, which was exported to Microsoft Excel using the table to excel tool.

Results

2013

1,383 platforms fell within the study area in 2013. 460 platforms were found in hypoxic zones, while 612 were found in near-hypoxic zones, and 311 were found in not hypoxic zones (table 1). The probability that a platform selected at random would fall within a hypoxic zone was 0.33, while the probability of a selected platform falling within a near-hypoxic zone was 0.44, and the probability of a selected platform falling within a not hypoxic zone was 0.22 (table 1). A map of these platforms is shown in figure 2.

The total area in which dissolved oxygen was measured in 2013 was 21,390.2825 km^2. Of this area, 7,082.2924 km^2 was hypoxic, 11,883.0690 km2 was near-hypoxic, and 2,424.9211 km^2 was not hypoxic (table 2). A map of these data is shown in figure 3.

2015

1,541 platforms fell within the study area in 2015. 93 platforms were found within hypoxic zones, while 1,309 were found in near-hypoxic zones, and 139 were found within not hypoxic zones (table 3). The probability that a platform selected at random would fall within a hypoxic zone was 0.06, while the probability that a selected platform would fall within a near-hypoxic zone was 0.85, and the probability that a selected platform would fall within a not hypoxic zone was 0.09 (table 3). A map of these platforms is shown in figure 5.

The total area in which dissolved oxygen was measured in 2015 was 23,576.9105 km^2. Of this area, 1,351.2498 km^2 was hypoxic, 19,782.8712 km^2 was near-hypoxic, and 2442.7895 km^2 was not hypoxic (table 4). A map of these data is shown in figure 6.

Discussion

Hypoxic area in the northern Gulf of Mexico has been increasing over time, but exploited populations of marine organisms in the region do not appear to be declining due to hypoxia alone (Bianchi et al. 2010). Organisms in the region are traditionally resilient to disturbance, but changes in fishing effort and reductions in bycatch have made it difficult to determine a clear link between hypoxia and fisheries production (Bianchi et al. 2010). In contrast, explosive severance procedures have been shown to have a great effect on organisms that reside on offshore petroleum platforms (Gitschlag 2003). Mobile organisms' natural distribution shifts in response to hypoxia may also protect them from the impacts of explosive severance in hypoxic areas.

Total area of dissolved oxygen data was not consistent among the two years studied (tables 1, 3). This, combined with the addition of new platforms, could make the use of the absolute number of platforms within a dissolved oxygen class unreliable when comparing years. Thus, the probability of selecting a platform from each dissolved oxygen class at random was calculated. Probability of selection is more informative than number of platforms alone when considering explosive severance planning in the real world.

It appears as if the probability of selecting a platform within a hypoxic zone is not consistently large enough to feasibly recommend that all explosive severance procedures only take place in hypoxic conditions. However, this does not eliminate the utility of a future map with real-time data. There are certainly many platforms that fall within hypoxic zones in the two years studied, and there appears to be distinct areas where hypoxic zones traditionally occur. If those areas are not hypoxic at the time of a planned explosive severance operation, decision-makers could use historical maps and maps with real-time data to better plan the operation with the knowledge that it is only a matter of time before the area becomes hypoxic.

More abundant than platforms that fall within hypoxic zones are the platforms that fall within near-hypoxic zones. Platforms in near-hypoxic zones are particularly important to monitor, as those areas may become hypoxic over time depending on environmental conditions. Further research is needed to determine the threshold at which species of interest vacate platforms due to low dissolved oxygen, as this threshold may be different than the accepted definition of hypoxia, depending on the species.

These maps may be useful to the oil and gas industry, fishers, and regulators who mandated the eventual destruction of platforms in the Gulf of Mexico. With an evidencebased approach, it would be sensible to mandate more flexible destruction deadlines. Flexible deadlines may increase the probability that the platform slated for destruction is destroyed in when its surrounding waters are hypoxic. It has been estimated that 2,000-6,000 fish perish upon the detonation of a single platform, so even a slight increase in the probability that a platform slated for destruction would fall within a hypoxic zone could have an impact (Gitschlag et al. 2000). Of course, from a purely habitat-centered perspective the most sensible course of action would be to leave platforms intact to become derelict artificial reefs. Explosive severance procedures can cost tens of thousands of dollars (Kaiser and Pulsipher 2003), so it is assumed that the oil and gas industry would support leaving platforms intact. However, little is known about what long-term effects derelict platforms would have on the ecology of the region.

