

Final Report to
Gulf States Marine Fisheries Commission

Applicant Name: Gulf Offshore Research Institute (GORI)

Title: MMEERSET Phase One: developing platform-based offshore aquaculture using a multi-use approach at Station Padre.

Subgrant No.: ACQ-210-039-2020-GORI

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I. Executive Summary

Using a multi-use business approach, offshore oil and gas platform sites were investigated to develop the first platform-based offshore aquaculture pilot project in the Gulf of Mexico (GOM). Our investigators performed a comprehensive feasibility assessment of two platform sites (North Padre Island 975 and 969, located at 26°50'31N, 96°58'47W and 26°49'57N, 96°56'23W, respectively) to support site-specific development and provide economic and spatial analyses of broad interest to potential investors/stakeholders. Primary deliverables produced during this project include a user-friendly economic model and regional maps identifying suitable areas for platform- and non-platform associated offshore development specific to the Station Padre study site in the northwest GOM.

Our work concluded that: 1) the economics of an offshore platform-based aquaculture system producing cobia could be cost competitive under a range of assumptions, but the economics of red drum are significantly more challenging; 2) site characterization revealed favorable conditions for an offshore aquaculture farm and no conflicts that would preclude farm development at Station Padre; and 3) ocean parameters measured are characteristic of highly exposed, open ocean conditions, and aquaculture infrastructure installed on site will need to withstand this high energy environment.

II. Objectives

1. Economic Analysis: Build a model to assess the economic potential for platform-based offshore aquaculture under various production and operating scenarios.
2. Spatial Analysis: Conduct a geospatial analysis to determine whether Station Padre is located in a suitable area for farm development.
3. Environmental Analysis: Collect/compile environmental data at Station Padre and assess the suitability of various pen and grid infrastructure types in this region.

III. Procedures

1. A bio-economic discounted cash flow model was built to assess whether platform-based marine aquaculture systems in the northern GOM are cost effective. The models were parameterized with current estimates of costs, production rates, and market values to estimate breakeven costs circa 2021. Sensitivity analysis (varying costs in the model to determine what factors are most critical for profitable operations) were also completed. Multi-use options for increasing profitability are discussed.
2. A regional geospatial analysis was conducted in ArcGIS to determine and map offshore aquaculture suitability areas in the Station Padre Area of Interest. Using the AquaMapper geodatabase consisting of 170+ geospatial data layers in the categories of military, navigation, oceanographic, biological, industrial, and administrative, multi-criteria analysis within the framework of ArcGIS was used to identify alternate ocean uses within this region, characterize physical and environmental habitat conditions, and determine the optimal site(s) for farm development.
3. A Nortek Signature 500 current profiler unit (ADCP) was deployed at the Station Padre site to collect data on current direction, velocity and wave height. This data was used to characterize the environmental conditions at the site and assess the suitability of different pen models for use in the area.

IV. Economic Analysis

Prepared by: Dr. Brian Snyder

Previous Economic Analyses

A number of authors have assessed the economic costs of cage-based marine aquaculture in a variety of species and geographies. These studies have spanned nearly two decades, and due to the diversity of inputs, they reach a variety of conclusions about the profitability of the industry. Ruiz Campo and Zuniga-Jara (2018) provide a detailed analysis, but here we describe those studies most relevant to the present model. Kam et al. (2003) conducted an early study of the hypothetical feasibility study of a cage-based Pacific threadfin offshore aquaculture system in Hawaii. They estimated a farm-gate production cost of \$4/lb, which was slightly higher than the contemporary price. Using a 10% discount rate, the system failed to break even over a 20-year period. Posadas and Bridger (2004) found more positive results by modelling the production costs of cobia, red snapper, and red drum in the Gulf of Mexico. Given a market premium of \$1/kg and high growth rates, all three species returned positive net present values. Posadas and Kim did not assume a platform-based system and instead envisioned a purpose-built \$1.5 million aquaculture service vessel.

Jin (2008) built a bio-economic model of offshore cod and Atlantic salmon production in southern New England. While Jin's parameterization will be different from a warm-water system envisioned here, the model structure is similar. Jin found that offshore aquaculture could be cost competitive, as long as the price of fish remained above \$2/kg, the feed cost remained below \$1/kg, and the feed conversion ratio was below 2. Jin also found that feed costs and the costs of fingerlings accounted for the majority of the total costs. Kaiser et al. (2010) analyzed the costs of platform-based cobia in the Gulf of Mexico and found that the system could be cost competitive, but only under optimistic scenarios. However, Kaiser et al. used high discount rates of 10 to 30%. While this may have been appropriate for an extremely high-risk industry, growing operating experience in the years since suggests that a lower discount rate may be more reasonable. Lipton and Kim (2007) collected data from commercial rock bream aquaculture in Korea and used a financial simulator to model performance. Under ideal conditions, Lipton and Kim found that rock bream aquaculture is profitable, but profitability was more uncertain under more realistic scenarios. More recently, de Bezerra et al. (2016) used data from two cage-based cobia production systems to compare production costs of an offshore, large-scale, industrial system with a near shore, small-scale, family system. They found the production costs to be lower in the industrial system, but both systems experienced relatively short payback times of 3.88 years for the family system and 2.07 years for the industrial system. Similarly, Thomas et al. (2019) studied Cobia culture in the Caribbean and found that in the majority of systems studied the NPV was positive.

Methods

We built a bioeconomic model of the costs of a platform-based marine aquaculture system in the Northern Gulf of Mexico and parameterized the model with current estimates of costs, production rates, and fish values to estimate breakeven fish costs circa 2021. We parameterized the model for both cobia and red drum and for each species we assumed that 10, 15,000 m³ cages were established around an offshore platform. We assume that all capital costs are incurred in year 0, and that revenue in year 1 is decreased by 50% due to the delay between start-up and the initial harvest as most fish require more

than 12 months to reach marketable size. The use of the platform would incur rental costs, but would help to lower operating costs by reducing vessel needs and fuel use.

Model Structure

Following Kaiser et al. (2011), we developed a net present value model to predict the breakeven production cost of selected finfish species. In each year, the net cash flow will be calculated and discounted at rate i . Cash flows will be summed across years according to:

where R_t is the net revenue in year t . R_t is composed of capital costs (CAPEX), operating costs (OPEX), and revenues generated by the sale of the produced fish. CAPEX is principally composed of the costs of the net pens, moorings, and vessels. OPEX is principally composed of fingerling costs, food costs, fuel costs, employee wages, insurance and platform rental. Fish growth is calculated on an annual basis and is multiplied by the market price to estimate revenue. A breakeven fish production cost may then be calculated.

Parameterization

Cost data from the available literature and industry operating experience were used to parameterize the models. Table 1 depicts the main parameters. All of these variables are subject to uncertainty, and when reliable estimates were not possible, we attempted to conservatively overestimate the costs. Several parameters are especially critical and require further discussion. The growth rate of Cobia and Red Drum were informed by the literature (Garces-Boticaio 1991; Wurts and Stickney 1993; Miller 1995; Liao et al. 2004; Faulk 2005). However, there is a significant variance in fish growth rates associated with environmental and dietary variation and given that precise environmental variables are not known, our growth estimates are uncertain. Similarly, while we derived the ex-vessel fish price from an analysis of 2018-2019 NOAA Fisheries data, these prices are for wild caught fish and vary across states. Thus, the actual prices received may differ.

