Drivers of Variation in the Distributions of Fishes Associated with Petroleum Platforms in the Northwestern Gulf of Mexico as Derived from Submersible-rotating Video Surveys

Causas de Variación en las Distribuciones de Peces Asociadas con Plataformas Petroleras en el Noroeste del Golfo de México Derivadas de Encuestas por Video con Rotación Sumergible

Causes de la Variation de la Répartition des Poissons Associés aux Plates-formes Pétrolières dans le Nord-ouest du Golfe du Mexique, à Partir d'Enquêtes Vidéo à rotation Submersible

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EXTENDED ABSTRACT

Introduction

The heterogeneity in conditions that platform-associated fishes are exposed to over the range at which platforms occur, and their importance to valuable fisheries, have led to considerable effort to study fish assemblages on petroleum platforms in the Gulf of Mexico (GOM) over the past decades. For example, Gallaway and Lewbell (1982) defined three depth-based faunal assemblage zones for platforms in the U.S. Gulf of Mexico (GOM): the 'coastal' (shoreline – 30 m), 'offshore' (30 – 60 m), and 'bluewater' (> 60 m) zones. Additionally, fish assemblages on petroleum platforms are influenced by the distribution of turbid water layers, temperature, salinity, dissolve oxygen (DO) concentration, primary productivity in the water column, and the extent to which platforms are exposed to Caribbean water masses (Gallaway and Lewbel 1982, Stanley and Wilson 1996, 1997, 2000, 2003, Munnelly et al. 2019). The vertical distribution of fishes on platforms is also variable and is influenced by DO concentration (Stanley and Wilson 2004, Reeves et al. 2018, Munnelly et al. 2019) and artificial light (Barker et al. 2018). We set out to build upon the existing literature by studying the drivers of species-specific horizontal and vertical distribution patterns around platforms at a larger spatial scale. The objective of this study was to identify the environmental and structural parameters having an influence on the horizontal and vertical distributions of conspicuous fishes associated with offshore petroleum platforms across the range at which they occur.

Methods

We surveyed 54 petroleum platforms in the GOM over a period of two years (May – August of 2017 and 2018). Submersible-rotating video (SRV) camera and YSI EXO sondes were deployed at these platforms to simultaneously observe fishes and record environmental parameters. Of the 54 study platforms, three were surveyed four times (twice in each year), 50 were surveyed twice (in a single year), and two were surveyed once.

The environmental parameters recorded by the sonde were DO concentration (mg/L), temperature (°C), and salinity (psu). These parameters were averaged across the entire water column to characterize each survey event in a first dataset later used to understand fish horizontal distribution patterns (referred to as the 'horizontal distribution dataset'). In the second dataset later employed to understand fish vertical distribution patterns (referred to as the 'vertical distribution dataset'), DO concentration, temperature and salinity were averaged across 10-meter depth layers. Seafloor depth (m), as well as platform characteristics, were recorded in the field or determined in QGIS using data from the Bureau of Ocean and Energy Management (BOEM 2019). Platform characteristics included: seafloor depth (m); age (years); number of other platforms within 1, 2, 3, and 5 km; length of pipeline within 1, 2, 3, and 5 km; distance from shore (km); and number of legs. The encounter or non-encounter of fish species was recorded from camera data at each 10-meter depth layer. Encounter/non-encounter data were chosen instead of abundance data to minimize the impact of differing levels of visibility across survey events. For horizontal distribution analysis, these data were further reduced to encounter/non-encounter at each survey event.

To understand the horizontal and vertical distribution patterns of fishes around petroleum platforms, we fitted two sets of binomial generalized additive mixed models (GAMMs), which integrated the environmental and structural parameters as smoothed predictors, and a tensor term to account for spatial autocorrelation at a broad scale. Horizontal distribution GAMMs also included random effects for site, survey team, and visibility (scored 1 – 3). Vertical distribution GAMMs included the same random effects but with "depth bin within platforms" included as a random effect instead of site. The GAMM fitting procedure was followed by a 'Leave Group Out Cross Validation' procedure (Hastie et al. 2001).