Tables and figures

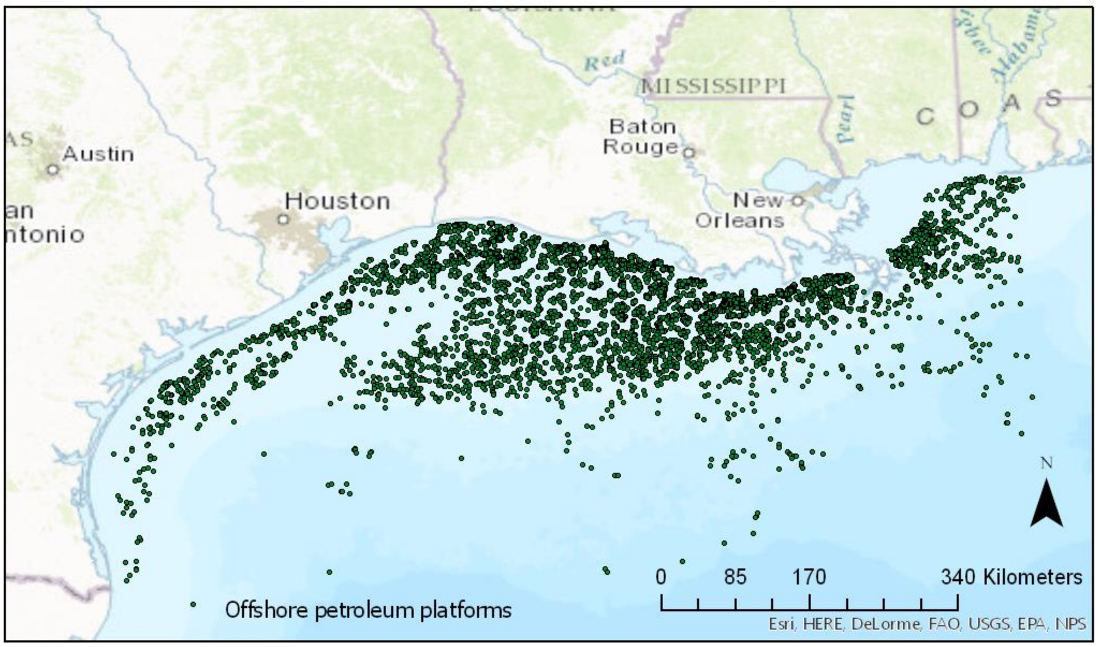

Figure 1. Offshore petroleum platforms in the Gulf of Mexico as of October 2016. 7,225 platforms are present.

2013

Class	Number of platforms	Probability of selection
Hypoxic (0-2 mg/L O_2)	460	0.3326
Near-hypoxic (2-5 mg/L O_2)	612	0.4425
Not hypoxic (5+ mg/L O_2)	311	0.2248
Total	1383	

Table 1. Number of offshore petroleum platforms by dissolved oxygen class and probability of selecting a platform that lies within each class. Data from 2013.

Class	Area (km^2)
Hypoxic (0-2 mg/L O_2)	7082.2924
Near-hypoxic (2-5 mg/L O_2)	11883.0690
Not hypoxic (5+ mg/L O_2)	2424.9211
Total	21390.2825

Table 2. Area (km^2) of each dissolved oxygen class within the range of data in 2013.

