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Research Article

Neritic Larval Fish Distribution in the Oceanic Area of the Campeche Bay, Gulf of Mexico

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Abstract

Composition and abundance of larval fishes in Campeche Bay were studied during two seasons, winter, 2013 (24 stations) and summer, 2014 (31 stations). Sampling was carried out with open-close nets, mouth 75 cm and 505 µm mesh. The data of salinity and temperature allowed distinguishing three oceanic sub-regions: North, East, and West. There were 236 taxa, belonging to 74 families, 168 species, 154 taxa occurred in winter and 171 in summer; the composition in both cruises was similar with around 70 % of oceanic and 30 % of neritic larvae. The larval density was almost three times larger in summer than winter. The Campeche Bay hydrodynamics fits well with the results; the West sub-region is located where a cyclonic gyre takes place, the North and East sub-regions are located in the area of influence of warm currents over the Yucatan shelf. The hydrodynamics also allows understanding the differences in the proportion of neritic larvae among the three oceanic sub-regions, the West and East with the lower and higher number of neritic larvae, respectively. The large difference among regions is related to some neritic taxa occurring exclusively in some of them. Of the total taxa, 55 neritic occurred only once and it means that more than a half of neritic taxa were represented by one organism, 31 from 85 neritic taxa occurred in the layers of 600 to 1000 m depth. Of the neritic larvae, only *Syacium papillosum* and Apogon sp. appear among the 20 more abundant.

Introduction

The composition, abundance, and distribution of ichthyoplankton in the oceanic waters of Campeche Bay, the southern Gulf of Mexico have not been studied. Most the studies have been carried out on the continental shelf, and few include some oceanic stations but no samples below 200 m. It could mention the papers of Olvera-Limas et al., [1] on some particular species, Flores-Coto and Ordónez-López [2] on the mesopelagic fishes, Flores-Coto and Sánchez-Ramírez [3] on carangids, and Flores et al., [4] with a summary of ichthyoplankton research in the area.

Such papers let us have an idea of the dominant taxa in a general way, for an instant, the dominance in the oceanic area of families of mesopelagic species mainly Myctophidae and Gonostomatidae and those of neritic habitat on the continental shelf, like Sciaenidae, Carangidae, Clupeidae, Engraulidae.

Larval fish distribution around the world depends on the biology of the species and the hydrodynamic regime [5-10]. On the first item, the plankton biomass which means food availability is significant. In the southern Gulf of Mexico, the zooplankton biomass and ichthyoplankton density have a direct relationship, and their distribution patterns are similar, with the lowest values in the oceanic area [11,12]; high biomass densities occurred in the coastal regions of the main rivers [13].

In the continental shelf off Tabasco y Campeche, the hydrodynamics are dominated by a current over the Yucatan shelf (which is a branch of the Yucatán current) and the continental water discharges; environment very different from the oceanic adjacent area in the Campeche Bay where the hydrodynamic is driven by a semi-permanent cyclonic gyre [14] and coastal currents generated by wind force, which change of direction depending on the climatic season [15].

But also the Yucatan shelf current (from now on called YSC) has a significant role because the composition and distribution of larval fish assemblages are determinate firstly by the reproductive habits of the adults, but finally, modulated by the hydrographic stressors that characterize each area.

Richards et al., [16] in their analysis of larvae at the borders of the Loop current in the center of the gulf, recorded among the 25 more abundant families a high proportion of neritic components; however, one would expect in the oceanic waters of Campeche Bay a lower density of larvae and a lower proportion of neritic larvae, as it has been previously reported by Flores-Coto et al., [17] and Espinosa-Fuentes et al., [18].

The present paper analyzes the neritic larval fish composition and distribution in the oceanic waters of Campeche Bay from the surface to 1000 m depth, during winter and summer seasons of

2013 and 2014, assuming that the dominant hydrographic features are the controlling factors and to a lesser extent, the larvae biology.

Materials and Methods

The study area was located in the oceanic waters of Campeche Bay, the southern Gulf of Mexico between 18º and 21º 30´ N and 93º and 96º W. The zooplankton samples were obtained, from 24 stations made during the winter (ZOOMEP I, January 23-February 3, 2013) and 31 in the summer (ZOOMEP II, June 4-14, 2014). In the sampling, we used open-close nets 75 cm mouth and 505 µm mesh, in five 200 m strata (0 to 1000 m) resulting in 270 samples (Figure 1).

Samples were initially preserved in 4% formalin neutralized with sodium borate and changed into 70% alcohol 48h later. Fish larvae were all extracted from each sample and identified to the lower taxonomic level as possible. Salinity and temperature data were obtained from a Conductivity, Temperature and Depth profiler (CTD).

For the recognition of larvae assemblages, the Bray-Curtis similarity index was applied [19].

