Characterizing the Potential Habitat of Ichthyoplankton in the Gulf of Mexico for Species with Contrasting Life Histories

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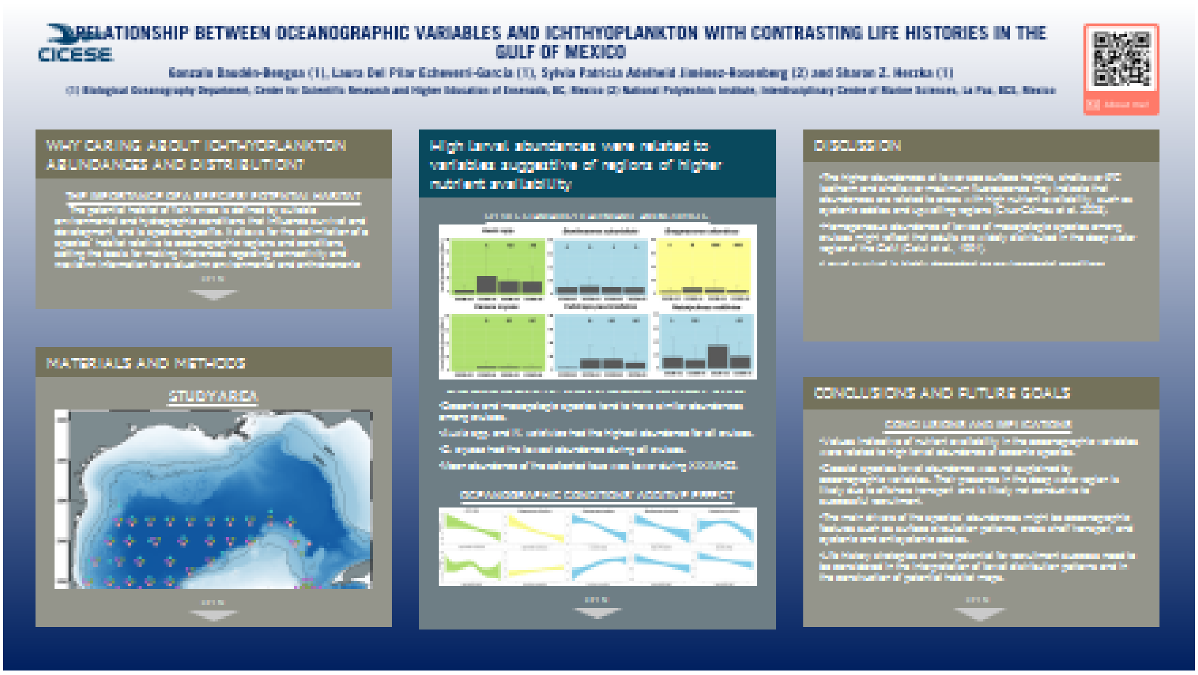
Abstract

Potential habitat models have become an increasingly used method for characterizing fish larval habitat. Describing the potential habitat of fish larvae can yield insight into distribution patterns over temporal and spatial scales that cannot be easily characterized w discrete ichthyoplankton surveys, as well as setting a reference against which to assess the impact of anthropogenic and natural disturbances. Potential habitats are defined based on larval distribution and the environmental conditions that are suitable for development and survival. In the central Gulf of México (GoM), mesoscale circulation is dominated by the Loop Current (LC), LC-derived anticyclonic eddies that are transported westward and cyclonic eddies; these features influence productivity and water column characteristics and hence larval habitat. A semi-permanent cyclonic eddy in the Bay of Campeche (southern GoM) and other processes such as regional upwelling and offshore transport can also influence larval potential habitat. Between 2011-2017 nine oceanographic cruises covering the Mexican EEZ were conducted and fish larvae were collected using a bongo net sampler. Five taxa with different life history strategies, abundance and distribution patterns, spawning seasonality, and of varying economic importance were selected for the characterization of their potential habitat (Auxis spp., Benthosema suborbitale, Bregmaceros atlanticus, Caranx crysos and Cubiceps pauciradiatus). Their potential habitat will be characterized using generalized additive models correlating larval distribution with environmental parameters derived from in situ CTD and satellite-based measurements. The results of this study will yield insight into the potential larval habitat of representative fish species throughout the central and southern Gulf of Mexico.

