Spatio-temporal Variation in Fish Density and Distribution Within a Gulf of Mexico Shipping Channel

Variación Espacio-temporal en la Densidad y Distribución de Peces en un Canal de Envío en el Golfo de México

Variation Spatio-temporelle de la Densité et de la Répartition des Poissons dans un Chenal d'Expédition du Golfe du Mexique

DEREK BOLSER*, JACK EGERTON, and BRAD ERISMAN
The University of Texas — Marine Science Institute
750 Channel View Drive, Port Aransas, Texas 78373 USA.
*derekbolser@utexas.edu

ABSTRACT

Man-made channels are ubiquitous throughout the Gulf coast of the United States. In the north-western Gulf of Mexico (GOM), they can represent the only local connection between bays and the coastal ocean for tens of kilometers. As such, many fishes move in and out of these channels depending on life history stage, resource availability, and environmental conditions. Further, these channels have been identified as important multi-species spawning aggregation sites. Here, we report early results from a long-term hydroacoustic monitoring study of fishes in the Aransas Channel in Port Aransas, Texas. Starting in January 2018, we conducted bi-weekly surveys of the channel with a Simrad EK80 echosounder in order to describe fish density and spatial distribution. We also collected environmental data (e.g. temperature, salinity, dissolved oxygen) in the channel and nearby bays. To assess relationships between environmental data and fish density, we fit linear and quadratic models to our data. Environmental data were not significantly associated with fish density in any linear models, but temperature was significantly associated with fish density in a quadratic model. This quadratic relationship was driven by exceptionally high fish density during a 'cold snap', and the presence of massive, densely packed fish school on a warm survey day. Fish density within the channel was higher at the deeper, Gulf-ward edge of the channel on colder survey days, while fishes were more uniformly distributed on warmer survey days. Upon completion of this study, we hope to better understand the importance of channel habitat, and identify specific times and environmental conditions in which fishes are most likely to be densely packed in the channel.

KEYWORDS: Fish distribution, hydroacoustics, shipping channel, Gulf of Mexico, environmental drivers

INTRODUCTION

In the north-western GOM, ship channels can be the only connection between the coastal ocean and bays and estuaries for tens of kilometers. As such, they are vital to movement between these areas for marine life. Channel and bay mouths have also been identified as crucial habitat for multi-species fish spawning aggregations (FSAs) (Grüss et al. 2018). These areas are ideal intersections of the migration triangle for many species, as the jetties that often line them provide high-relief, hard substrate for fishes to form FSAs around, and high flow rates disperse eggs and larvae in to inshore nursery habitats. With Red Drum (*Scianops ocellatus*), for example, adults spawn at the mouths of channels and estuaries (Holt 2008, Lowerre-Barbieri et al. 2011), eggs and larvae get dispersed within the estuary, where they mature in to juveniles (Holt et al. 1983, Rooker et al. 1998), and then move offshore, often through channels, to their adult habitat. In addition to fish eggs and larvae, other types of organic matter and nutrients are circulated within and through these areas, making them productivity hotspots that affect the ecology of some regions (Santora et al. 2017).

The coastal waters of the northwestern GOM experience considerable seasonal variation in environmental conditions (i.e. 6 – 30 degrees C in temperature from January—October 2018 in Port Aransas), with conditions in shallower estuarine waters being even more variable. This region is prone to extreme episodic events (i.e. cold fronts, hurricanes) that rapidly change water conditions. Both rapid and gradual changes (i.e. drought cycles) in environmental conditions are known prompt distribution shifts in estuarine fishes (Dance and Rooker 2015, Callihan et al. 2015, Ajemian 2018), which have consequences that stretch across the larger trophic web (Fuiman 2018). Environmental conditions are inherently more stable in deeper waters, and due to their relatively deep depth when compared to surrounding waters, it is possible that ship channels could act as refuge habitat for fishes as they attempt to avoid rapid changes, in addition to their role as a conduit for fish movement between habitats and spawning sites. The sometimes conflicting functions of safe navigation areas for large vessels, passageways and habitat for marine life, and popular fishing locations make ship channels important for study, yet there has been little effort to understand how fish populations and communities use these areas. There is a growing need for studies that integrate multi-species approaches to more effectively identify habitats that are essential for ecosystem function, given the increasing adoption of ecosystem-based fisheries management (Hussey et al. 2015). Further, as next-generation spatial models are incorporated as the basis for fishery management advice, there is a need for studies with high spatial resolution that address connectivity dynamics (Berger et al. 2017). Thus, the objectives of this study were:

i) to describe variation in average fish density across the Aransas Channel,
ii) to examine how environmental conditions may play a role in explaining this variation, and
iii) to describe spatial variation in fish density in the Aransas Channel.