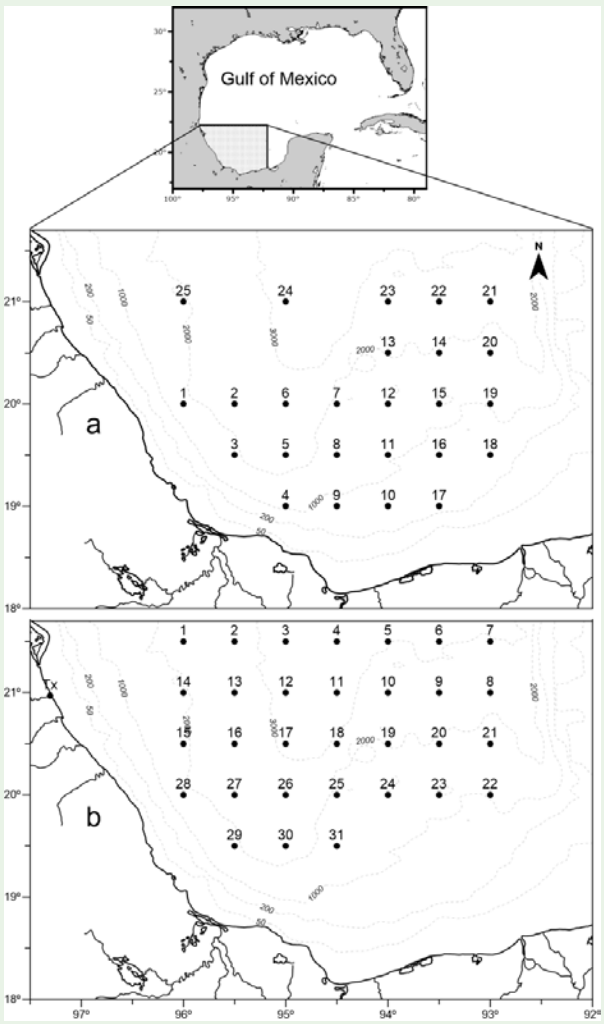

Figure 1: Study area and stations located in Campeche Bay, Gulf of Mexico. a - Winter cruise, b - Summer cruise

Results

Oceanic regions

Temperature and salinity properties of the sampled water masses allowed the identification of three oceanic sub-regions, here designated as North (NOR), East (EOR), and West (WOR) (Figures 2a and 2b).

During the winter cruise considering the average temperature of the first level (0 - 200 m) the NOR had values of > 21°C, the WOR of < 19.8°C and the EOR between 20 and 21°C (Figure 2a). Interestingly, during the summer cruise, the same sub-regions were also identified, in similar geographic areas. The NOR with temperatures of > 21°C, the WOR with < 20°C, and the EOR with values between previous sub-regions (Figure 2b). The differences among sub-regions in both cruises were lower but persisted to depth levels of 800 - 1000 m (Figures 3a and 3b).

Salinity differences among sub-regions were small, in the winter cruise. The average values were < 36.35 in WOR, > 36.4 in the NOR and 36.33 to 36.4 in the EOR. In the summer cruise the values were 34.42 to 36.25, in the NOR, 36.00 to 36.24 in the WOR and 36.17 to 36.26 in the EOR (Figures 4a and 4b).

Common and exclusive taxa in the oceanic sub-regions

A total of 5,612 larvae were collected, only 3,431 larvae were

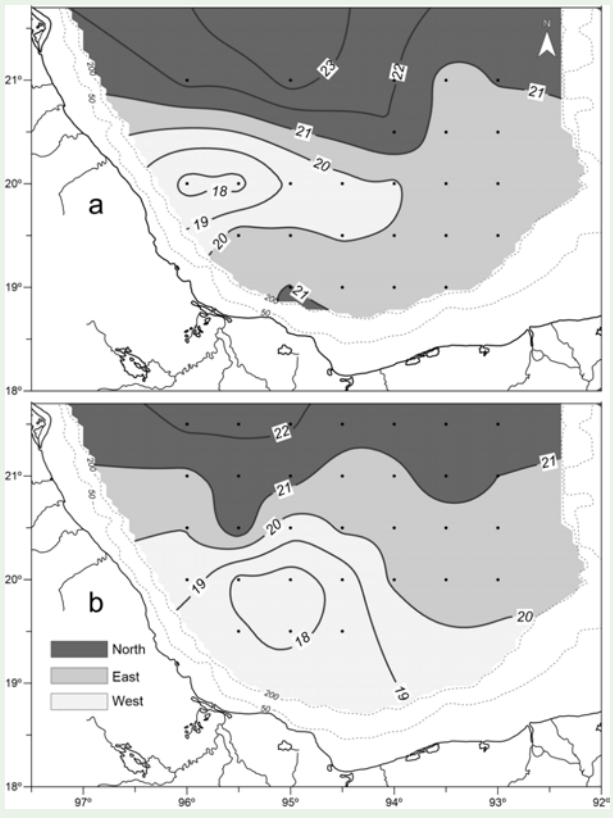

Figure 2: Oceanic sub-regions delimited by the average temperature of 0-200 m layer.
< 20°C, West sub-region, > 21°C North sub-region, between 20 and 21°C East sub-region.

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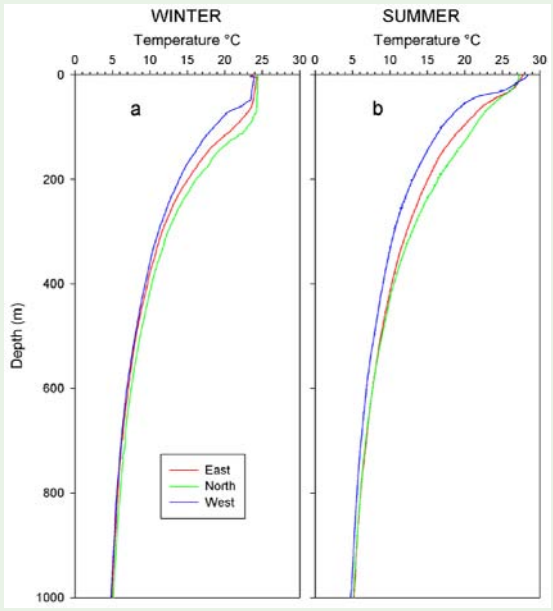

Figure 3: Temperature profiles (0-1000 m) in three sub-regions of the Campeche Bay, Mexico, during winter and summer cruises.

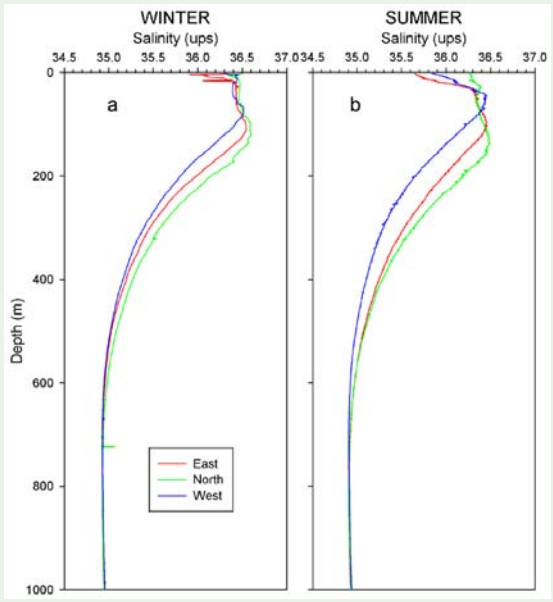

Figure 4: Salinity profiles (0-1000 m) in three sub-regions of the Campeche Bay, Mexico, during winter and summer cruises.

identified corresponding to 236 taxa, 76 families, 148 genera, 161 species. In winter 154 taxa were recorded and 171 in the summer. About 88 taxa were common, 66 only occurred in winter and 83 in summer (Tables 1, 2, 3 and 4).