RELATIONSHIP BETWEEN OCEANOGRAPHIC VARIABLES AND ICHTHYOPLANKTON WITH CONTRASTING LIFE HISTORIES IN THE GULF OF MEXICO



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WHY CARING ABOU A UNDANCES AND DISTRIBUTION?

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THE IMP CI L HABITAT

The potential habitat of fish larvae is defined by suitable environmental and hydrographic conditions that influence survival and development, and is spec graphic regions and conditions, setting the ba evaluating environmental and anthropogenic impa

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In order to define a sp oceanographic variables and abundance. Howeve a high abundance of larvae in areasthat do not favor nterpretation of the relationships between oc

HYPOTHESIS

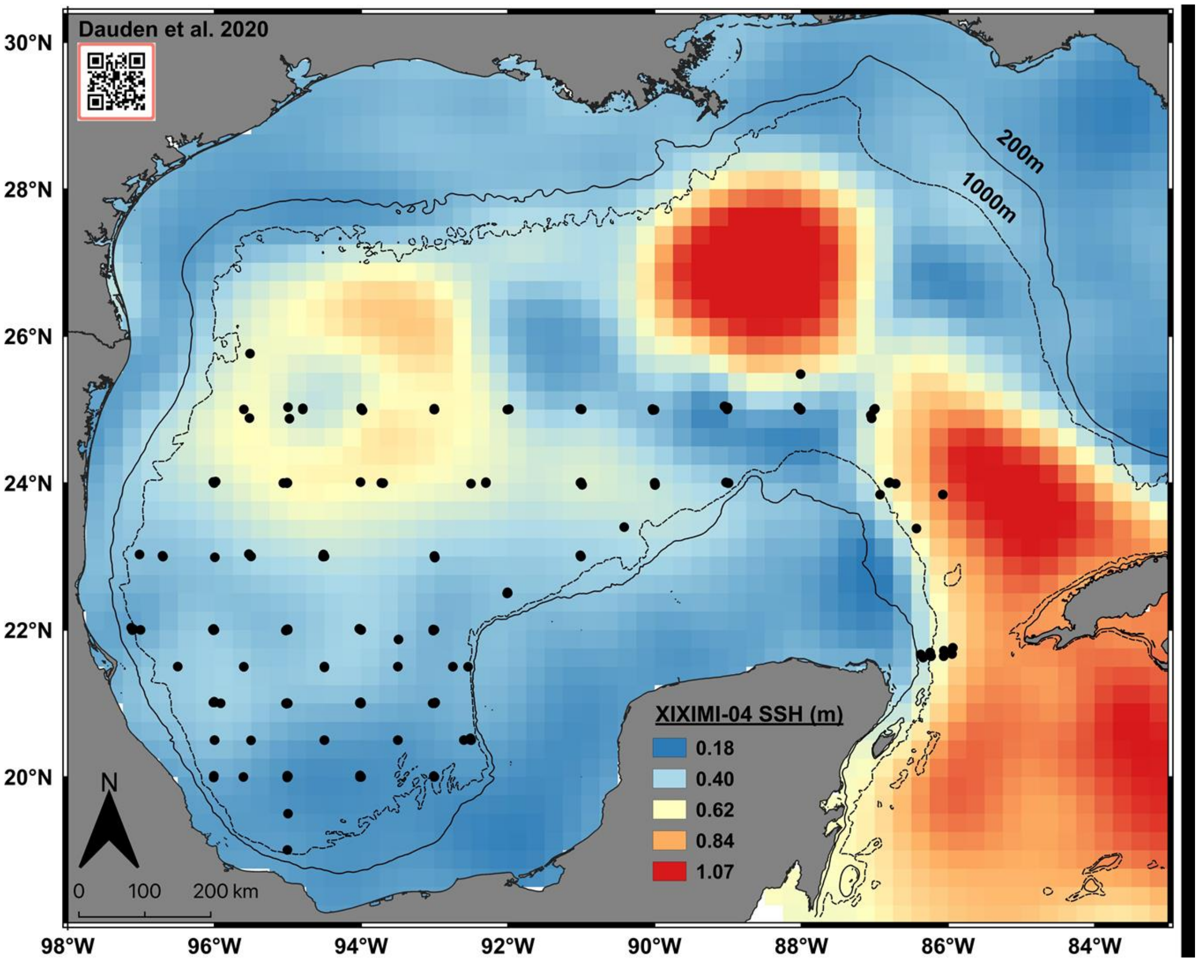
The abundance of species with contrasting life history strategies should vary relative to oceanographic conditions. We predict that larval abundances of oceanic species' will be correlated with lower sea surface heights and a shallower 6ºC isotherm, indicative of cyclonic circulation conducive to higher nutrient availability and productivity. In contrast, the larvae of species with neritic habitat during the adult stage that are transported to oceanic regions will show lower correlations with oceanographic variables