METHODS

Twenty hydroacoustic and YSI EXO sonde surveys were conducted in the Aransas channel from January – July 2018 in conjunction with sonde sampling of nearby bays by the Mission Aransas National Estuarine Research Reserve's System-Wide Monitoring Program. A Simrad EK80 echosounder with a 120kHz split-beam transducer (circular beam width of 6.8º; pulse duration of 0.128 ms; ping rate set at maximum) was used for hydroacoustic surveys. The transducer was mounted on the side of the survey vessel on a pole with the transducer angled vertically at 1 m depth in order to sample fishes in the water column. The echosounder was calibrated according to the standard method of Foote (Foote 1987) using a tungsten carbide sphere for 120 kHz echosounder calibration. Hydroacoustic data was geo-referenced with a Garmin GPS, and data was recorded on a laptop computer. Hydroacoustic data was processed with Echoview software. Fish density was derived through echo integration (Winfield et al. 2012). Thresholds of – 61 dB and -55 dB were for the volume backscattering coefficient (sv) and target strength (TS), respectively, in order to exclude plankton and other small scattering objects/organisms from this analysis. The Nv (number of fish per volume) and M (number of fish per analysis cell) indices was used to correct for the detection of multiple echoes that would bias *in situ* TS estimation (Sawada et al. 1993, Yule et al. 2013). In areas where *in situ* TS could not be derived, TS from adjacent analysis cells was smoothed in to facilitate calculation of fish density.

Correlation analysis and graphical examination of data were used to identify factors suitable for inclusion in models, and along with mechanistic physiological justification of monotonic and bitonic relationships, the limited degrees of freedom available led to the selection of single-predictor simple linear and quadratic models to describe the relationship between environmental factors and fish density. Fish density data were log +1 transformed to meet the assumptions necessary for these analyses. Environmental factors considered in models included temperature, salinity, dissolved oxygen, turbidity, pH, and chlorophyll a. These analyses were conducted in R, and spatial data were analyzed in QGIS software.

RESULTS

Due to high correlations between environmental data from nearby bays and data from the Aransas Channel, further analyses and interpretation were focused relationships between fish density and channel conditions. No predictors in linear models significantly explained variation in fish density. One predictor significantly explained variation in fish density in quadratic models: temperature in the Aransas Channel (p = 0.026).

Two notable outliers are seen when the relationship between temperature and fish density was assessed (Figure 1). One (far left outlier) represents the survey conducted on January 17th, 2018 (Figure 1). This survey was conducted in the midst of a severe 'cold snap'; temperature in the Aransas Ship Channel was 7.92°C, while temperatures in the nearby Mesquite and Copano Bays were 6.6° C. There were days where the difference in temperature between the bays and channel were greater, but no survey was conducted in colder conditions. The other (corresponding to the far right outlying point; Figure 1) was conducted on June 7th, 2018, and there were no obvious environmental disturbances in the days preceding this survey. However, further inspection of the echogram revealed that this anomalously high average fish density was due to the presence of one exceptionally large and dense school. Clearly, this quadratic relationship is driven by the two outlying points.

Fish density was low in the bay-ward side of the channel and high closer to the mouth on cold survey days (< 16°C) (Figure 2). Fish density was low overall on survey days in the moderate temperature range (16 - 24°C), aside from one hotspot associated with a known deep hole (Figure 2.). This contrasts with warm survey days (> 24° C), where fish density was high across the channel, with hotspots distributed throughout (Figure 2).