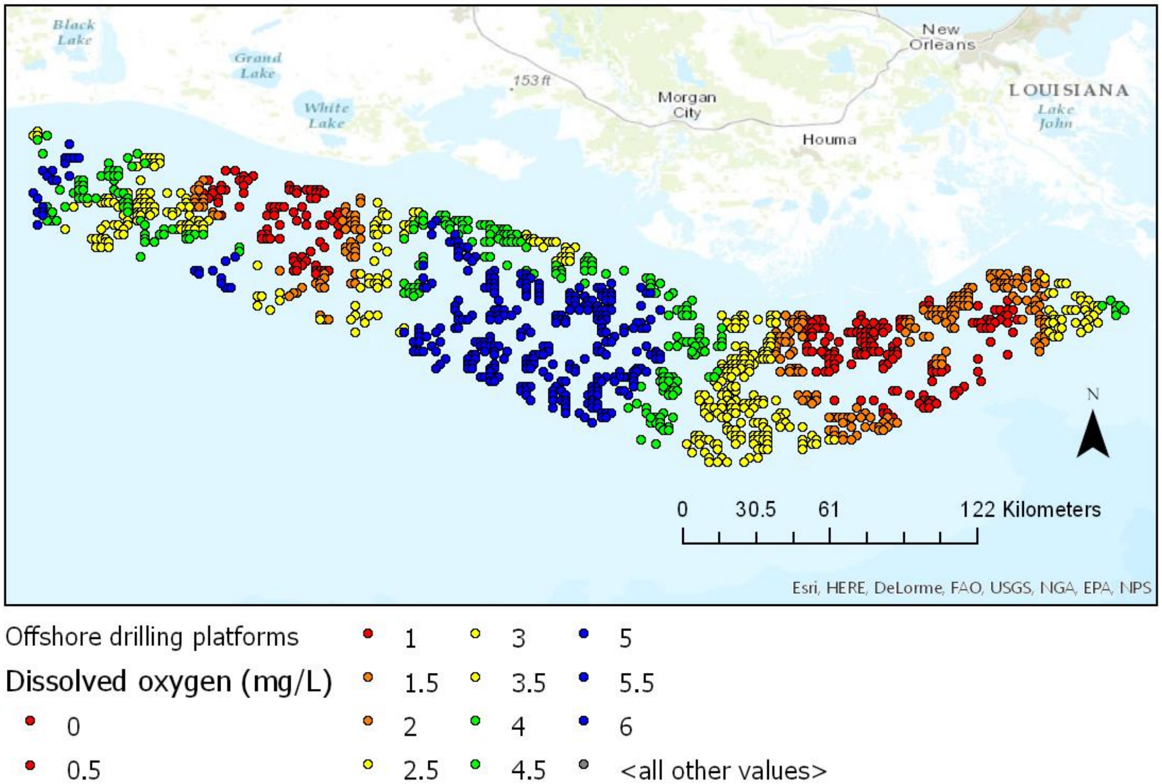

Figure 2. Petroleum platforms offshore of Louisiana, USA, classified by dissolved oxygen (mg/L) content of surrounding waters in June-July 2013.