Table 1. Assumptions used in the bioeconomic discounted cash flow model

VARIABLE	COBIA	RED DRUM
# OF CAGES	10	10
CAGE VOLUME (M ³)	15,000	15,000
COST OF NET-PEN OR CAGE (\$/M ³)	50	50
GROWTH RATE (KG/YR)	3.0	1.2
INITIAL STOCKING DENSITY (KG/M ³)	0.1	0.1
INITIAL FISH WEIGHT (KG)	0.01	0.01
PRICE PER FINGERLING (\$)	3.0	0.4

TRANSPORTATION COST PER FINGERLING (\$)	0.5	0.5
SURVIVAL RATE	0.8	0.8
FCR	1.5	1.5
UNEATEN FEED RATE	0.1	0.1
FEED COST, BULK-RATE (\$/MT)	1,000	1,000
HARVESTING COST (\$/KG)	0.1	0.1
EX-VESSEL PRICE (\$/KG)	6.77	6.1
DISCOUNT RATE	0.05	0.05
PLATFORM RENTAL (MILLION \$/YR)	1	1
VESSEL CAPITAL COSTS (MILLION)	1	1
TAX RATE (%)	30	30

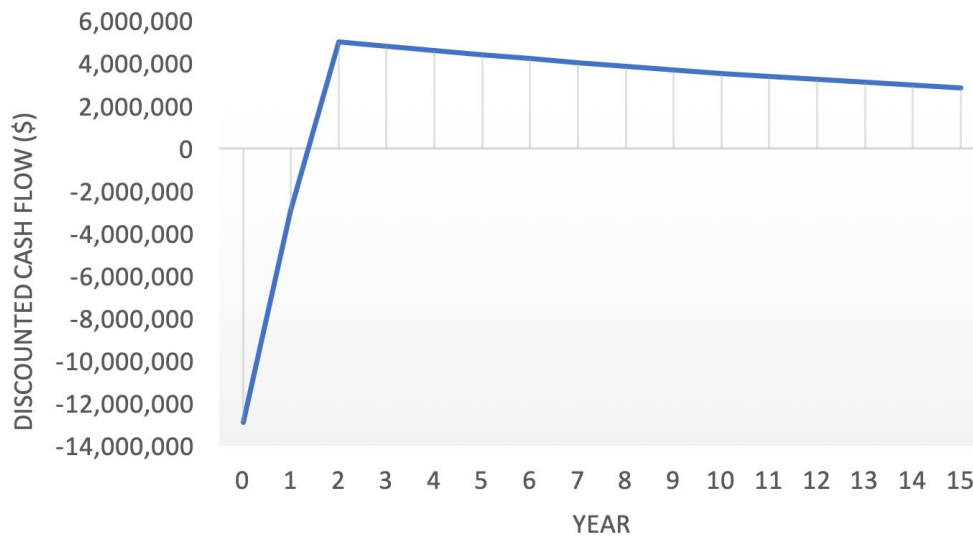
In any NPV analysis, the discount rate is critical to the results. We used a low discount rate of 4.5%, consistent with recent estimates of the cost of capital in the farming and agricultural sector (Damodaran 2021). Given the novel nature of offshore aquaculture, a risk premium may be warranted, and we explore this possibility in the sensitivity analysis below. Further, we note that the low discount rate used in this analysis may not apply beyond the current (2020-2021) period of low interest rates.

Results

Cobia

The results suggest that an offshore Cobia aquaculture system could be cost competitive under a range of assumptions. Under the baseline parameterization, the cobia aquaculture system has a net present value of \$38 million over 15 years, given a capital cost of \$13 million. Figure 1 illustrates the discounted cash flow of the cobia system. As shown in the figure, net present cash flow decreases slowly, commensurate with a low discount rate. Figure 1 also shows that the first-year capital costs are relatively low, and roughly 50% of those costs are dedicated towards the cage system. As a result, the system is able to pay back its capital costs in under four years. Part of this low capital cost may be the result of the lease of the platform. By leasing the platform, operators may be able to shift what would otherwise be incurred as capital expenses to operating expenses which would improve the profitability of the system.

Figure 1. The discounted cash flow of the Cobia system.



Sensitivity

Table 3 shows the breakeven ex-vessel Cobia price given various parameterizations of the discount rate, Cobia growth rate and cage price. The model is highly variable to changes in the ex-vessel price of Cobia and its growth rate such that if our parameterizations are inaccurate by 20-30%, the net profitability of the system will change. In contrast, the model is not particularly sensitive to the fingerling price, the cage cost, or the price of food.

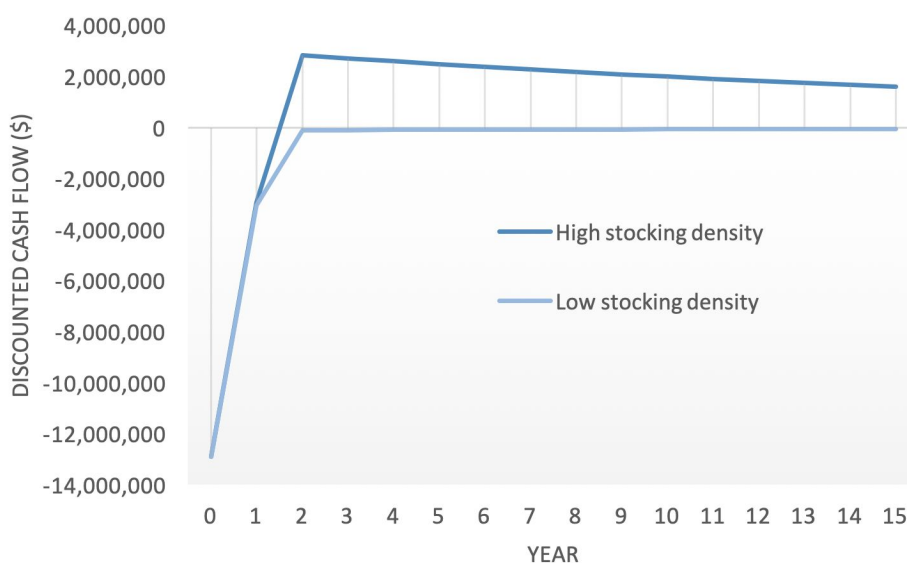
Table 3. Sensitivity of the Cobia aquaculture system to changes in selected parameters

VARIABLE (UNIT)	DEFAULT VALUE	BREAKEVEN VALUE	% CHANGE
EX-VESSEL PRICE (\$/KG)	6.77	5.3	21.5
GROWTH RATE (KG/YR)	3	2.1	29.3
CAGE PRICE (\$/M ³)	50	189.4	-278.8
FINGERLING PRICE (\$)	3	6.3	-111.3
FEED PRICE (\$/T)	1000	1853	85.3

Red Drum

The economics of Red Drum are significantly more challenging than those of Cobia. Given the assumptions in Table 1, Red Drum aquaculture is not cost effective, however, the model is sensitive to the initial stocking density. When the stocking density of Red Drum is increased (Miller 1995), the profitability improves. Figure 2 shows two scenarios. In both, the growth rate of Red Drum is limited to 1.2, but the stocking density is changed from 0.1 kg/m³ to 0.2 kg/m³. When stocking density is doubled the NPV changes from -\$17 million to \$14 million.

Figure 2. The net present cash flow from Red Drum aquaculture under high (0.2 kg/m³) and low (0.1 kg/m³) stocking conditions.



Discussion

In order for some complementary system to improve the economics of the aquaculture system, there must be an incentive for both systems, presumably in the form of cost reduction. The most obvious potential for cost reduction is shared use of the platform itself. For joint use with renewable energy facilities, platform space might be used to house the equipment required to increase voltage for transport to shore, particularly if the site is far (10-20 km) from shore.

Under the specified assumptions, Cobia culture is expected to be cost effective. While additional simultaneous uses may improve the profitability of the system, they do not appear to be required. In contrast, Red Drum culture may require additional simultaneous use. Given the stocking and growth assumptions described in Table 1, an additional nominal income of about \$1.8 million per year is required for Red Drum culture to break even. This increased cost could be met by simultaneous use for renewable energy generation. For example, airborne wind energy systems may be well-suited to the GOM and cost effective. Leake (2020) estimated that a 500 MW airborne wind energy system in the Northern Gulf Of Mexico would have capital costs on the order of \$500 to \$900 million with a net present value over 30 years on the order of \$150 to \$300 million. While a 500 MW farm may be larger than required for integration with a marine aquaculture system, the positive results suggest that smaller

wind energy systems may be a useful complement to aquaculture systems. Assuming that costs scale linearly with capacity, we estimate that a 50 MW airborne wind energy system might, if integrated with a Red Drum aquaculture system, meet excess costs.

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V. Spatial Analysis

Prepared by: Dr. Abigail Bockus and Dr. Kenneth Riley

Spatial Summary

Geospatial maps and spatial model criteria are provided in Appendix I. As of January 2021, there were 1,831 oil and gas platforms in the offshore waters of the Gulf of Mexico (GOM). The two platforms of interest (hereafter referred to as Station Padre platforms) are located in federal waters 35 miles NE of Port Mansfield, TX (and 23-25 miles off the coast of Padre Island, TX) in water depths of 155 and 156 ft., respectively. Geospatial analysis of site suitability was conducted across 23 primary data parameters spanning 4 categories (Military, Navigational, Industrial, Biological; Appendix II). Of these, 12 were not located within 10 miles of the Station Padre Area of Interest (AOI, approx. 20 km x 20 km) and excluded from further consideration. It was found that the Station Padre AOI is located within a Military Operating Area (Corpus Christi OPAREA), which covers an extensive portion (approx. 30,000 sq. km) of the northwest GOM. Additionally, Station Padre platforms are located 80 and 215 m from a shipping fairway, which transects the Station Padre AOI. Construction of artificial structures is prohibited within the fairway and heavy vessel traffic is present in the center of the fairway. There are four shipwrecks in the region but they are located 15.4 – 26 km from the Station Padre platforms. There is one artificial reef within the AOI and three others within the vicinity of the study site, with the closest artificial reef located 7.5 km from the Station Padre platforms. There is one deep-sea coral site located 6.6 km from the Station Padre platforms and other deep-sea coral and coral Essential Fishery Habitat (hard bottom) located outside the AOI, 16.5+ km from the platforms. Within the AOI, excluding space designated for other ocean uses plus safety buffer zones (specifications in Appendix I) yielded the Station Padre Opportunity Area, which represents the area available for offshore aquaculture farm development within the AOI. *Site characterization revealed favorable conditions for an offshore aquaculture farm and no conflicts that would preclude farm development at Station Padre.* In fact, it was determined that 77% of the AOI represents Opportunity Area for future farm development. Next, the feasibility criteria outlined in Appendix I will be used to complete a comprehensive spatial feasibility assessment to identify the optimal site(s) for an offshore aquaculture farm within the Station Padre AOI. This assessment and resulting map will be included in the final project report and disseminated with the other project materials.