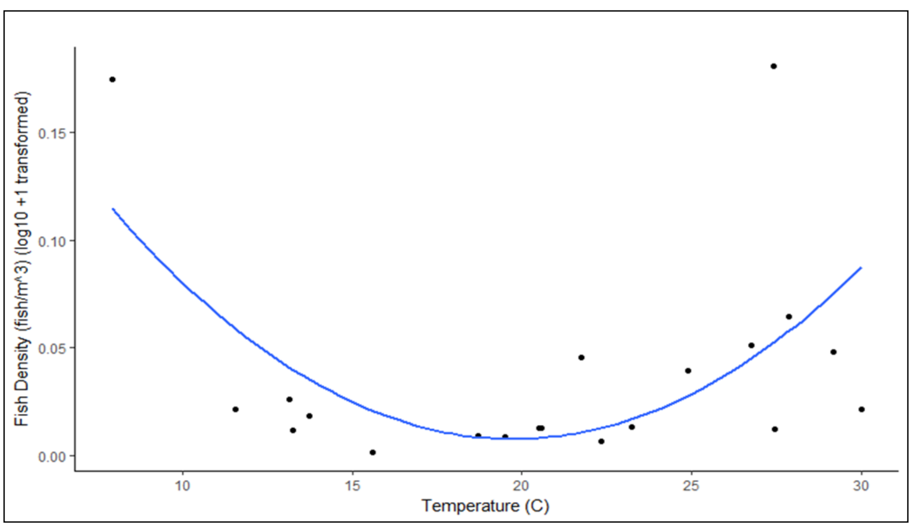

Figure 1. Fit of a simple quadratic model to temperature and fish density data from January – July 2018 in the Aransas ship Channel.

From January – July 2018, fish density has been highest on average at the ocean-ward end of the channel, with hotspots of fish density observed in the middle of the channel (Figure 2). These hotspots loosely correspond to an area of water mixing that was consistently observed during sampling.

DISCUSSION

Our results suggest that fish density in the Aransas channel is influenced by episodic temperature events, and support anecdotal accounts from fishers and biologists in the region that fish abundance greatly increases in local ship channels when cold fronts impact the region (Brad Erisman, The University of Texas at Austin, *Personal Communication*). A quadratic relationship between temperature and fish density was expected given that fishes are expected to respond to both high and low extremes, although the relationship shown in this study was clearly driven by two outlying points (Figure 1). Temperature is known to affect the distribution of estuarine and coastal species in the GOM (e.g. Dance and Rooker 2015) and may set the stage for large-scale fish distribution (Pörtner 2001, Perry 2005, but see Jutfelt et al. 2018 and references therein). Though temperatures of the bays of the region and the Aransas Channel were highly correlated, small differences, such as the one observed on the coldest survey day (6.6°C in the bays vs. 7.9°C in the channel), could be important for explaining distribution shifts of fishes on the edge of their thermal tolerance. These data and accounts may support the potential use of the Aransas channel as a refuge habitat, as well as an area of movement between the bay systems and coastal ocean, but more data is needed to define the roles that the channel plays for fishes with a high degree of confidence.

Though not represented by these data, further study may reveal that gradual changes in environmental conditions also influence fish density. For example, in a hydroacoustic study of Barataria Bay, Louisiana, Boswell et al. (2010) found fish biomass to be highest in the fall, next highest in the spring, and lower in the winter and summer. Further study of the Aransas channel may reveal a similar pattern, particularly due to the formation of a Red Drum spawning aggregation at the end of the jetties lining the channel in the fall months (Holt 2008), and a Sheepshead (*Archosargus probatocephalus*) spawning aggrega-