The taxa composition in both cruises was similar with around 70 % of larvae from an oceanic stock and 30 % of the neritic stock. The larval density in summer represents 66.8 % of the total of both cruises, and the density of neritic larvae was 13.1 % in winter and 26.5 % in summer.

Table 1: Common taxa among oceanic sub-regions in Campeche Bay, Gulf of Mexico, during winter cruise (January 25 to February 3, 2013).

COMMON TAXA IN THREE OCEANIC SUB-REGIONS					
Family	**Taxa**	**Habitat**	**NOR**	**EOR**	**WOR**
Antenaridae	Antennarius spp.	Neritic	0.013	0.01	0.032
Mugilidae	*Mugil cephalus*	Neritic	0.006	0.01	0.004
Congridae	*Rhynchoconger flavus*	Neritic	0.011	0.009	0.003
Sternoptychidae	*Argyropelecus slandeni*	Oceanic	0.034	0.003	0.012
Sternoptychidae	Argyropelecus spp.	Oceanic	0.127	0.101	0.077
Myctophidae	*Benthosema suborbitale*	Oceanic	0.041	0.144	0.161
Bregmacerotidae	*Bregmaceros atlanticus*	Oceanic	0.015	0.055	0.031
Bregmacerotidae	*Bregmaceros cantori*	Oceanic	0.023	0.39	0.008
Chiasmodontidae	*Chiasmodon niger*	Oceanic	0.015	0.032	0.03
Gonostomatidae	*Cyclothone acclinidens*	Oceanic	0.01	0.002	0.03
Gonostomatidae	*Cyclothone alba*	Oceanic	0.095	0.144	0.071
Gonostomatidae	*Cyclothone braueri*	Oceanic	0.066	0.063	0.043
Gonostomatidae	*Cyclothone pallida*	Oceanic	0.113	0.052	0.029
Gonostomatidae	*Cyclothone pseudopallida*	Oceanic	0.038	0.06	0.036
Gonostomatidae	Cyclothone spp.	Oceanic	0.053	0.092	0.043
Myctophidae	*Diaphus mollis*	Oceanic	0.017	0.012	0.008
Myctophidae	Diaphus spp.	Oceanic	0.119	0.158	0.047
Myctophidae	*Diogenichthys atlanticus*	Oceanic	0.026	0.043	0.047
Myctophidae	*Electrona rissoi*	Oceanic	0.011	0.063	0.041

Gonostomatidae	*Gonostoma atlanticum*	Oceanic	0.033	0.071	0.056
Melamphaidae	*Melampaes simus*	Oceanic	0.03	0.006	0.035
Myctophidae	*Myctophum obtusirostre*	Oceanic	0.042	0.089	0.013
Myctophidae	Myctophum spp.	Oceanic	0.035	0.02	0.008
Myctophidae	*Notolychnus valdiviae*	Oceanic	0.028	0.106	0.138
Gonostomatidae	*Sigmops elongatum*	Oceanic	0.059	0.025	0.024
Sternoptychidae	*Sternoptyx diaphana*	Oceanic	0.039	0.089	0.063
Sternoptychidae	*Sternoptyx pseudobscura*	Oceanic	0.03	0.142	0.155
COMMON TAXA IN NORTH AND WEST SUB-REGIONS					
Family	**Taxa**	**Habitat**	**NOR**	**WOR**	
Bothidae	*Bothus ocellatus*	Neritic	0.015	0.007	
Tetraodontidae	Canthigaster spp.	Neritic	0.005	0.025	
Scaridae	Scarus spp.	Neritic	0.014	0.015	
Trichiuridae	*Aphanopus intermedius*	Oceanic	0.006	0.004	
Sternoptychidae	*Argyropelecus hemigymnus*	Oceanic	0.011	0.022	
Gonostomatidae	Gonosthoma spp.	Oceanic	0.012	0.048	
Myctophidae	*Myctophum asperum*	Oceanic	0.006	0.031	
Alepisauridae	*Omosudis lowii*	Oceanic	0.021	0.004	
COMMON TAXA IN EAST AND WEST SUB-REGIONS					
Family	**Taxa**	**Habitat**	**EOR**	**WOR**	
Callionymidae	*Callionymus bairdi*	Neritic	0.021	0.008	
Synaphobranchidae	*Dysomma anguillare*	Neritic	0.05	0.01	
Scorpaenidae	*Pontinus rathbuni*	Neritic	0.006	0.003	
Rachycentridae	*Rachycentrum canadum*	Neritic	0.023	0.022	
Scorpaenidae	Scorpaena spp.	Neritic	0.006	0.008	
Sternoptychidae	*Argyropelecus affinis*	Oceanic	0.003	0.004	
Gonostomatidae	*Bonapartia pedaliota*	Oceanic	0.014	0.006	
Bregmacerotidae	Bregmaceros spp.	Oceanic	0.06	0.014	
Myctophidae	*Hygophum taaningi*	Oceanic	0.016	0.014	
Myctophidae	Lampadena spp.	Oceanic	0.007	0.004	
Paralepididae	*Lestidiops affinis*	Oceanic	0.002	0.006	
Bothidae	*Monolene sessilicauda*	Oceanic	0.007	0.005	
Phosichthyidae	*Pollichthys mauli*	Oceanic	0.011	0.003	
Scopelarchidae	Scopelarchus spp.	Oceanic	0.018	0.008	
COMMON TAXA IN NORTH AND EAST SUB-REGIONS					
Family	**Taxa**	**Habitat**	**NOR**	**EOR**	
Apogonidae	Apogon spp.	Neritic	0.025	0.091	
Bothidae	Bothus spp.	Neritic	0.01	0.021	
Mugilidae	*Mugil curema*	Neritic	0.004	0.019	
Serranidae	Serranus spp.	Neritic	0.03	0.021	
Myctophidae	*Ceratoscospelus warmingii*	Oceanic	0.061	0.007	
Gonostomatidae	*Cyclothone obscura*	Oceanic	0.005	0.005	
Gempylidae	*Diplospinus multistriatus*	Oceanic	0.01	0.043	
Linophrynidae	*Haplophryne mollis*	Oceanic	0.004	0.003	
Myctophidae	*Lampanyctus nobilis*	Oceanic	0.005	0.007	