CONTRASTING LIFE HISTORIES OF SELECT ICHTHYOPLANKTON TAXA COLLECTED IN THE DEEP WATER REGION OF THE GoM

Species	Adult (Max. Size SL)	Habitat	Depth (m)	Spawning season	Importance
Caranx crysos (Carangidae)	 70cm	Coastal Epipelagic	0 - 100	Apr. - May Aug. - Sep.	Commercial and sport fishing
Auxis spp. (*rochei* & *thazard*) (Scombridae)	 67cm	Neritic Epipelagic	0 - 200	Yearly Peak: Jan. - Apr.	Food chain link Commercial and sport fishing
Bregmaceros atlanticus (Bregmacerotidae)	 7cm	Neritic Oceanic Mesopelagic	50 - 2000	Yearly	Biogeographic indicator
Cubiceps pauciradiatus (Nomeidae)	 20cm	Oceanic Epi. - Mesopelagic	50 - 820	Apr. - Jun.	Prey of commercially important species
Benthosema suborbitae (Myctophidae)	 4cm	Oceanic Epi. - Mesopelagic	50 - 750	Yearly Peak: Apr. - May	Industrial food production Biogeographic indicator
Notolychnus valdiviae (Myctophidae)	 6cm	Oceanic Epi. - Mesopelagic	25 - 800	Yearly Peak: Apr. - May	Industrial food production Biogeographic indicator

Selected species with contrasting life histories.