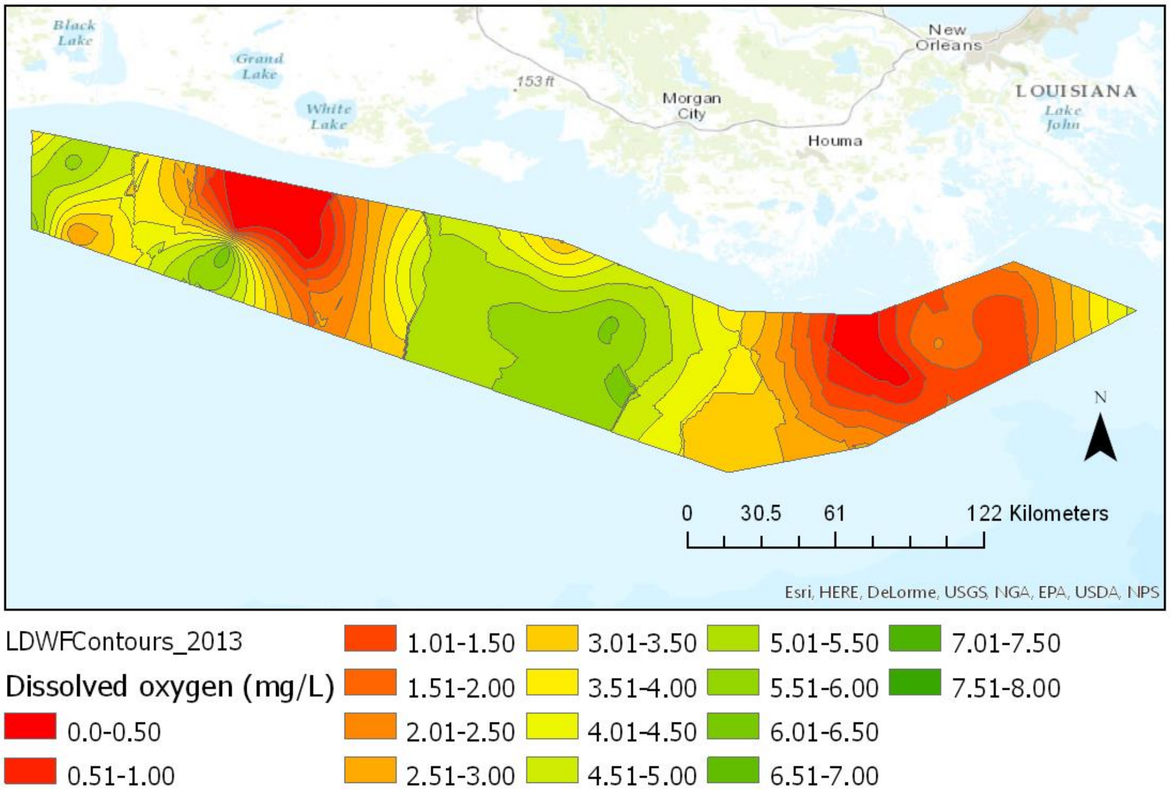

Figure 3. Dissolved oxygen (mg/L) in waters offshore of Louisiana, USA, in June-July 2013.