Myctophidae	*Myctophum affine*	Oceanic	0.02	0.016	
Myctophidae	*Myctophum nitidulum*	Oceanic	0.025	0.044	
Notosudidae	*Scopelosaurus mauli*	Oceanic	0.021	0.008	
Myctophidae	*Symbolophorus rufinus*	Oceanic	0.004	0.012	
Acropomatidae	*Synagrops bellus*	Oceanic	0.004	0.004	
Phosichthyidae	*Vinciguerria nimbaria*	Oceanic	0.005	0.011	

Values = average density. NOR = North Oceanic sub-region, EOR = East Oceanic sub-region, WOR = West Oceanic sub-region.

Table 2: Exclusive taxa in each oceanic sub-region in Campeche Bay, Gulf of Mexico, during winter cruise (January 24 to February 3, 2013).

EXCLUSIVE TAXA IN EAST OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Mugilidae	*Agonostoma moticula*	Neritic	0.002
Serranidae	*Anthias nicholsi*	Neritic	0.013
Labridae	*Bodianus rufus*	Neritic	0.007
Paralichthydae	*Citharichthys cornutus*	Neritic	0.011
Paralichthydae	*Citharichthys gymnorhinus*	Neritic	0.004
Paralichthydae	*Citharichthys macrops*	Neritic	0.006
Paralichthydae	Citharichthys spp.	Neritic	0.003
Paralichthydae	*Citharichthys spilopterus*	Neritic	0.014
Carangidae	*Decapterus punctatus*	Neritic	0.025
Bothidae	*Engyophrys senta*	Neritic	0.004
Paralichthydae	*Etropus microstomus*	Neritic	0.016
Labridae	*Halichoeres cyanocephalus*	Neritic	0.007
Sciaenidae	*Micropogonias furnieri*	Neritic	0.013
Ophichthidae	*Myrophis punctatus*	Neritic	0.004
Ophichthidae	Ophichthus spp.	Neritic	0.004
Pomatomidae	*Pomatomus saltatrix*	Neritic	0.006
Scorpaemidae	*scorpaena plumieri*	Neritic	0.002
Sparidae	Sparisoma spp.	Neritic	0.017
Paralichthyidae	*Syacium papillosum*	Neritic	0.005
Cynoglosidae	Symphurus spp.	Neritic	0.006
Synodontidae	*Synodus foetens*	Neritic	0.011
Synodontidae	Synodus spp.	Neritic	0.014
Alepisauridae	*Alepisaurus ferox*	Oceanic	0.004
Percophidae	*Bembrops gobioides*	Oceanic	0.007
Percophidae	Bembrops spp.	Oceanic	0.007
Trichiuridae	*Benthodesmus tenuis*	Oceanic	0.006
Bregmacerotidae	*Bregmaceros houdei*	Oceanic	0.007
Ophidiidae	Brotula spp.	Oceanic	0.016
Gonostomatidae	*Cyclothone microdon*	Oceanic	0.018
Myctophidae	*Diaphus brachycephalus*	Oceanic	0.011
Directmidae	*Diretmichthys parini*	Oceanic	0.005
Microstomatidae	*Dolicholagus longirostris*	Oceanic	0.007
Stomiidae	Eustomias spp.	Oceanic	0.006
Evermanellidae	*Evermannella melanoderma*	Oceanic	0.007

Congridae	Gnathophis spp.	Oceanic	0.007
Myctophidae	*Hygophum benoiti*	Oceanic	0.003
Myctophidae	Hygophum spp.	Oceanic	0.045
Phosichthyidae	*Icthyococus ovatus*	Oceanic	0.006
Myctophidae	Lampanyctus spp.	Oceanic	0.004
Gempylidae	*Lepidocybium flavobrunneum*	Oceanic	0.004
Trichiuridae	*Lepidopus altifrons*	Oceanic	0.005
Myctophidae	*Myctophum selenops*	Oceanic	0.006
Myctophidae	Nannobrachium spp.	Oceanic	0.015
Gempylidae	*Nealotus tripes*	Oceanic	0.014
Polynemidae	Polydactilus spp.	Oceanic	0.006
Family	**Taxa**	**Habitat**	**Averaje density**
Sternoptychidae	Polyipnus spp.	Oceanic	0.004
Scorpaenidae	Pterois spp.	Oceanic	0.006
Paralepididae	*Sudis atrox*	Oceanic	0.007
Congridae	*Uroconger syringinus*	Oceanic	0.007
Sternoptychidae	*Valenciennellus tripunctulatus*	Oceanic	0.016
Phosichthyidae	*Vinciguerria attenuata*	Oceanic	0.011
Phosichthyidae	*Vinciguerria poweriae*	Oceanic	0.003
EXCLUSIVE TAXA NORTH OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Diodontidae	*Chilomycterus schoepfi*	Neritic	0.004
Priacanthidae	*Heteropriacanthus cruentatus*	Neritic	0.020
Malacantidae	*Malacanthus plumieri*	Neritic	0.017
Synodontidae	*Synodus*	Neritic	0.013
Sternoptychidae	*Argyropelecus acuelatus*	Oceanic	0.007
Myctophidae	Ceratoscospelus spp.	Oceanic	0.043
Bothidae	*Chascanopsettalugubris*	Oceanic	0.005
Myctophidae	*Diaphus effulgens*	Oceanic	0.007
Ophidiidae	Dicrolene spp.	Oceanic	0.007
Gonostomatidae	*Margrethia obtusirostre*	Oceanic	0.011
Myctophidae	*Nannobrachium atrum*	Oceanic	0.015
Myctophidae	*Notoscopelus caudispinosus*	Oceanic	0.006
Gonostomatidae	Sigmops spp.	Oceanic	0.032
Paralepididae	*Stemonosudis rothschildi*	Oceanic	0.011
Cynoglosidae	*symphuruspiger*	Oceanic	0.010
Phosichthyidae	Vinciguerria spp.	Oceanic	0.025
EXCLUSIVE TAXA WEST OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Tetraodontidae	*Canthigaster rostrata*	Neritic	0.003
Mullidae	*Mulloidichthys martinicus*	Neritic	0.013
Nettastomidae	*Nettenchelys pygmaea*	Neritic	0.013
Sphyraenidae	Sphyraena spp.	Neritic	0.013
Microstomatidae	Bathylagos spp.	Oceanic	0.008