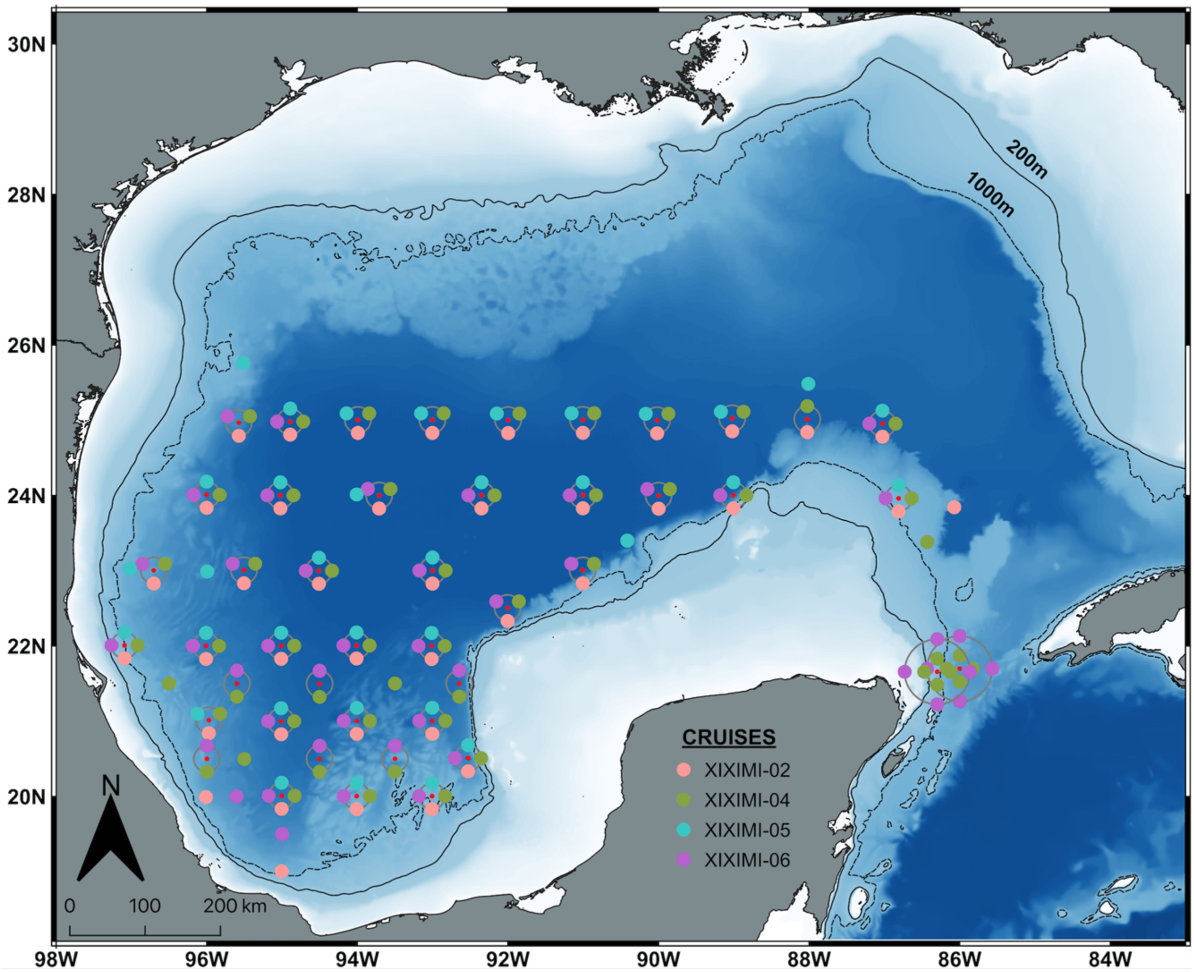
THE GULF OF MEXICO'S DEEP WATER REGION



The circulation patterns and productivity of the deep water of the southern Gulf of Mexico (south of 25ºN) are dominated by mesoscale oceanographic features, of which the Loop Current, anticyclonic LC eddies and a cyclonic eddy in the Bay of Campeche are predominant.

MATERIALS AND METHODS

STUDY AREA



All stations were located in the deep water region (depths > 1000 m) of the GoM's Mexican EEZ as well as in the Yucatan Channel (18ºN–25ºN, 82ºW–95ºW). Colors indicate stations covered during each cruise. Samples were collected with oblique tows from the surface to a depth of 200 m using a bongo net sampler (60 cm diameter, 335 µm mesh size).

OCEANOGRAPHIC CONDITIONS

Hydrographic parameters and oceanographic conditions were obtained by coupling in situ measurements with remote sensing data. Depth of 6ºC isotherm was used as an indicator of mesoscale features (Hamilton et al. 2016).