Environmental Characterization

An additional 26 data parameters were analyzed across the Station Padre AOI to characterize the physical and environmental characteristics of the study site.

Physical characteristics

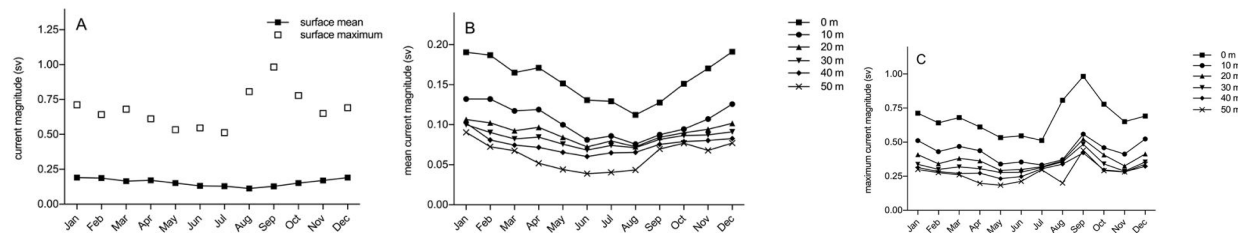


Figure 1. Current magnitude (sv) by depth and month. A) Mean and maximum current magnitude at the surface by month. B) Mean current magnitude by depth and month. C) Maximum current magnitude by depth and month. Each point represents a mean $\pm$ standard deviation calculated across the Area of Interest. Data obtained from hycom for 1992 - 2012.

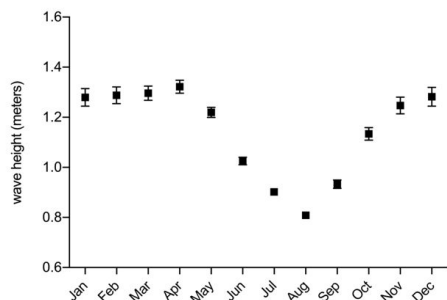


Figure 2. Wave height (meters) by month. Each point represents a mean $\pm$ standard deviation calculated across the Area of Interest. Data obtained from the Marine and Hydrokinetic Data Repository, U.S. Department of Energy.

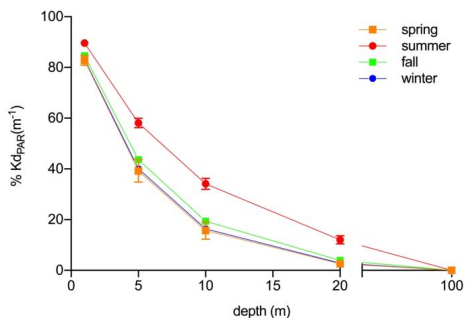


Figure 3. Light attenuation ($\% Kd_{PAR}(m^{-1})$) by depth and season. Each point represents a mean $\pm$ standard deviation calculated across the Area of Interest. Data obtained from National Environmental Satellite Data and Information Service, NOAA for 2019.

Temperature

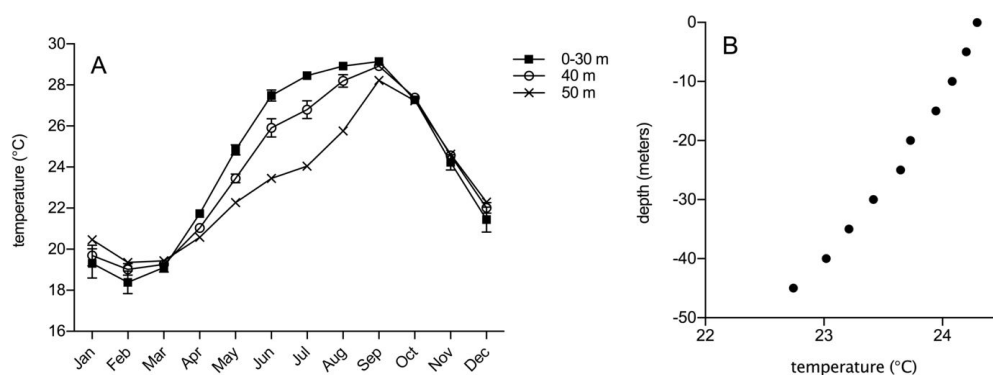


Figure 4. Temperature ($^{\circ}C$) by depth and month. A) Temperature for three depth strata by month. Each point represents a mean $\pm$ standard deviation calculated across the Area of Interest. Data obtained from hycom for 1992 - 2012. B) Temperature profile by depth. Data obtained from Ecological Marine Unit Explorer, ArcGIS Living Atlas for one location within the Area of Interest.

Salinity

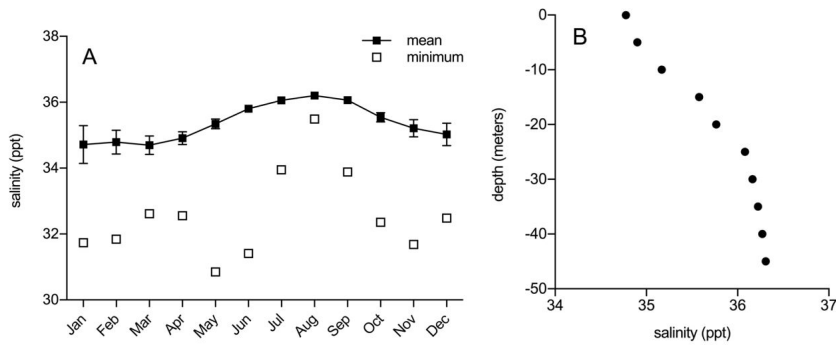


Figure 5. Salinity (ppt) by depth and month. A) Mean and minimum salinity by month. Each point represents a mean averaged across all depths (0 – 50 m) for the entire Area of Interest. Data obtained from hycom for 1992 - 2012. B) Salinity profile by depth. Data obtained from Ecological Marine Unit Explorer, ArcGIS Living Atlas for one location within the Area of Interest.

Dissolved Oxygen

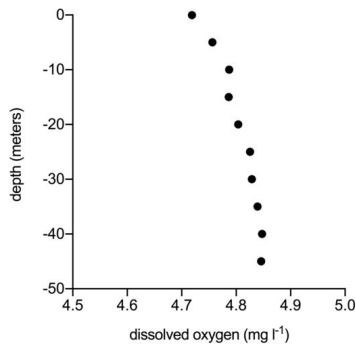


Figure 6. Dissolved oxygen profile (mg l⁻¹) by depth. Data obtained from Ecological Marine Unit Explorer, ArcGIS Living Atlas for one location within the Area of Interest.

Nutrients

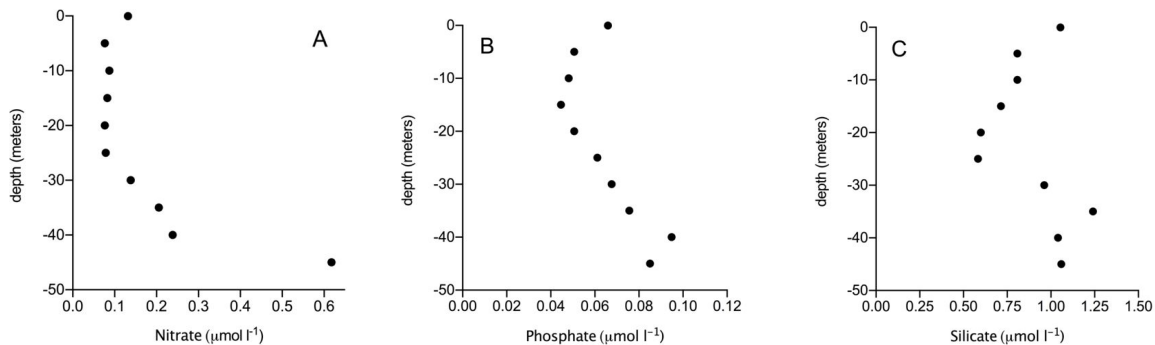


Figure 7. Nutrient profiles by depth. Concentrations of Nitrate (A), Phosphate (B) and Silicate (C) in seawater by depth. Data obtained from Ecological Marine Unit Explorer, ArcGIS Living Atlas for one location within the Area of Interest.