Berycidae	Beryx spp.	Oceanic	0.010
Stomiidae	*Chauliodus sloani*	Oceanic	0.005
Chiasmodontidae	Chiasmodon spp.	Oceanic	0.008
Nomeidae	*Cubiceps pauciradiatus*	Oceanic	0.008
Gempylidae	*Gempylus serpens*	Oceanic	0.005
Myctophidae	*Hygophum reinhardtii*	Oceanic	0.013
Myctophidae	*Lampanyctus alatus*	Oceanic	0.017
Myctophidae	*Lepidophanes gaussi*	Oceanic	0.006
Myctophidae	*Lepidophanes guentheri*	Oceanic	0.005
Melanocetidae	*Melanocetus johnsoni*	Oceanic	0.006
Microstomatidae	*Melanolagus bericoides*	Oceanic	0.019
Myctophidae	*Nannobrachium lineatun*	Oceanic	0.013
Myctophidae	*Notoscopelus resplendens*	Oceanic	0.008
Alepisauridae	Omosudis spp.	Oceanic	0.003
Nomeidae	*Psenes pellucidus*	Oceanic	0.010
Scopelarchidae	*Scopelarchus analis*	Oceanic	0.008
Phycidae	Urophycis spp.	Oceanic	0.013

Table 3: Common taxa among oceanic sub-regions in Campeche Bay, Gulf of Mexico, during summer cruise (4-14 June 2014).

COMMON TAXA IN THREE SUB-REGIONS					
Family	**Taxa**	**Habitat**	**NOR**	**EOR**	**WOR**
Bothidae	*Bothus ocellatus*	Neritic	0.425	0.781	0.433
Sternoptychidae	*Maurolicus weitzmani*	Neritic	0.206	0.318	0.645
Paralichthydae	*Syacium papillosum*	Neritic	0.579	1.499	0.705
Sternoptychidae	*Argyropelecus affinis*	Oceanic	0.471	0.201	0.304
Sternoptychidae	*Argyropelecus hemigymnus*	Oceanic	0.208	0.281	0.171
Sternoptychidae	*Argyropelecus sladeni*	Oceanic	0.289	0.369	0.639
Sternoptychidae	Argyropelecus spp.	Oceanic	0.342	0.423	0.686
Myctophidae	*Benthosema suborbitale*	Oceanic	0.506	0.770	0.692
Gonostomatidae	*Bonapartia pedaliota*	Oceanic	0.222	0.227	0.154
Bregmacerotidae	*Bregmaceros atlanticus*	Oceanic	0.910	1.016	0.760
Bregmacerotidae	*Bregmaceros cantori*	Oceanic	1.132	0.589	1.325
Myctophidae	*Centrobranchus nigroocellatus*	Oceanic	0.282	0.128	0.143
Myctophidae	Ceratoscopelus spp.	Oceanic	0.227	0.377	0.638
Gonostomatidae	*Cyclothone acclinidens*	Oceanic	0.335	0.598	0.426
Gonostomatidae	*Cyclothone alba*	Oceanic	0.403	0.191	0.595
Gonostomatidae	*Cyclothone braueri*	Oceanic	0.235	0.388	0.555
Gonostomatidae	*Cyclothone microdon*	Oceanic	0.380	0.569	0.286
Gonostomatidae	*Cyclothone pallida*	Oceanic	0.255	0.334	0.595
Gonostomatidae	*Cyclothone pseudopallida*	Oceanic	0.229	0.418	0.207
Gonostomatidae	Cyclothone spp.	Oceanic	0.547	0.530	0.535
Myctophidae	*Diaphus mollis*	Oceanic	0.482	0.893	0.367
Myctophidae	Diaphus spp.	Oceanic	0.843	1.264	0.844
Myctophidae	*Diogenichthys atlanticus*	Oceanic	0.803	0.636	1.962
Gempylidae	*Diplospinus multistriatus*	Oceanic	0.576	0.293	0.276