FISH LARVAE

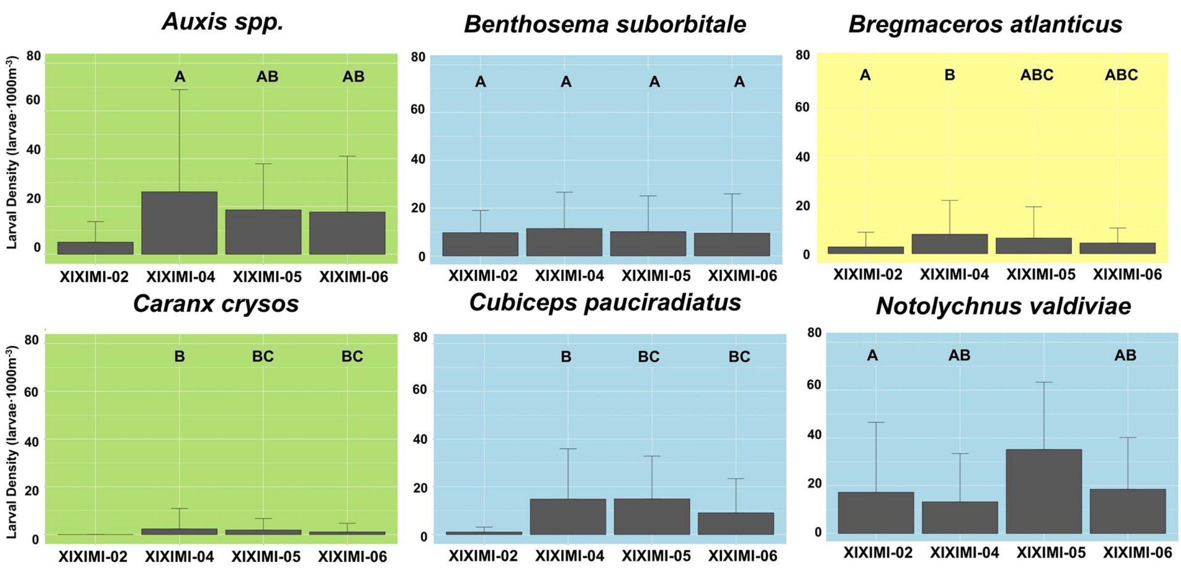
Fish larvae were sorted according to meristic and taxonomic characteristics based on identification guides for the Gulf of Mexico (Richards, 2006). *Auxis* species *(rochei* and *thazard*) were grouped due to the impossibility of identification during the early stages of development.

STATISTICAL ANALYSES

Generalized Additive Models and Mixed models (R studio) were used to define the oceanographic conditions related to larval abundance.

HIGH LARVAL ABUNDANCES WERE RELATED TO VARIABLES SUGGESTIVE OF REGIONS OF HIGHER NUTRIENT AVAILABILITY

SPECIES STANDARDIZED ABUNDANCE AMONG CRUISES



Post-hoc comparison using Bonferroni t-test. Matching letters show non-significant mean differences at the 0.05 level.

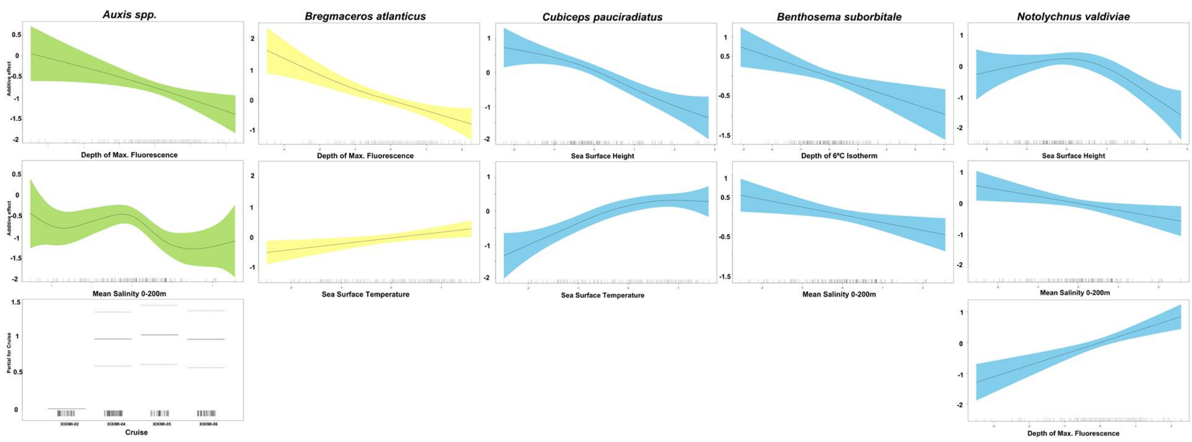
-Oceanic and mesopelagic species tend to have similar abundances among cruises.