	Nitrate	Phosphate	Silicate
surface	1.9-2.2	0.0001	9.2-9.9
benthic (mean)	0.51-1.01	0.0007-0.003	5.9-7.4

Table 1. Mean nutrient ranges (mol m⁻³) at the surface and benthos across the Area of Interest. Data obtained from Bio-ORACLE (Tyberghein et al. 2012; Assis et al. 2017)

Environmental Characterization Summary: Mean current decreased from 0.2 to 0.05 sv as depth increased from 0-50 m. Maximum current displayed a similar pattern with depth with the highest maximum current occurring at the surface. Maximum current was 0.75 sv for the majority of the year, increasing to a maximum of 1.00 sv in September. Wave height ranged from 0.8 to 1.3 m. Wave height was 1.3 m for the majority of the year, decreasing in the summer months to a low of 0.8 m in August. Wave direction ranged from 270° in December to 311° in July, blowing NW year round. Wave energy period ranged from 4.52 seconds in August to 5.65 seconds in February. Wind direction ranged from 73° in January to 147° in July, blowing offshore year round (annual average 122°) at a speed between 2.3 m sec⁻¹ in December to 6.0 m sec⁻¹ in May (annual average 4.2 m sec⁻¹). By a depth of 5 m, 40% light attenuation was achieved in spring, fall, and winter and 60% in summer. Temperature ranged from 18 – 29 °C, with distinct depth stratification during the summer months. The site displayed full strength seawater year round (35 ppt) and a dissolved oxygen concentration above 4.7 mg l⁻¹. Throughout the water column (0-50 m), nitrate ranged from 0.2-0.8 umol l⁻¹ (mean 0.24 ± 0.24), phosphate ranged from 0.04 to 0.09 umol l⁻¹ (mean 0.06 ± 0.02) and silicate ranged from 0.6 to 1.2 umol l⁻¹ (mean 0.89 ± 0.22). Further, benthic composition in the AOI ranged from 100% mud to 70:30 mud to sand and the presence of gravel was below 1% (data not included)..

Tyberghein L, Verbruggen H, Pauly K, Troupin C, Mineur F, De Clerck O (2012) Bio-ORACLE: A global environmental dataset for marine species distribution modelling. *Global Ecology and Biogeography*, 21, 272–281.

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VI. Environmental Analysis

Prepared by: Tyler Sclodnick

Summary

The environmental conditions at Station Padre were measured using oceanographic instruments deployed directly adjacent to the rig. The parameters measured are characteristic of highly exposed, open ocean conditions with a mean near surface current of 0.23 m/s and mean significant wave height of 0.89 m. Any aquaculture infrastructure installed on site will need to withstand this high energy environment. Submersible infrastructure is highly recommended as the surface conditions will cause rapid and drastic deterioration of infrastructure that will be costly and poses a high risk of escapement.

Purpose

A rigorous characterization of the environment where aquaculture equipment is to be deployed is an essential step in project feasibility analysis. The oceanographic conditions determine the growth rate of fish, suitable pen models, system design constraints, and much more. A month-long data set capturing waves, current, and temperature will allow initial assessments of infrastructure needs and fish growth rates as well as provide inputs for future work on grid design and deposition modeling.

Approach/Methods

A Signature 500 acoustic doppler current profiler (ADCP) was deployed 150 m north of Station Padre in 51 m of water from July 3rd to Aug 16th, 2020. The unit was installed in a collar buoy, with a one-meter chain leading to an anchor which was tethered to the oil rig for recovery. The unit collected wave data every 2 hours with a vertically facing acoustic transducer sending pings at 2 Hz for 17 minutes. Current data was collected with four slanted acoustic transducers collecting data every hour with pings at 1 Hz for 2 minutes. A vertical current profile was created with 4 m depth bins. Temperature was measured at the ADCP unit at 49 m of depth.

Findings/Results

The significant wave height was between 0.35 and 1.40 m with maximum waves between 0.39 and 2.81 m during normal conditions. However, Hurricane Hanna passed over the study site (figure 1) as a category 1 hurricane on July 25th creating conditions which saw the significant wave height reach 6.22 m and exceed 4 m for over 24 hours. The mean significant wave height over the entire deployment period was 1.04 m and the mean excluding hurricane Hanna was 0.89 m. The maximum wave height during the deployment was 10.39 m and the maximum wave was greater than 5 m for 26 hours. Figure 2 shows a time series of wave conditions during the deployment.

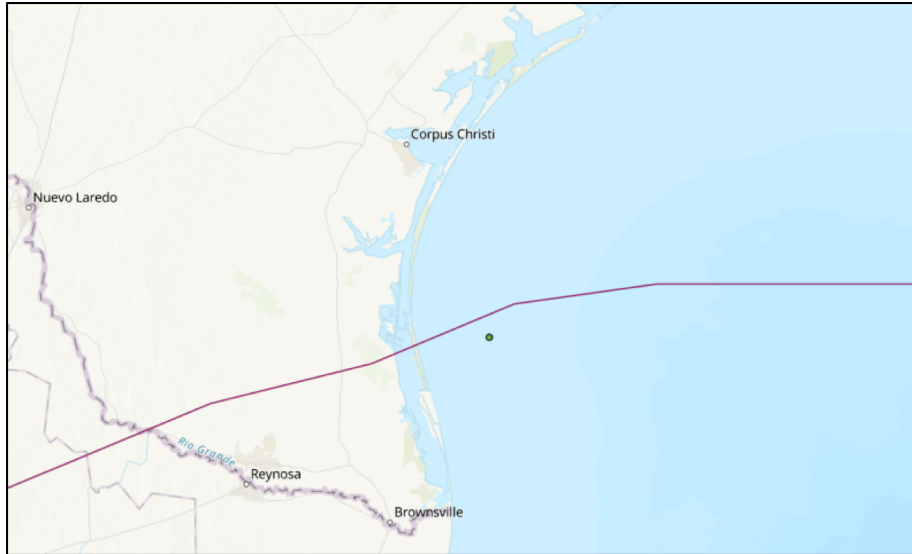


Figure 1: Path of Hurricane Hanna (purple line) and the location of Station Padre (blue dot). The eye of the storm passes within 15 km of the oil rig.

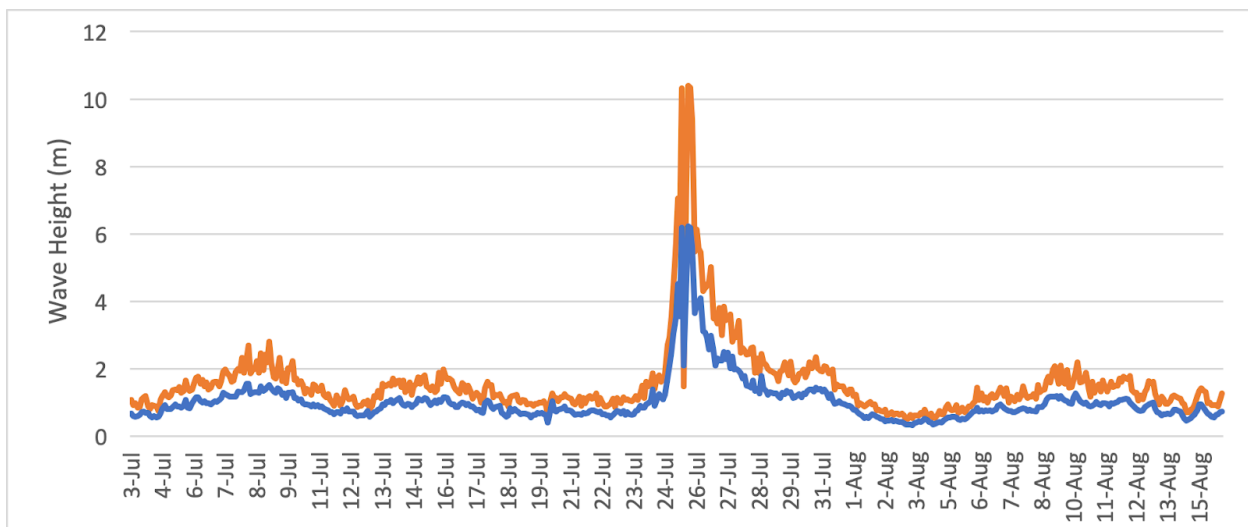


Figure 2: Significant wave height (H_{m0}) and maximum wave height (H_{max}) over the deployment period