Microstomatidae	*Dolicholagus longirostris*	Oceanic	0.129	0.239	0.255
Myctophidae	*Electrona risso*	Oceanic	0.270	0.316	0.113
Gonostomatidae	*Gonostoma atlanticum*	Oceanic	0.395	0.443	0.655
Myctophidae	*Hygophum macrochir*	Oceanic	0.184	0.341	0.472
Myctophidae	*Hygophum reinhardtii*	Oceanic	0.355	0.759	0.637
Myctophidae	*Hygophum taaningi*	Oceanic	0.390	0.529	0.558
Myctophidae	*Lampadena luminosa*	Oceanic	0.351	0.712	0.402
Myctophidae	*Lampanyctus alatus*	Oceanic	0.160	0.756	0.269
Myctophidae	Lampanyctus spp.	Oceanic	0.351	0.325	0.223
Myctophidae	*Lepidophanes guentheri*	Oceanic	0.248	0.128	0.173
Melamphaidae	*Melamphaes simus*	Oceanic	0.421	0.562	0.463
Myctophidae	*Myctophum affine*	Oceanic	0.328	0.210	0.154
Myctophidae	*Myctophum asperum*	Oceanic	0.550	0.518	0.414
Myctophidae	*Myctophum nitidulum*	Oceanic	0.361	0.606	0.504
Myctophidae	*Myctophum obtusirostre*	Oceanic	0.213	0.544	0.836
Myctophidae	Myctophum spp.	Oceanic	0.590	0.363	0.559
Myctophidae	*Notolychnus valdiviae*	Oceanic	0.880	1.022	0.549
Gonostomatidae	*Sigmops elongatum*	Oceanic	0.464	0.902	0.405
Sternoptychidae	*Sternoptyx diaphana*	Oceanic	0.335	0.354	0.346
Sternoptychidae	Sternoptyx spp.	Oceanic	0.333	0.489	0.820
Myctophidae	*Symbolophorus rufinus*	Oceanic	0.303	0.293	0.719
Sternoptychidae	*Valenciennellus tripunctulatus*	Oceanic	0.329	0.415	0.367
Phosichthyidae	Vinciguerria spp	Oceanic	0.701	0.340	0.462
COMMON TAXA IN NORTH AND WEST SUB-REGIONS					
Family	**Taxa**	**Habitat**	**NOR**	**WOR**	
Exocoetidae	Cheilopogon spp.	Neritic	0.294	0.679	
Myctophidae	*Ceratoscopelus warmingii*	Oceanic	0.650	0.154	
Myctophidae	*Gonichthys cocco*	Oceanic	0.229	0.424	
Myctophidae	*Myctophum selenops*	Oceanic	0.467	0.272	
Myctophidae	*Nannobrachium lineatum*	Oceanic	0.227	0.547	
Myctophidae	Nannobrachium spp.	Oceanic	0.336	0.594	
Scopelarchidae	Scopelarchus spp.	Oceanic	0.217	0.154	
Melamphaidae	Scopeloberyx spp.	Oceanic	0.984	0.173	
Phosichthyidae	*Vinciguerria poweriae*	Oceanic	0.183	0.360	
COMMON TAXA IN EAST AND WEST SUB-REGIONS					
Family	**Taxa**	**Habitat**	**EOR**	**WOR**	
Microdesmidae	*Microdesmus lanceolatus*	Neritic	1.428	0.924	
Congridae	*Rhynchoconger flavus*	Neritic	0.285	0.340	
Stomiidae	*Chauliodus danae*	Oceanic	0.358	0.499	
Myctophidae	*Hygophum benoiti*	Oceanic	0.358	0.164	
Myctophidae	*Lampanyctus nobilis*	Oceanic	0.425	0.132	
Myctophidae	Notoscopelus spp.	Oceanic	0.719	0.376	
Paralepididae	*Stemonosudis rothschildi*	Oceanic	0.334	0.173	
Phosichthyidae	*Vinciguerria attenuata*	Oceanic	0.734	0.154	
COMMON TAXA IN NORTH AND EAST SUB-REGIONS					

Family	Taxa	Habitat	NOR	EOR	
Scombridae	*Auxis thazard*	Neritic	0.345	0.810	
Carangidae	Caranx spp	Neritic	0.155	0.332	
Paralichthydae	Citharichthys spp.	Neritic	0.259	0.152	
Diodontidae	Diodon spp.	Neritic	0.129	0.274	
Synaphobranchidae	*Dysomma anguillare*	Neritic	0.314	0.393	
Scombridae	*Euthynnus alletteratus*	Neritic	0.223	0.945	
Howellidae	Howella spp.	Neritic	0.416	0.369	
Carangidae	*Selene setapinnis*	Neritic	0.187	1.735	
Carangidae	Selene spp.	Neritic	0.323	0.184	
Serranidae	Serranus spp.	Neritic	0.189	0.573	
Scombridae	Thunnus spp	Neritic	0.232	0.373	
Bregmacerotidae	Bregmaceros spp	Oceanic	0.227	0.663	
Stomiidae	Chauliodus spp.	Oceanic	0.128	0.231	
Coryphaenidae	Coryphaena spp.	Oceanic	0.259	0.376	
Myctophidae	*Hygophum hygomii*	Oceanic	0.195	0.525	
Myctophidae	Hygophum spp.	Oceanic	0.253	0.673	
Phosichthyidae	*Ichthyococcus ovatus*	Oceanic	0.288	0.700	
Myctophidae	Lampadena spp.	Oceanic	0.187	0.421	
Paralepididae	*Lestidiops affinis*	Oceanic	0.339	0.611	
Paralepididae	Lestidiops spp.	Oceanic	0.642	0.355	
Myctophidae	*Lobianchia gemellarii*	Oceanic	0.259	0.661	
Gonostomatidae	*Margrethia obtusirostre*	Oceanic	0.256	0.247	
Myctophidae	*Nannobrachium atrum*	Oceanic	0.289	0.381	
Alepisauridae	*Omosudis lowii*	Oceanic	0.972	0.837	
Chlorophthalmidae	*Parasudis truculentus*	Oceanic	0.320	0.332	
Sternoptychidae	Polyipnus spp.	Oceanic	0.146	0.917	
Scopelarchidae	*Scopelarchus analis*	Oceanic	0.266	0.321	
Scopelarchidae	*Scopelarchus michaelsarsi*	Oceanic	0.185	0.373	
Sternoptychidae	*Sternoptyx pseudobscura*	Oceanic	0.470	0.411	
Paralepididae	*Sudis atrox*	Oceanic	0.457	0.258	

Values = average density. NOR = North Oceanic sub-region, EOR = East Oceanic sub-region, WOR = West Oceanic sub-region.