-*Auxis* spp. and *N. valdiviae* had the highest abundance for all cruises.

-*C. crysos* had the lowest abundance during all cruises.

-Mean abundance of the selected taxa was lower during XIXIMI-02.

OCEANOGRAPHIC CONDITIONS' ADDITIVE EFFECT



-Only *Auxis* spp. abundance was influenced by cruise.

-SST had a positive effect and SSH had a negative effect on species' abundance.

-Greater larval abundances tended to be found at intermediate levels of the variables.

-*Auxis* spp. and *N. valdiviae* abundance was negatively and positively related to the Depth of Max. Fluorescence, respectively.

OCEANOGRAPHIC VARIABLES IN FINAL SPECIES GAMS

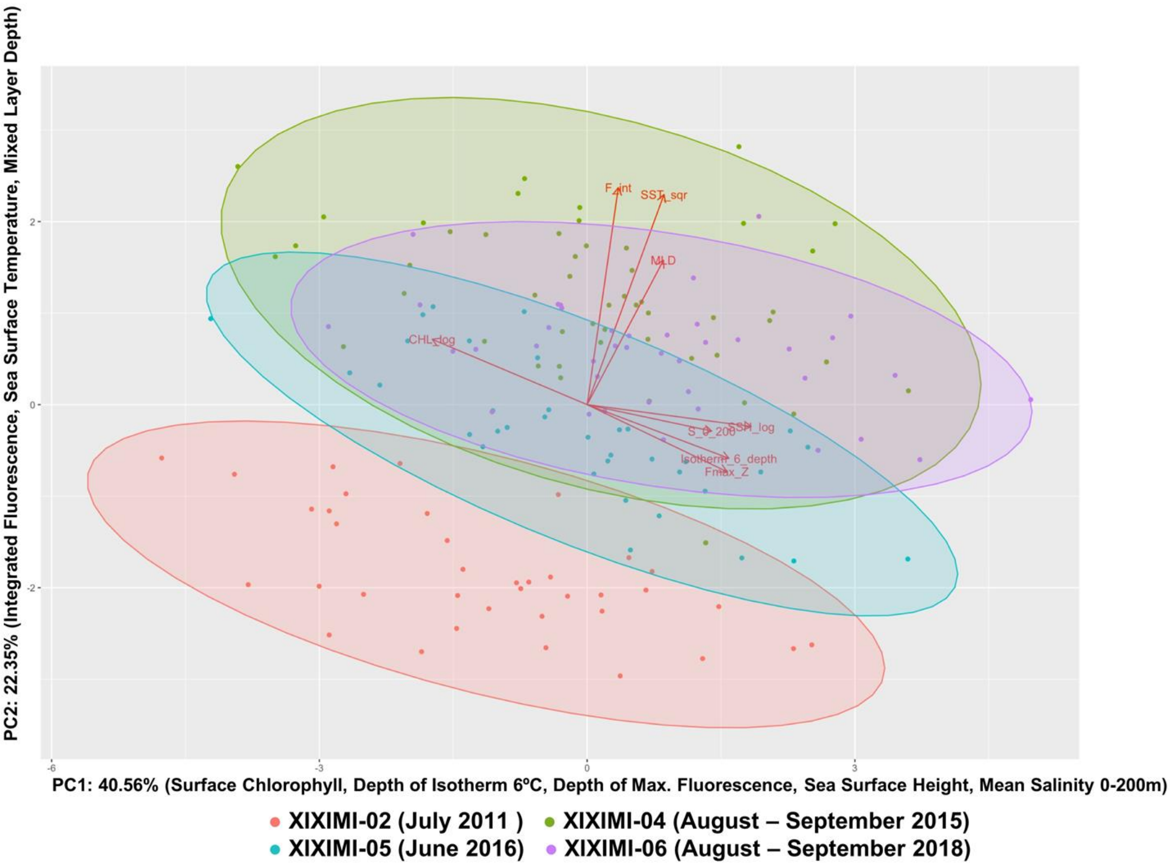
Oceanographic variables	*Auxis* spp.	*C. crysos*	*B. atlanticus*	*C. pauciradiatus*	*B. suborbitale*	*N. valdiviae*
Explained Variance % (Adj. R^2)	31.1	No model	17	27.2	12	21.6
Mixed Layer Depth (m)						
Depth 6°C Isotherm (m)					Depth 6°C Isotherm	
Salinity 0-200m (psu)	Sal. 0-200m				Sal. 0-200m	Sal. 0-200m
Depth Max. Fluorescence (m)	Depth Max. Fluor.		Depth Max. Fluor.			Depth Max. Fluor.
Integrated Fluorescence 0-200m						
Sea surface Temperature (°C)			SST	SST		
Surface Chlorophyll a ($mg \cdot m^{-3}$)						
Sea Surface Height (m)				SSH		SSH
Cruise	Cruise					