Ocean currents varied between 0 and 0.73 m/s at 4.5 m, the shallowest depth measured, and 0 and 0.44 m/s at 20.5 m, the depth most representative of what fish and equipment will experience, during normal conditions. During Hurricane Hanna, currents reached 2.02 m/s at 4.5 m and 1.91 m/s at 20.5 m. Currents exceeded 1 m/s for 8 hours during the storm at 4.5 m and 5 hours at 20.5 m. The current at 4.5 m was on average 0.09 m/s faster than at 20.5 m over the course of the deployment. The mean current at 4.5 m was 0.25 m/s and 0.23 m/s when Hurricane Hanna is excluded. At 20.5 m, the mean current was 0.16 m/s and 0.14 m/s when excluding hurricane Hanna. Figure 3 shows a time series of current velocities at three depths over the course of the deployment and figure 4 shows directional rose plots of mean currents at those same three depths for the entire deployment period.

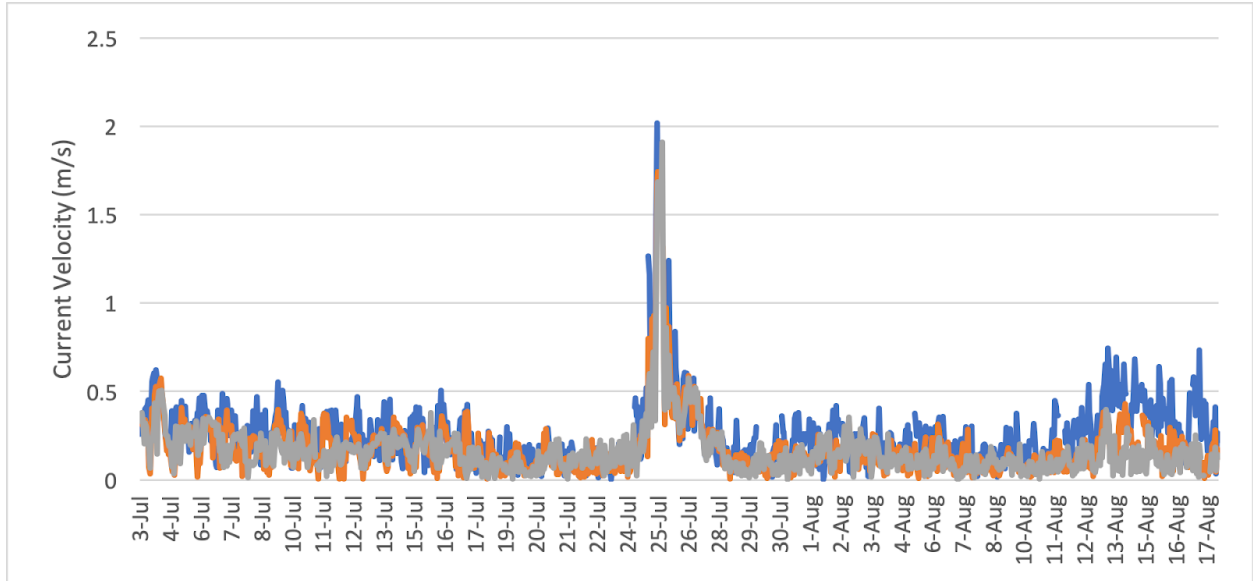


Figure 3: Current velocity at 4.5 m (blue), 12.5 m (orange) and 20.5 m (grey) over the deployment period.

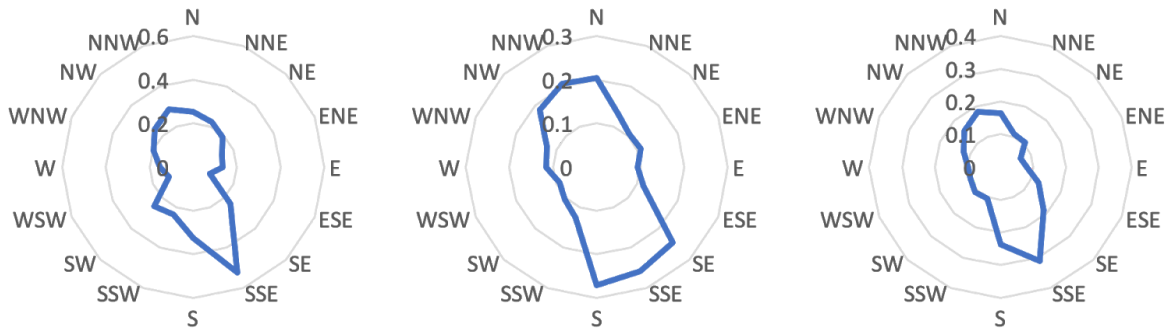


Figure 4: Current roses showing mean current at 4.5 m (left), 12.5 m (middle) and 20.5 m (right) over the entire deployment period.

The temperature at 49 m varied between 21.0 and 23.5°C during normal conditions although the temperature increased during Hurricane Hanna to a maximum of 28.7°C, presumably due to mixing of the thermal stratification. This indicates that the temperature at shallower depths is likely several degrees warmer, as is typical in areas of moderate mixing. Figure 5 shows a time series of the temperature as measured at 49 m.

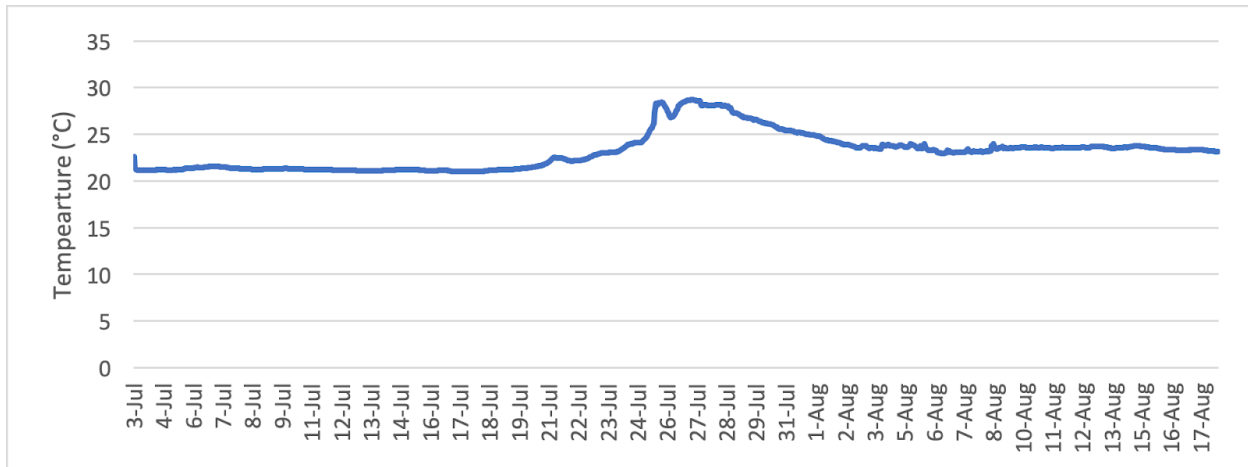


Figure 5: A time series of temperature as measured at 49 m of depth over the course of the deployment period.

Evaluation & Discussion

The oceanographic conditions are too rough for standard surface-oriented aquaculture equipment, both pens and feed systems. The constant chop of around 1 m waves will cause significant wear and tear over time that will require astute monitoring and frequent equipment retirement. Additionally, Hurricane Hanna created waves in excesses of 10 m and hurricane activity is not anomalous to this region. A farm in this location will experience storm events every year and direct hits such as this one every few years. Conditions such as these require submerged infrastructure to escape the constant energy and motion. Submerged pen systems can be safely operated in these conditions and have been for extended periods at several locations.

Additionally, the currents are stronger than encountered at most traditional aquaculture sites. Even the currents during normal conditions (~ 0.25 m/s or 0.5 knots) are about twice as strong as is typical. Most sites are protected from extreme weather events such as hurricanes. Rigorous engineering with detailed hydrostatic, quasi-static and dynamic modeling will be required for system design, however, the system would be stable and safe to operate with the right equipment. Figure 6 shows a conceptual layout of how a farm next to Station Padre may look.