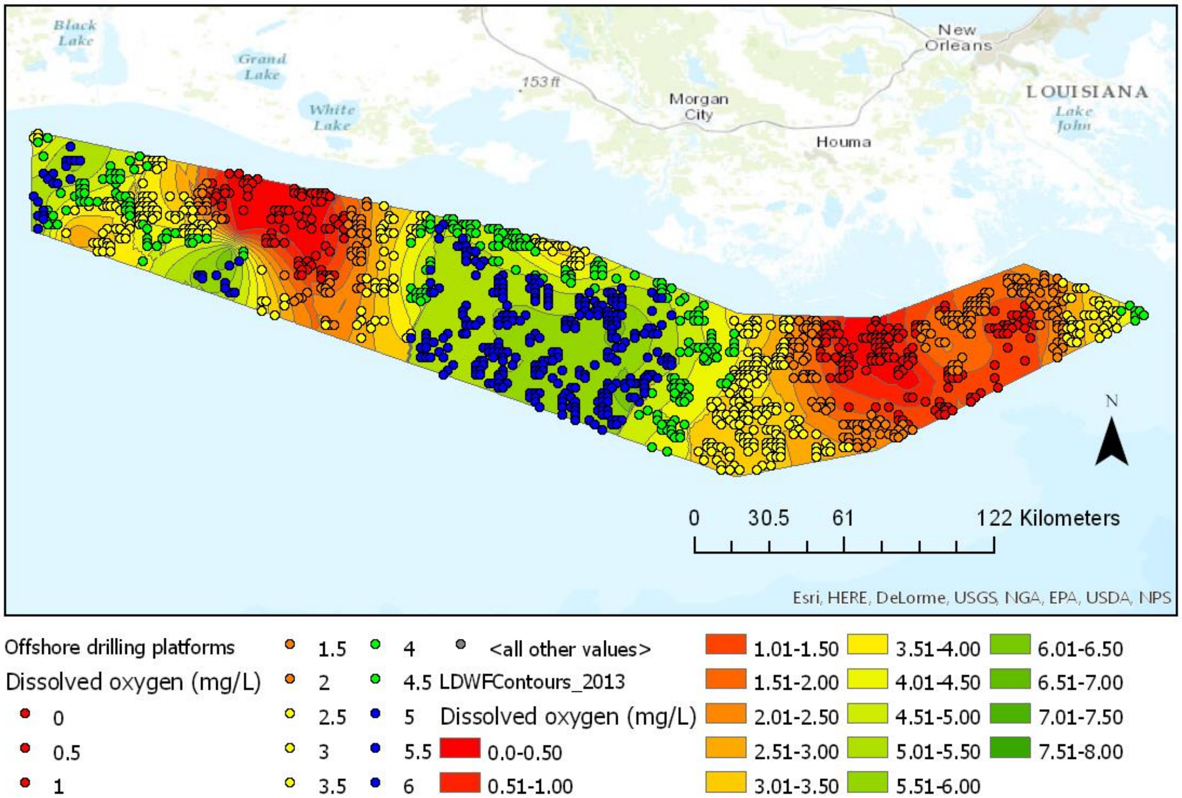

Figure 4. Petroleum platforms offshore of Louisiana, USA, classified by dissolved oxygen zone, and dissolved oxygen zones in June-July 2013.

2015

Class	Number of platforms	Probability of selection
Hypoxic (0-2 mg/L O_2)	93	0.0603
Near-hypoxic (2-5 mg/L O_2)	1309	0.8494
Not hypoxic (5+ mg/L O_2)	139	0.0902
Total	1541	

Table 3. Number of offshore petroleum platforms by dissolved oxygen class and probability of selecting a platform that lies within each class. Data from 2015.

Class	Area (km²)
Hypoxic (0-2 mg/L O_2)	1351.2498
Near-hypoxic (2-5 mg/L O_2)	19782.8712
Not hypoxic (5+ mg/L O_2)	2442.7895
Total	23576.9105

Table 4. Area (km^2) of each dissolved oxygen class within the range of data in 2015.