The more abundant and frequent species in both cruises were *Diogenichthys atlanticus, Notolychnus valdiviae, Benthosema suborbitale, Bregmaceros cantori, B. atlanticus, Gonostoma atlanticum, Sternoptyx diaphana* and the genera Diaphus, Cyclothone y Argyropelecus. Of the neritic larvae, only *Syacium papillosum* and Apogon sp. appear among the twenty-first more abundant.

The composition of the larval community was analyzed with Bray-Curtis dissimilarity index using the total taxa or only neritic larvae. However, the resulting stations groups did not correspond with the oceanic sub-region determined by temperature and salinity.

Considering, firstly that from the 236 total taxa, 151 and 85 were oceanic and neritic larvae, respectively and secondly, that there was no correspondence between the ocean sub-regions and stations groups, we analyzed the differences among oceanic sub-regions, considering common taxa in the three regions, as well as those occurring in two or only one (Tables 1,2,3 and 4).

The larger number of common taxa among three sub-regions was oceanic: 24 and 47 in winter and summer, respectively, with only three and five neritic larvae in each cruise. The number of common taxa among two sub-regions was lower. The low number of common taxa among the WOR with the other two, as well as its low number of neritic taxa, making it different. Therefore, the greatest similarity was among the NOR and EOR particularly in the summer (Table 5).

The large difference among sub-regions was attributed to a few neritic taxa occurring exclusively in some of them, those, in winter there were only four in the NOR and WOR and 22 in the EOR. Similarly, in summer cruise four and five neritic taxa occurred exclusively in the NOR and WOR, and 28 in the EOR (Table 5). The greatest diversity and frequency of neritic taxa corresponded to the EOR.

Table 4: Exclusive taxa in each oceanic sub-region in Campeche Bay, Gulf of Mexico during summer cruise (4-14 June 2014).

EXCLUSIVE TAXA IN EAST OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Ophichthidae	*Ahlia egmontis*	Neritic	0.332
Monacanthidae	*Aluterus scriptus*	Neritic	0.296
Antennariidae	*Antennarius spp*	Neritic	0.369
Serranidae	*Anthias woodsi*	Neritic	0.332
Scombridae	Auxis spp	Neritic	0.853
Balistidae	*Balistes capriscus*	Neritic	0.358
Tetraodontidae	Canthigaster spp	Neritic	0.425
Carangidae	*Caranx crysos*	Neritic	0.358
Paralichthydae	*Citharichthys arctifrons*	Neritic	0.126
Paralichthydae	*Etropus crossotus*	Neritic	0.332
Paralichthydae	*Etropus microstomus*	Neritic	0.332
Gerreidae	Eucinostomus spp.	Neritic	0.622
Fistulariidae	Fistularia spp.	Neritic	0.917
Lutjanidae	*Lutjanus campechanus*	Neritic	0.425
Lutjanidae	Lutjanus spp.	Neritic	1.712
Microdesmidae	*Microdesmus longipinnis*	Neritic	0.880
Microdesmidae	Microdesmus spp.	Neritic	0.136
Carangidae	*Oligoplites saurus*	Neritic	0.358
Ophichthidae	*Ophichthus gomesii*	Neritic	0.358
Ophichthidae	Ophichthus spp.	Neritic	0.425
Ophidiidae	*Ophidion nocomis*	Neritic	0.258
Rachycentridae	*Rachycentron canadum*	Neritic	0.332
Scombridae	*Scomberomorus regalis*	Neritic	0.229
Scorpaenidae	Scorpaena spp.	Neritic	1.069
Carangidae	*Selar crumenophtalmus*	Neritic	0.167
Carangidae	*Selene vomer*	Neritic	0.373
Sphyraenidae	*Sphyraena guachancho*	Neritic	1.712
Scombridae	*Thunnus atlanticus*	Neritic	1.428
Alepisauridae	Alepisaurus spp	Oceanic	0.837
Aulopidae	*Aulopus nanae*	Oceanic	0.378
Percophidae	Bembrops spp	Oceanic	0.185
Bregmacerotidae	*Bregmaceros maclellandii*	Oceanic	0.185
Chiasmodontidae	*Chiasmodon niger*	Oceanic	0.242
Nomeidae	*Cubiceps pauciradiatus*	Oceanic	0.332
Gonostomatidae	*Cyclothone obscura*	Oceanic	0.560
Stomiidae	Eustomias spp.	Oceanic	0.358
Nettastomatidae	*Hoplunnis tenuis*	Oceanic	0.350
Melamphaidae	Melamphaes spp.	Oceanic	0.544
Gempylidae	*Nealotus tripes*	Oceanic	0.285
Serranidae	*Pronotogrammus aureorubens*	Oceanic	0.425