Although the location is characterized as high-energy open ocean, these environments are now suitable for net pen aquaculture as appropriate submersible equipment have been developed and demonstrated over the last decade. However, a thorough design process will be necessary, especially if unique components are included such as feed lines that run from Station Padre to the pens. Also, a fish species that has the capability to swim in strong currents without an overly demanding energetic cost will be needed for success.

The environmental characterization portion of the project is considered to be a major success. Not only was data obtained despite the travel restrictions imposed by the COVID-19 pandemic, but a category 1 hurricane passed almost directly over the study site, allowing for both “standard condition” and extreme conditions to be captured.

VII. Dissemination Plan

Results will be synthesized into a final project report, articles for the press, and scientific presentations. Project results and deliverables will be disseminated through a number of avenues. These include partnering with Louisiana and Texas Sea Grant to regionally disseminate results through their extension agents and event infrastructure (e.g. LA Marine Extension Program quarterly meeting); publication on Gulf Offshore Research Institute and Innovasea System Inc.'s websites; multiple presentations at the World Aquaculture Society, Aquaculture America annual meeting; as well as featured articles in multiple aquaculture magazines.

Appendix I - Geospatial Maps and Model Criteria

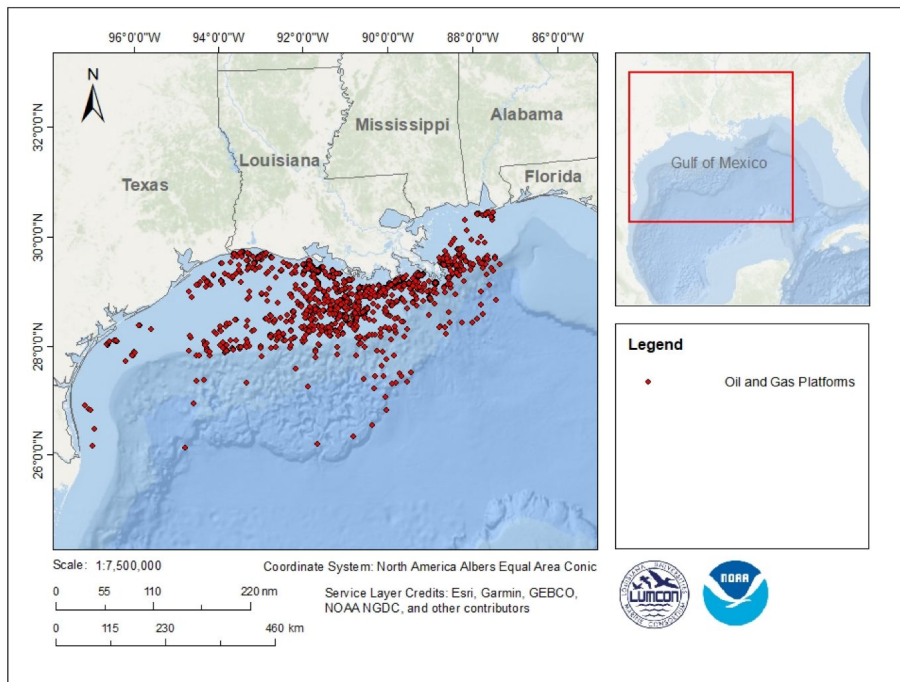


Figure A1. Map of regional oil and gas platforms across the Gulf of Mexico. Data obtained from BOEM.

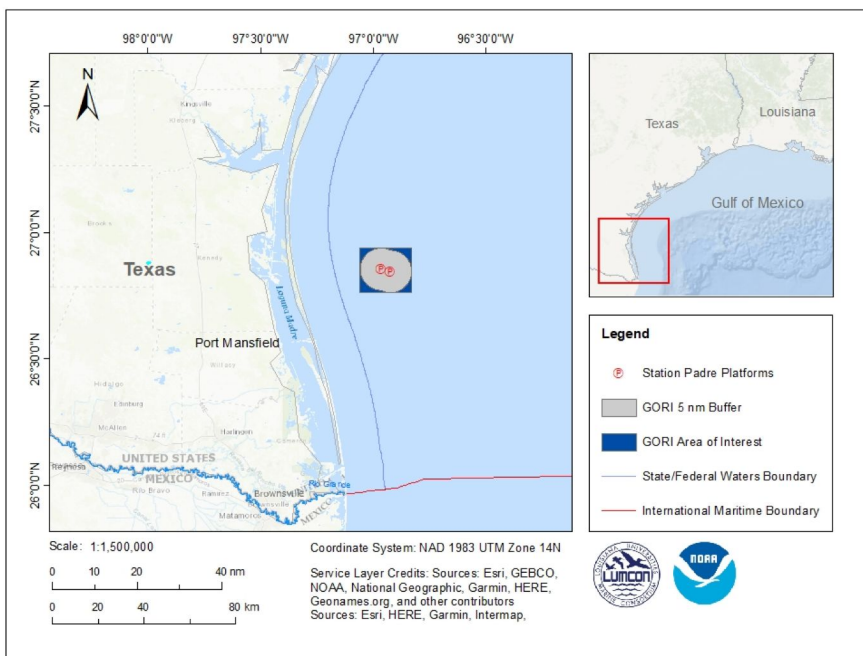


Figure A2. Map of Station Padre Area of Interest. Data obtained from NOAA.

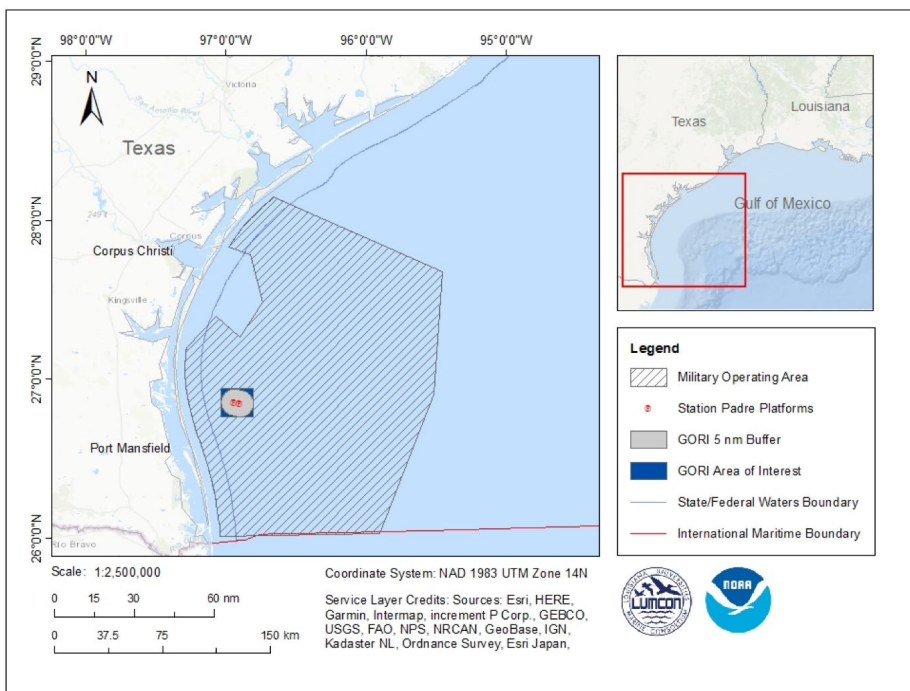


Figure A3. Map of military features near Station Padre. Data obtained from NOAA.

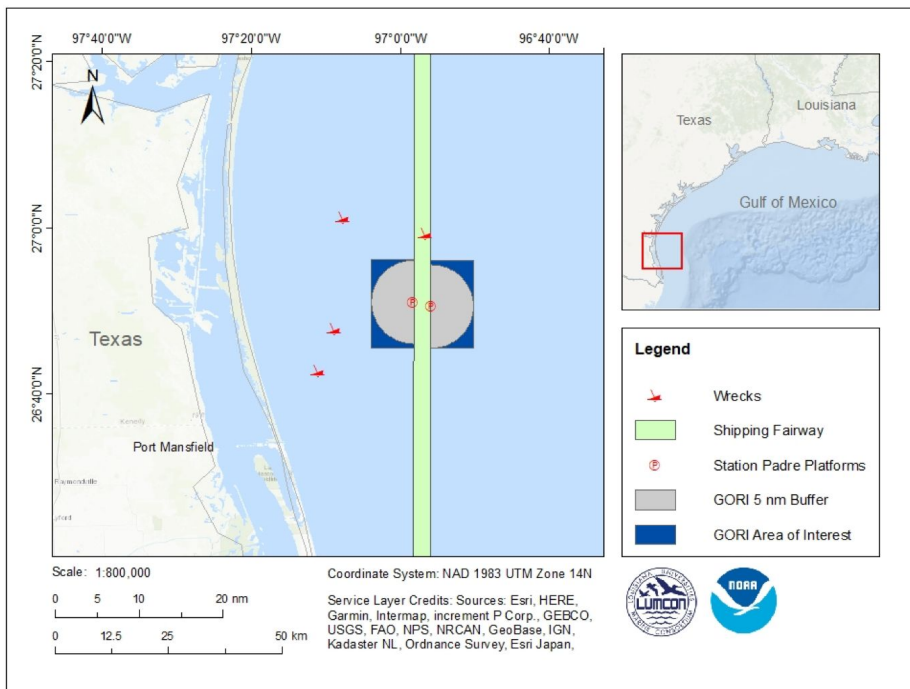


Figure A4. Map of navigational features near Station Padre. Data obtained from NOAA.