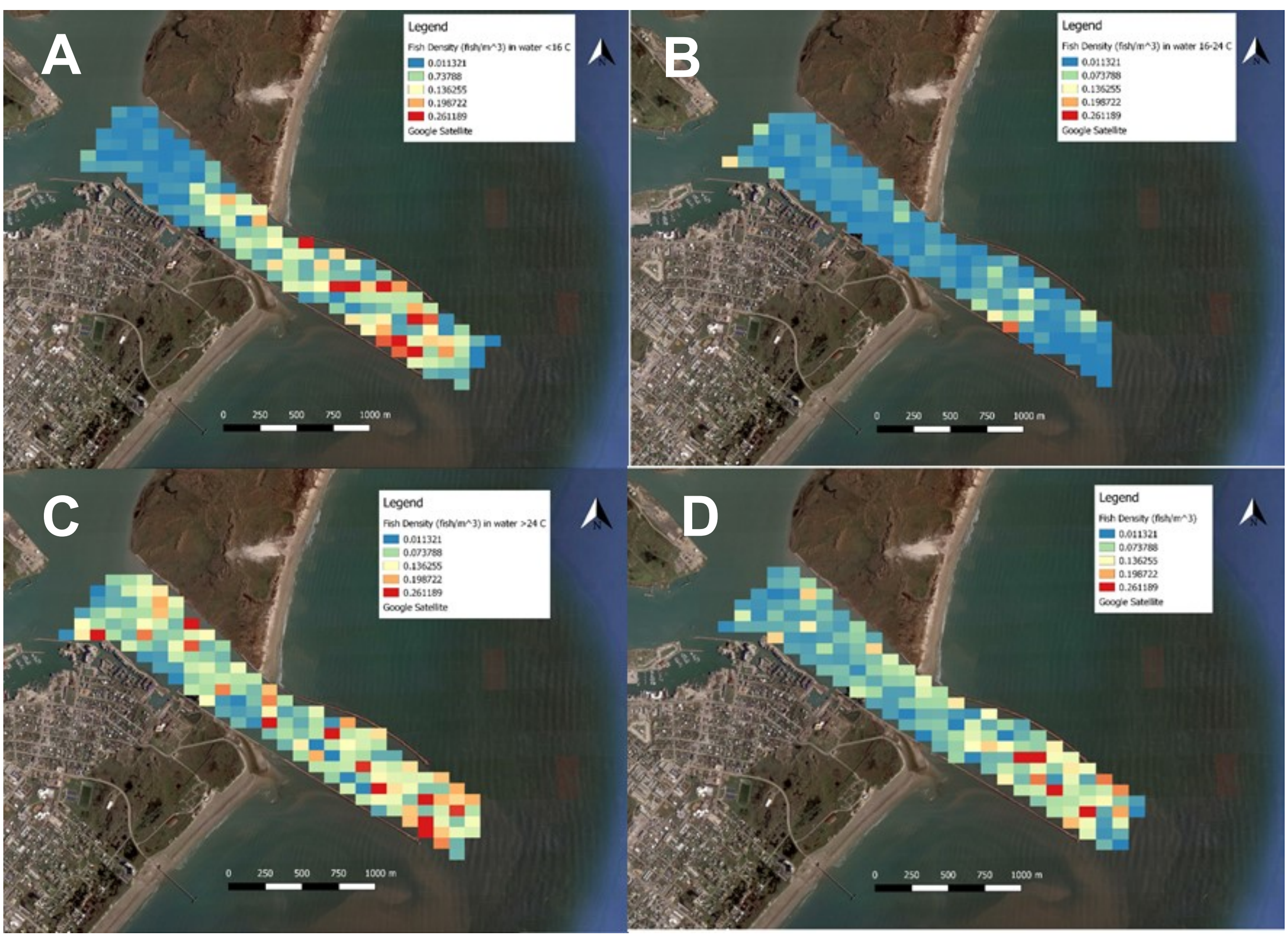

Figure 2. Fish density in cold (<16° C; panel A.), moderate (16-24° C; panel B.), and warm (<24 C°; panel C) temperatures, and the average spatial distribution of fish density in the Aransas Channel (panel D).

tion in the spring months (B.E.E., *Unpublished data*). Even if fishes are closely associated with the rocky jetty structure and not completely enumerated by hydroacoustics, the productivity associated with fish aggregations (Layman et al. 2013, Fuiman et al. 2015) may be expected to support an increase in overall fish density in the area.

Spatial distribution may be related to gradual changes in temperature, but more surveys are necessary to confirm this trend. The influence of episodic events on spatial distribution was not examined, and will be an avenue for future study. There were no clear gradients in environmental conditions from one end of the channel to the other, so partitioning of fish abundance as observed in Figure 2A. could be explained by factors that have not been included in preliminary analyses, such as bathymetry or water mixing and circulation.

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