Results and Discussion

Fishes that thrive in dynamic GOM ecosystems are likely to be tolerant to a wide range of environmental conditions, and given the relative scarcity of high-relief reef habitat in many areas, these species may have evolved to tolerate a range of conditions to remain platform associated. Overall, our results reflect this assumption, as the distribution of the majority of study species was not influenced by parameters included in models at the spatial and temporal scales that we sampled them (Table 1). Indeed, multiple studies have suggested strong association with nearshore platforms despite variation in environmental conditions (Reeves et al. 2018, Munnelly et al. 2019). However, environmental and structural parameters were influential in shaping the distributions of some species. Salinity was found to influence the horizontal distributions of Bermuda Chub (*Kyphosus sectatrix)* and Red Snapper (*Lutjanus campechanus*), and the vertical distributions of Atlantic Spadefish (*Chaetodipterus faber*), Bermuda Chub, Greater Amberjack (*Seriola dumerili*), Red Snapper, and Vermilion Snapper (*Rhomboplites aurorubens*) (Table 1). Dissolved oxygen concentration influenced the vertical distributions of Red Snapper and Greater Amberjack, as well as the horizontal distribution of Red Snapper (Table 1). For platform characteristics, distance from shore influenced the horizontal distributions of Bermuda Chub, Greater Amberjack, and Vermilion Snapper, and the number of platforms within five kilometers of the study platform influenced the horizontal distributions of Blue Runner (*Carynx crysus*) and Crevalle Jack (*Carynx hippos*).

Climate change is expected to affect the GOM through altered Mississippi River discharge, increased size and duration of hypoxic areas, and rising temperatures (Justić et al. 1996). The availability of high relief habitat in the GOM is changing as well, with petroleum platforms being removed at a far greater rate than they are being constructed in recent years (BOEM 2019). Our results suggest that changes in environmental conditions within the ranges that we studied are likely to affect the distributions of several platform associated species, but since environmental gradients and specific platform characteristics were not influential for the majority of study species (table 1), it is likely that the simple availability of platforms in different areas will have the greatest effect on the distribution of our focal species in the future.

KEYWORDS: Fish distribution; reef-associated fishes; petroleum platforms; Gulf of Mexico; generalized additive mixed models

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Table 1. Significant predictors for each species in horizontal and vertical distribution generalized additive mixed models.

Species	Significant Predictors for Horizontal Distribution	Significant Predictors for Vertical Distribution
Almaco Jack (*Seriola rivoliana*)	None	None
Atlantic Bumper (*Chloroscombrus chrysurus*)	None	None
Atlantic Spadefish (*Chaetodipterus faber*)	None	Salinity
Bermuda Chub (*Kyphosus sectatrix*)	Distance from Shore, Salinity	Salinity
Blue Runner (*Carynx crysus*)	Number of Platforms within 5 km	None
Cobia (*Rachycentron canadum*)	None	None
Crevalle Jack (*Carynx hippos*)	Number of Platforms within 5 km	None
Gray Snapper (*Lutjanus griseus*)	None	None
Gray Triggerfish (*Balistes capriscus*)	None	None
Greater Amberjack (*Seriola dumerili*)	Distance from Shore	Salinity, Dissolved Oxygen
Great Barracuda (*Sphyraena barracuda*)	None	None
Horse-Eye Jack (*Caranx latus*)	None	None
King Mackerel (*Scomberomorus cavalla*)	None	None
Lookdown (*Selene vomer*)	None	None
Rainbow Runner (*Elagatis bipinnulata*)	None	None
Red Snapper (*Lutjanus campechanus*)	Dissolved Oxygen, Salinity	Salinity, Seafloor Depth, Dissolved Oxygen
Vermilion Snapper (*Rhomboplites aurorubens*)	Distance from Shore	Salinity

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