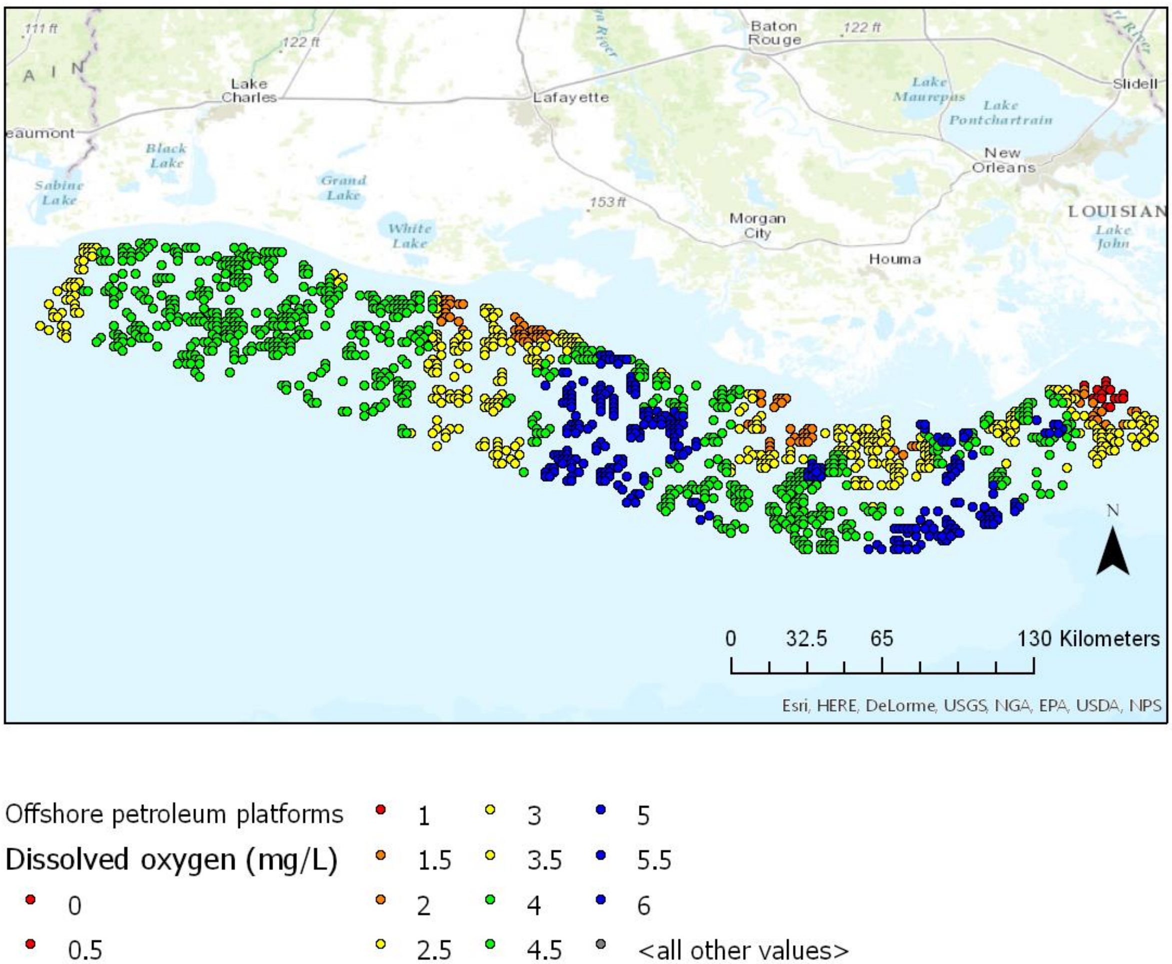

Figure 5. Petroleum platforms offshore of Louisiana, USA, classified by dissolved oxygen (mg/L) content of surrounding waters in June-July 2015.