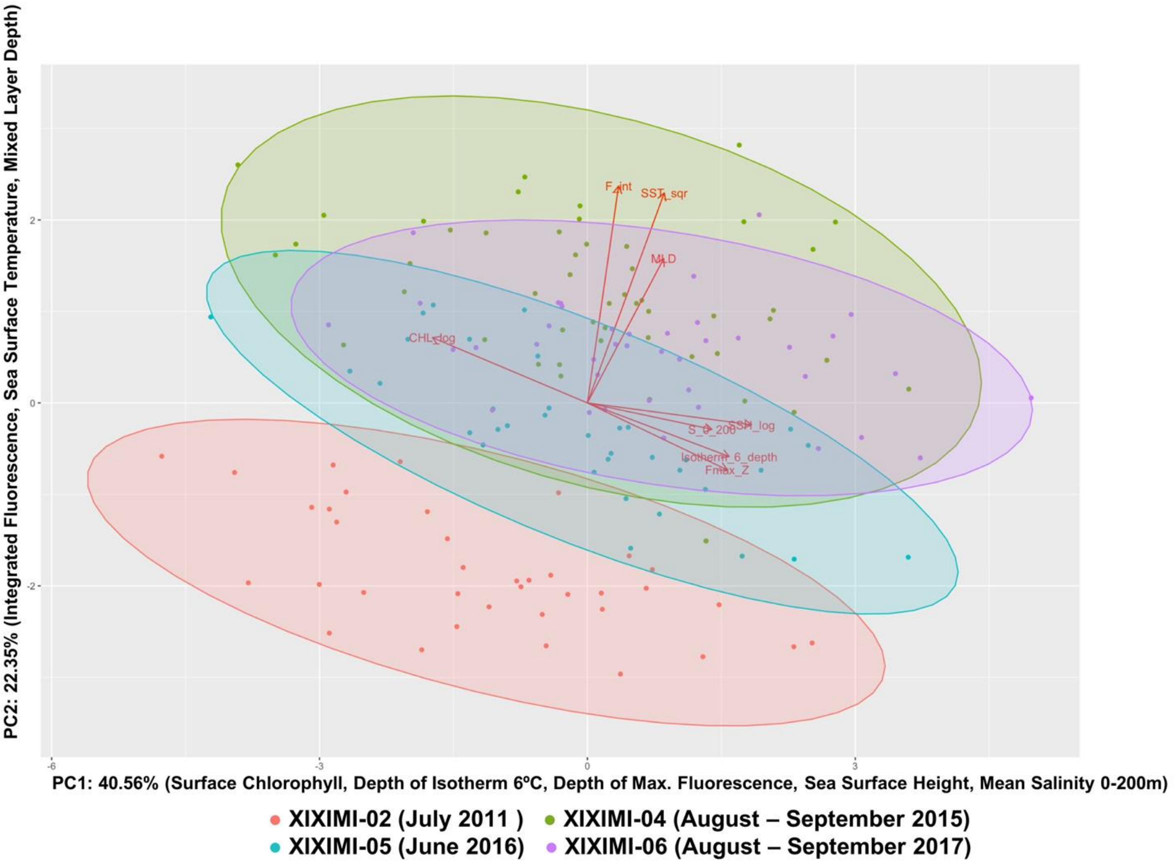
-Low values of explained variance were generated by all models (max. 31%).