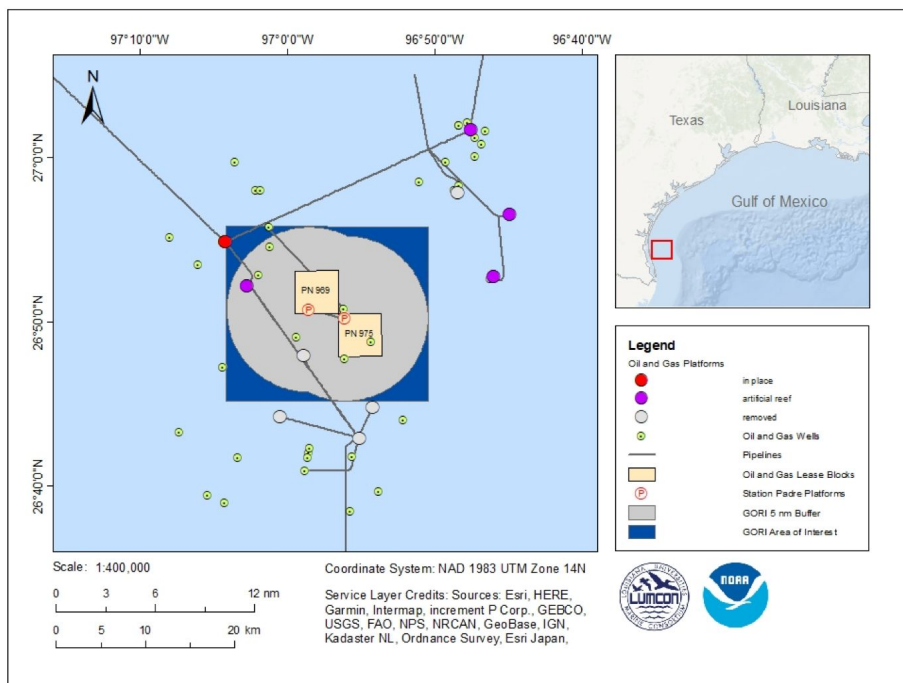


Figure A5. Map of industrial features near Station Padre. Data obtained from NOAA and BOEM.

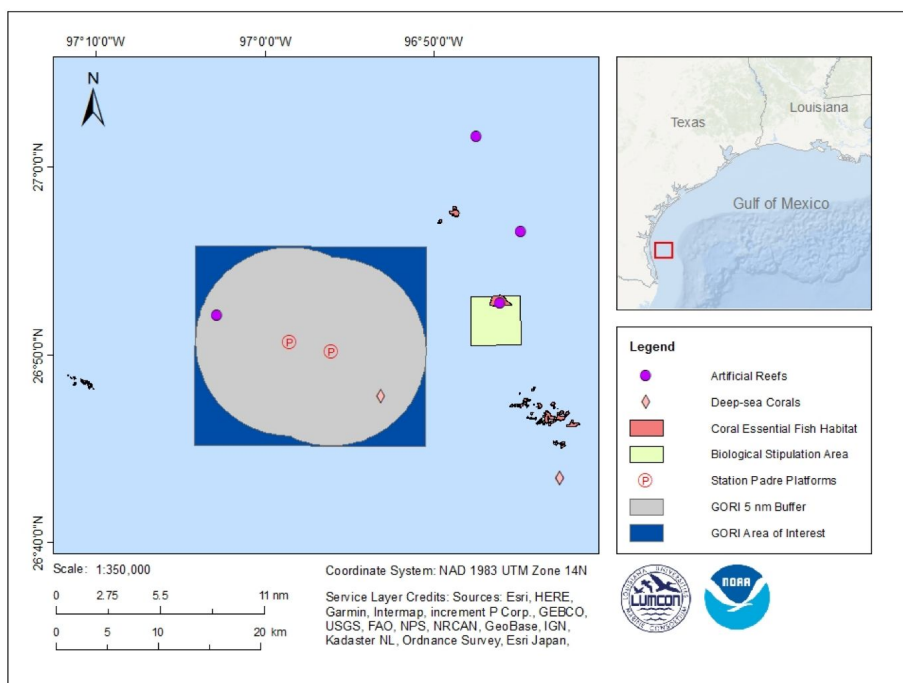


Figure A6. Map of biological features near Station Padre. Data obtained from NOAA and BOEM.

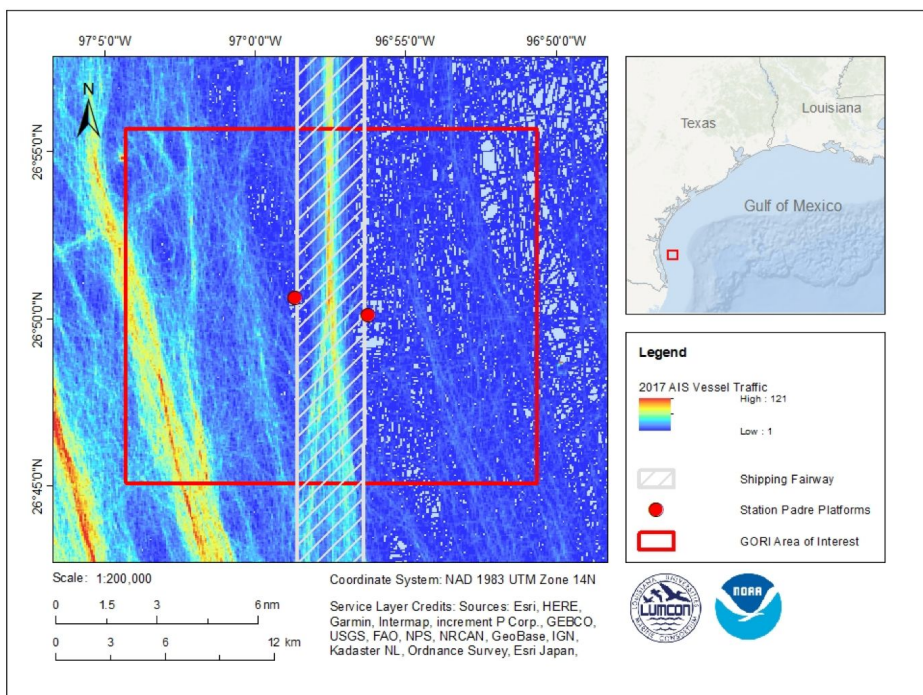


Figure A7. Map of vessel traffic activity near Station Padre. Data obtained from NOAA.

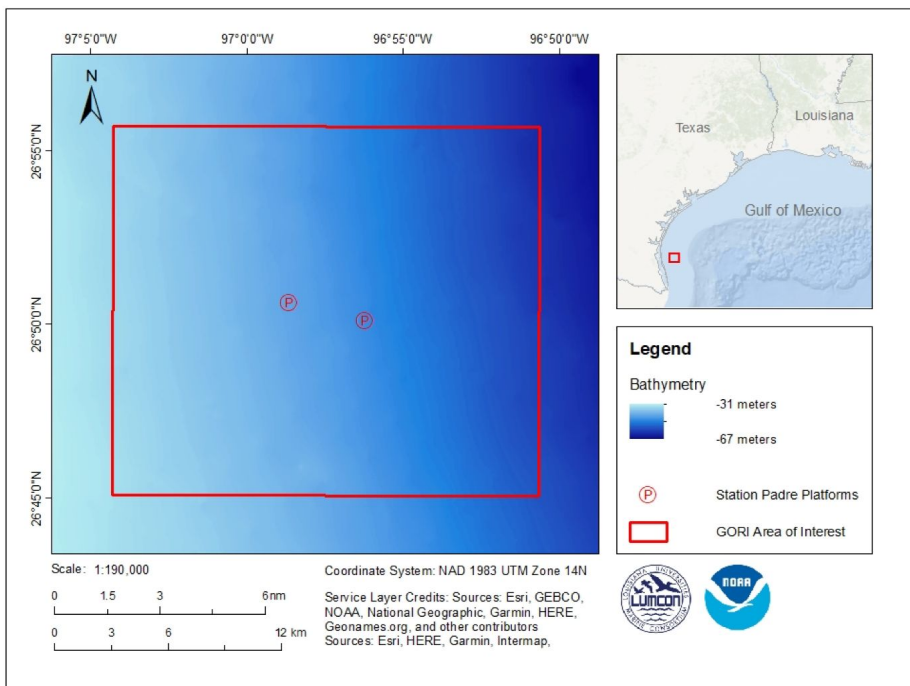


Figure A8. Map of bathymetry at Station Padre. Data obtained from NOAA.