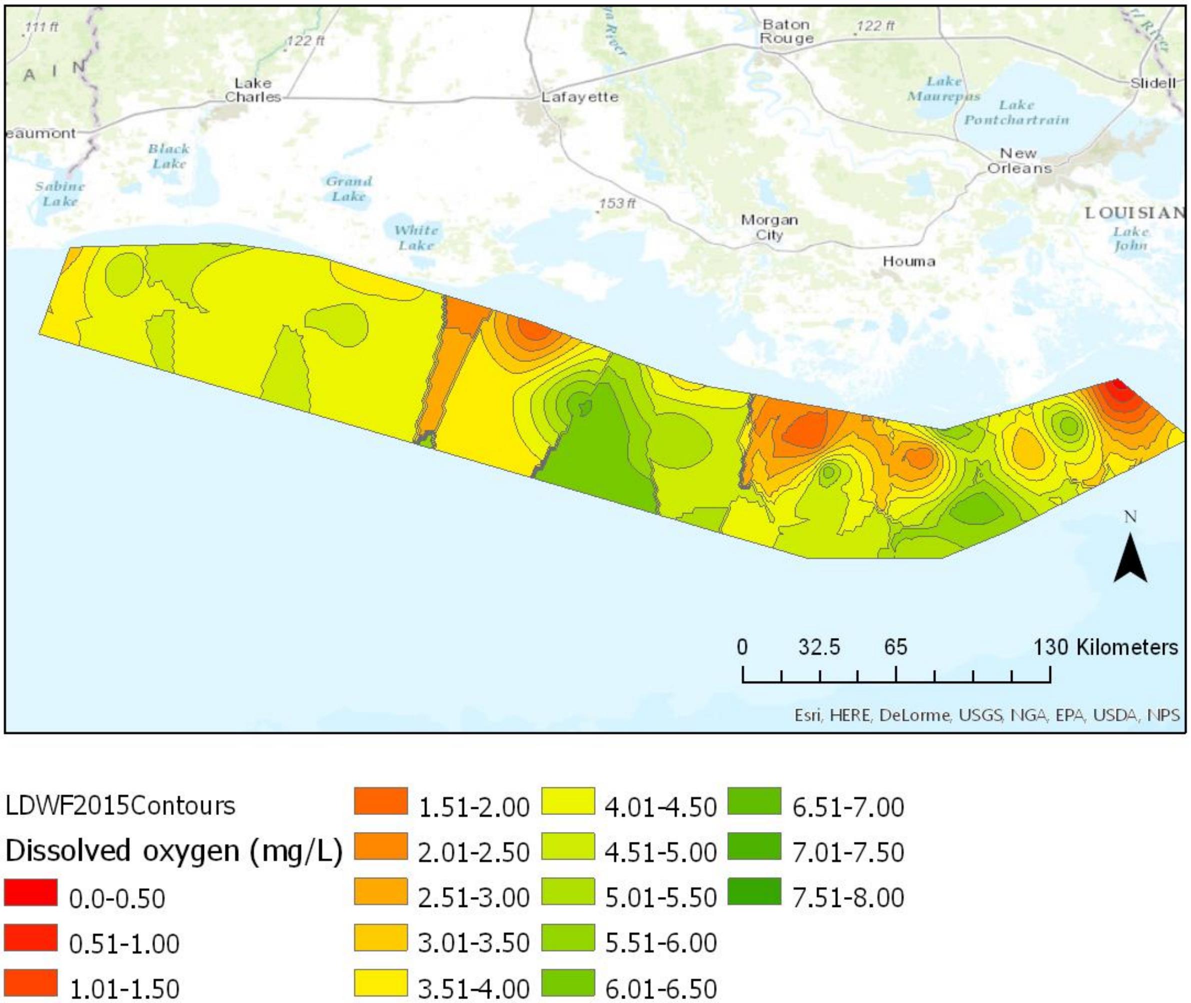

Figure 6. Dissolved oxygen (mg/L) contours in waters offshore of Louisiana, USA, in June-July 2015.