-A maximum of three variables were retained in each taxon-specific model

-Depth of Max. Fluorescence and Mean Salinity 0-200 m were included in three of the models.

PCA OF OCEANOGRAPHIC VARIABLES AS A FUNCTION OF CRUISE





-Deeper MLD coincided with higher values of integrated fluorescence and SST.

-Deeper 6ºC isotherm and max. fluorescence, and higher values of SSH and mean salinity, corresponded to lower values of surface chlorophyll.

-Although all cruises were held during the summer, the oceanographic conditions during XIXIMI-02 were the most different (lower integrated fluorescence, shallower MLD and colder SST).

DISCUSSION

-The higher abundances at lower sea surface heights, shallower 6ºC isotherm and shallower maximum fluorescence may indicate that abundances are related to areas with high nutrient availability, such as cyclonic eddies and upwelling regions (Cruz-Gómex et al. 2008).

-Homogeneous abundance of larvae of mesopelagic species among cruises might reflect that adults are widely distributed in the deep water region of the GoM (Catul et al., 1991).

-Larval survival is highly dependent on environmental conditions (Houde and Hoyt, 1987; Fuiman and Werner, 2002). Higher abundances coinciding with intermediate values of oceanographic parameters may suggest that extreme conditions lead to a higher mortality.

CONCLUSIONS AND FUTURE GOALS

CONCLUSIONS AND IMPLICATIONS

-Values indicative of nutrient availability in the oceanographic variables were related to high larval abundance of oceanic species.

-Coastal species larval abundance was not explained by oceanographic variables. Their presence in the deep water region is likely due to offshore transport and is likely not conducive to successful recruitment.

-The main drivers of the species' abundances might be oceanographic features such as surface circulation patterns, cross shelf transport, and cyclonic and anticyclonic eddies.

-Life history strategies and the potential for recruitment success need to be considered in the interpretation of larval distribution patterns and in the construction of potential habitat maps.

FUTURE GOALS

- Couple the modeling effort linking oceanographic variables with abundance data for each taxa including additional cruises and spatial coverage.

-Link modeling efforts with life history information to accurately map potential habitats in order to characterize their distribution and habitat boundaries.

-Evaluate the connectivity between the GoM's regions and dispersion of larvae coupling biological models with circulation oceanographic models.

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ABSTRACT

Potential habitat models have become an increasingly used method for characterizing fish larval habitat. Describing the potential habitat of fish larvae can yield insight into distribution patterns over temporal and spatial scales that cannot be easily characterized w discrete ichthyoplankton surveys, as well as setting a reference against which to assess the impact of anthropogenic and natural disturbances. Potential habitats are defined based on larval distribution and the environmental conditions that are suitable for development and survival. In the central Gulf of México (GoM), mesoscale circulation is dominated by the Loop Current (LC), LC-derived anticyclonic eddies that are transported westward and cyclonic eddies: these features influence productivity and water column characteristics and hence larval habitat. A semi-permanent cyclonic eddy in the Bay of Campeche (southern GoM) and other processes such as regional upwelling and offshore transport can also influence larval potential habitat. Between 2011-2017 four oceanographic cruises covering the deep water region of the Mexican EEZ were conducted, and fish larvae were collected using a bongo net sampler. Six taxa with different life history strategies, abundance and distribution patterns, spawning seasonality, and of varying ecological and economic importance were selected for the characterization of their potential habitat (*Auxis* spp., *Benthosema suborbitale*, *Bregmaceros atlanticus*, *Caranx crysos*, *Cubiceps pauciradiatus* and *Notolychnus valdiviae*). Their potential habitat will be characterized using generalized additive models correlating larval distribution with environmental parameters derived from in situ CTD and satellite-based measurements. The results of this study will yield insight into the potential larval habitat of representative fish species throughout the central and southern Gulf of Mexico.

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