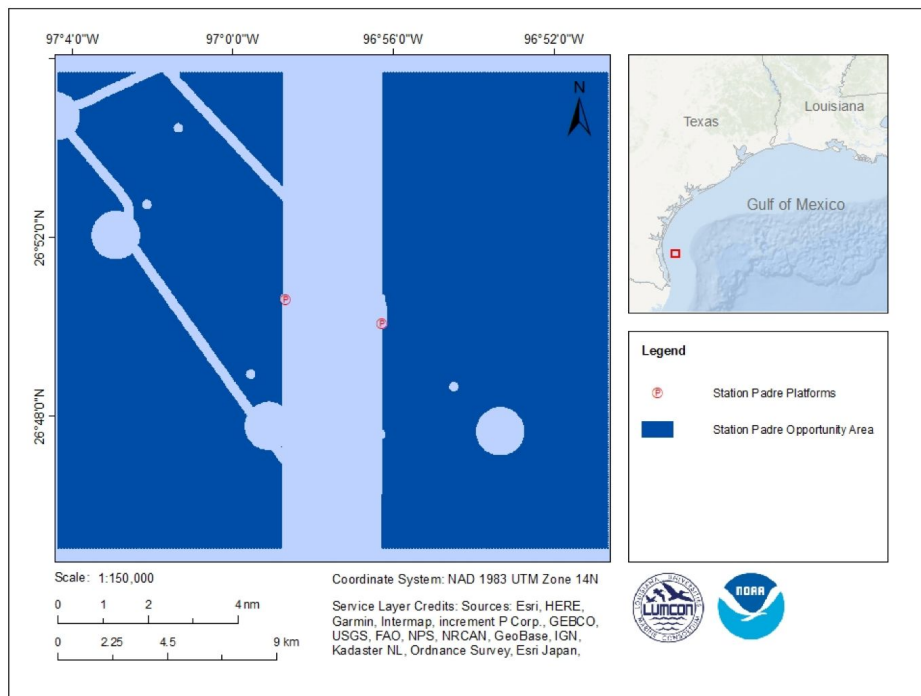


Figure A9. Map of offshore aquaculture opportunity area at Station Padre. Opportunity area represents space available for offshore aquaculture development after exclusion of areas designated for other ocean uses plus buffer zones of 200 or 1,000 m. Refer to the Table A1 for specifications.

Feature	Rule	Opportunity Assessment	Feasibility Assessment	Description
Station Padre Platforms	exclude + 200 m buffer	X	X	Industrial
Oil and Gas Platforms	exclude + 1 km buffer	X	X	Industrial
Oil and Gas Wells	exclude + 200 m buffer	X	X	Industrial
Oil and Gas Pipelines	exclude + 200 m buffer	X	X	Industrial
Shipping Fairway	exclude + 200 m buffer	X	X	Navigational
Deep-Sea Corals	exclude + 1 km buffer	X	X	Biological
Distance from Padre Platforms	prioritize surrounding 1 km		X	Proximity to Platforms for feeding logistics
Bathymetry	prioritize 50+ meter depth		X	Depth for farm operation and submergence

Table A1. Parameters included in the offshore aquaculture Opportunity and Feasibility Assessments of the Station Padre Area of Interest.

Appendix II - Datasets For Geospatial Assessment

Dataset	Date Range	Data Link	Metadata link	Located in Area of Interest	Located within 10 miles of AOI
Biological					
Artificial Reefs	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ArtificialReefs.zip	https://inport.nmfs.noaa.gov/inport/item/54191	YES	YES
Biological Stipulation Areas	2018	https://www.boem.gov/oil-gas-energy/mapping-and-data/gomr-geographic-information-system-gis-data-and-maps	https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Regional-Leasing/Gulf-of-Mexico-Region/Topographic-Features-Stipulation-Map-Package.pdf	NO	YES
Cetaceans Biological Important Areas	2015-2019	http://cetsound.noaa.gov/Assets/cetsound/data/CetMap_BIA_WGS84.zip	https://inport.nmfs.noaa.gov/inport/item/23643	NO	NO
Coral Essential Fish Habitat Gulf of Mexico	2019	https://www.fisheries.noaa.gov/resource/map/coral-essential-fish-habitat-efh-map-gis-data	https://www.fisheries.noaa.gov/resource/map/coral-essential-fish-habitat-efh-map-gis-data	NO	YES
Deep Sea Corals	1842-2017	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/DeepSeaCoralObservations.zip	https://inport.nmfs.noaa.gov/inport/item/54377	YES	YES
Harmful Algal Blooms - <i>Karenia brevis</i>	HABs (1954 - 2019) subset to use from 2000 to 2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/HarmfulAlgalBlooms.zip	https://inport.nmfs.noaa.gov/inport/item/58081	NO	NO
Hardbottom Matt Campbell				NO	YES

Industrial					
Bureau of Ocean Energy Management Active Lease Blocks	2018	https://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Alaska/AKUpdate.aspx ; https://www.data.boem.gov/Mapping/Files/actlease.zip	https://metadata.boem.gov/geospatial/GOM_Active_OG_Leases.xml ; https://metadata.boem.gov/geospatial/pac_lease.xml ; https://metadata.boem.gov/geospatial/OCS_Alaska_Current_OilGas_Leases.xml	YES	NO
Ocean Disposal Sites	2018	ftp://ftp.coast.noaa.gov/pub/MSP/OceanDisposalSites.zip	https://inport.nmfs.noaa.gov/inport/item/54193	NO	NO
Oil Platforms	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasPlatforms.zip	https://inport.nmfs.noaa.gov/inport/item/54390	YES	YES
Oil & Gas Active Leases	2020	https://www.data.boem.gov/Main/Mapping.aspx	https://www.data.boem.gov/Mapping/Files/actlease_meta.html	NO	NO
Oil Gas Wells	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasWells.zip	https://inport.nmfs.noaa.gov/inport/item/54392	YES	YES
Pipelines	2020	https://www.data.boem.gov/Main/Mapping.aspx ; https://www.data.boem.gov/Main/Pipeline.aspx#ascii	https://www.data.boem.gov/Mapping/Files/ppl_arcs_meta.html	YES	YES
Submarine Cables	2018	ftp://ftp.coast.noaa.gov/pub/MSP/SubmarineCables.zip	https://inport.nmfs.noaa.gov/inport/item/57238	NO	NO
Submarine Cable Areas	2017	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://inport.nmfs.noaa.gov/inport/item/48898	NO	NO
Military					

Military Operating Area Boundaries Gulf of Mexico	2017	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://inport.nmfs.noaa.gov/inport/item/48898	YES	YES
Unexploded Ordnance	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance.zip	https://inport.nmfs.noaa.gov/inport/item/54407	NO	NO
Unexploded Ordnance_FUDS	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance_FUDS.zip	https://inport.nmfs.noaa.gov/inport/item/54409	NO	NO
Navigational					
Aids to Navigation	2019	ftp://ftp.coast.noaa.gov/pub/MSP/AidsToNavigation.zip	https://inport.nmfs.noaa.gov/inport/item/56120	NO	NO
Electronic Navigational Chart Wrecks	2019	https://nauticalcharts.noaa.gov/data/gis-data-and-services.html	https://nauticalcharts.noaa.gov/data/gis-data-and-services.html	NO	YES
Lightering Zones	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/LightingZones.zip	https://inport.nmfs.noaa.gov/inport/item/54387	NO	NO
Pilot Boarding Stations	2018	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PilotBoarding.zip	https://inport.nmfs.noaa.gov/inport/item/54394	NO	NO
Shipping Fairways	2018	http://encdirect.noaa.gov/theme_layers/data/shipping_lanes/Shippinglanes.zip	https://inport.nmfs.noaa.gov/inport/item/39986	YES	YES