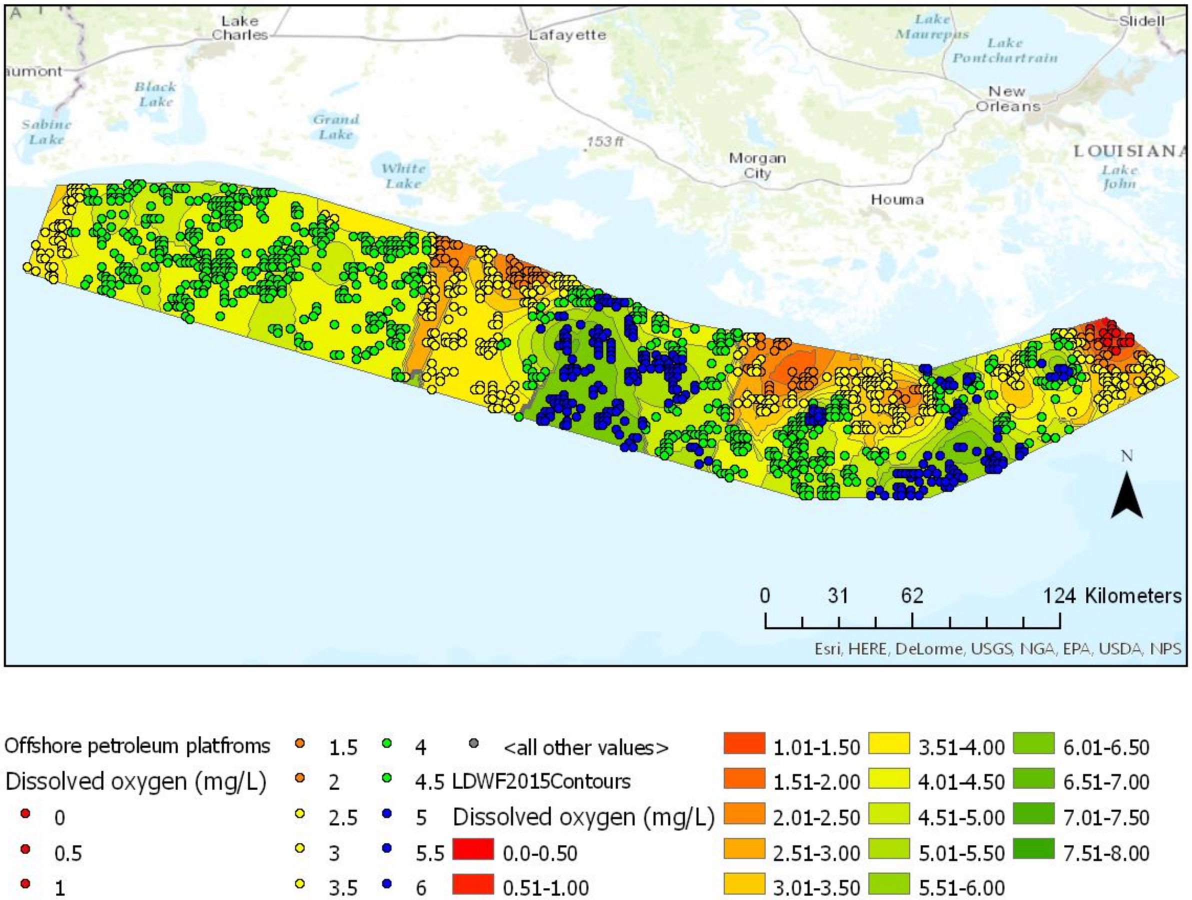

Figure 7. Petroleum platforms offshore of Louisiana, USA, classified by dissolved oxygen zone, and dissolved oxygen zones in June-July 2015.

Acknowledgements

Dr. David Maidment and Paul Ruess are thanked for their valuable feedback throughout the Geographic Information in Water Resources course, and especially for feedback regarding this project.

References.

Bianchi, T. S., S. F. DiMarco, J. H. Cowan, R. D. Hetland, P. Chapman, J. W. Day, and M. A. Allison. 2010. The science of hypoxia in the Northern Gulf of Mexico: a review. Science of the Total Environment, 408(7):1471-1484.

Chesney, E. J., D. M. Baltz, and R. G. Thomas. 2000. Louisiana estuarine and coastal fisheries and habitats: perspectives from a fish's eye view. Ecological Applications, 10(2): 350-366.

Gallaway, B.J. and G.S. Lewbel. 1982. The ecology of petroleum platforms in the northwest Gulf of Mexico: a community profile. U.S. Fish and Wildlife Service, Office of Biological Sciences, Washington DC TWS/OBS-82/27. Bureau of Land Management, Gulf of Mexico OCS Regional Office, 92 p.

Gallaway, B.J., S.T Szedlmayer, and W.J. Gazey. 2009. A life history review for red snapper in the Gulf of Mexico with an evaluation of the importance of offshore petroleum platforms and other artificial reefs. Reviews in Fisheries Sciences 17:48-67.

Gitschlag G.R., M.J. Schirripa, and J.E. Powers. 2000. Estimation of fisheries impacts due to underwater explosives used to sever and salvage oil and gas platforms in the US Gulf of Mexico. OSC Study MMS 2000-087. New Orleans, LA: National Marine Fisheries Service, US Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

Gitschlag, G.R., M.J. Schirripa, and J.E. Powers. 2003. Impacts of red snapper mortality associated with the explosive removal of oil and gas structures on stock assessments of red snapper in the Gulf of Mexico. In: D.R> Stanley and A. Scarborough-Bull (eds.). Fisheries, Reefs, and Offshore Development. Am. Fish. Soc. Symp. 36:83-94.

Kaiser, M. J., and A. G. Pulsipher. 2003. The cost of explosive severance operations in the Gulf of Mexico. Ocean & coastal management, 46(6):701-740.

National Marine Fisheries Service. 2014. Fisheries Economics of the United States, 2012. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-137, 175p

Rabalais, N., R. Turner, and W. Wiseman. 2002. Gulf of Mexico Hypoxia, a.k.a. "The Dead Zone" Annual Review of Ecology and Systematics, 33:235-263.