Nomeidae	Psenes spp.	Oceanic	0.332
Scopelarchidae	*Scopelarchoides danae*	Oceanic	0.369
Phosichthyidae	*Vinciguerria nimbaria*	Oceanic	0.285
EXCLUSIVE TAXA WEST OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Stomiidae	*Chauliodus sloani*	Oceanic	0.127
Myctophidae	*Diaphus brachycephalus*	Oceanic	0.238
Gonostomatidae	Gonostoma spp.	Oceanic	0.169
Microstomatidae	*Melanolagus bericoides*	Oceanic	0.388
Stomiidae	Melanostomias spp.	Oceanic	0.340
Stomiidae	*Photostomias guernei*	Oceanic	0.499
Scorpelarchidae	*Scopelarchus guentheri*	Oceanic	0.216
Dactylopteridae	*Dactylopterus volitans*	Neritic	0.340
Mirapinnidae	*Eutaeniophorus festivus*	Neritic	0.160
Scombridae	*Katsuwonus pelamis*	Neritic	0.679
Syngnathidae	*Syngnathus louisianae*	Neritic	0.499
EXCLUSIVE TAXA NORTH OCEANIC SUB-REGION			
Family	**Taxa**	**Habitat**	**Average density**
Paralichthyidae	*Cyclopsetta fimbriata*	Neritic	0.195
Bothidae	*Engyophrys senta*	Neritic	0.172
Muraenidae	*Gymnothorax ocellatus*	Neritic	0.259
Nettastomatidae	*Nettenchelys pygmaea*	Neritic	0.294
Pomacentridae	Stegastes spp.	Neritic	0.243
Alepisauridae	*Alepisaurus brevirostris*	Oceanic	0.146
Caproidae	*Antigonia capros*	Oceanic	0.195
Chlorophthalmidae	*Chlorophthalmus agassizi*	Oceanic	0.200
Coryphaenidae	*Coryphaena equiselis*	Oceanic	0.328
Opisthoproctidae	*Dolichopteryx binocularis*	Oceanic	0.227
Evermannellidae	*Evermanella balbo*	Oceanic	0.294
Nettastomatidae	Facciolella spp.	Oceanic	0.259
Ipnopidae	*Ipnops murrayi*	Oceanic	0.745
Paralichthyidae	*Cyclopsetta fimbriata*	Neritic	0.195
Myctophidae	*Lepidophanes gaussi*	Oceanic	0.452
Trichiuridae	Lepidopus spp.	Oceanic	0.195
Stomiidae	Leptostomias spp.	Oceanic	0.984
Macrouridae	Mesobius spp.	Oceanic	0.160
Myctophidae	*Nannobrachium cuprarium*	Oceanic	0.289
Myctophidae	*Notoscopelus caudispinosus*	Oceanic	0.648
Paralepididae	Paralepis spp.	Oceanic	0.119
Nomeidae	*Psenes arafurensis*	Oceanic	0.147
Paralepididae	*Uncisudis advena*	Oceanic	0.294
Paralepididae	Uncisudis spp	Oceanic	0.195

Table 5: Number of common and exclusive, neritic and oceanic taxa, occurring in each oceanic sub-region and season.

WINTER						SUMMER				
Taxa			Oceanic	Neritic		Oceanic	Neritic			
			109	45		117	54			
Total			154			171				
WINTER						**SUMMER**				
Common Taxa	**N-W**	**N-E**	**W-E**	**ALL**		**Common Taxa**	**N-W**	**N-E**	**W-E**	**ALL**
Oceanic	5	11	9	24		Oceanic	8	19	6	47
Neritic	3	4	5	3		Neritic	1	11	2	5
Total	8	15	14	27		Total	9	30	8	52
WINTER						**SUMMER**				
Exclusive Taxa	**North**	**East**	**West**			**Exclusive Taxa**	**North**	**East**	**West**	
Oceanic	12	30	18			Oceanic	18	15	7	
Neritic	4	**22**	4			Neritic	5	**28**	4	
Total	16	52	22			Total	23	43	11	

N = North Oceanic subregion, E = East Oceanic sub-region, W = West Oceanic sub-region.

Table 6: Taxa present once.

WINTER		SUMMER	
Neritic	**Oceanic**	**Neritic**	**Oceanic**
Agonostoma moticula	*Alepisaurus ferox*	*Ahlia egmontis*	*Alepisaurus brevirostris*
Anthias nicholsi	*Argyropelecus acuelatus*	Antennarius spp.	Alepisaurus spp.
Bodianus rufus	Bathylagos spp.	*Anthias woodsi*	*Antigonia capros*
Canthigaster rostrata	*Bembrops gobioides*	Auxis spp.	Bembrops spp.
Chilomycterus schoepfi	Bembrops spp.	*Balistes capriscus*	*Bregmaceros maclellandii*
Citharichthys gymnorhinus	*Benthodesmus tenuis*	Canthigaster spp.	*Chauliodus sloani*
Citharichthys macros	Beryx spp.	*Caranx crysos*	*Chiasmodon niger*
Citharichthys spp.	Ceratoscopelus spp.	*Citharichthys arctifrons*	*Chlorophthalmus agassizi*
Engyophrys senta	*Chascanopsetta lugubris*	*Cyclopsetta fimbriata*	*Coryphaena equiselis*
Halichoeres cyanocephalus	*Chauliodus sloani*	*Dactylopterus volitans*	*Cubiceps pauciradiatus*
Heteropriacanthus cruentatus	Chiasmodon spp.	*Engyophrys senta*	*Diaphus brachycephalus*
Micropogonias furnieri	*Cubiceps pauciradiatus*	*Etropus crossotus*	*Dolichopteryx binocularis*
Mulloidichthys martinicus	*Diaphus effulgens*	*Etropus microstomus*	Eustomias spp.
Myrophis punctatus	Dicrolene spp.	*Eutaeniophorus festivus*	*Evermannella balbo*
Nettenchelys pygmaea	*Diretmichthys parini*	Fistularia spp.	Facciolella spp.
Ophichthus spp.	*Dolicholagus longirostris*	*Gymnothorax ocellatus*	Gonostoma spp.
Pomatomus saltatrix	Eustomias spp.	*Katsuwonus pelamis*	*Hoplunnis tenuis*
Scorpaena plumieri	*Evermannella melanoderma*	*Lutjanus campechanus*	*Ipnops murrayi*
Sphyraena spp.	*Gempylus serpens*	Lutjanus spp.	Lepidopus spp.
Syacium papillosum	Gnathophis spp.	Microdesmus spp.	Leptostomias spp.
Symphurus spp.	*Hygophum benoiti*	*Nettenchelys pygmaea*	*Melanolagusbericoides*
Synodus spp.	*Hygophum reinhardtii*	*Oligoplites saurus*	Melanostomias spp.
Synodus synodus	*Ichthyococcus ovatus*	*Ophichthus gomesii*	Mesobius spp.
	Lampanyctus spp.	Ophichthus spp.	*Nannobrachium cuprarium*
	Lepidocybium flavobrunneum	*Rachycentron canadum*	*Nealotus tripes*
	Lepidophanes gaussi	*Scomberomorus regalis*	Paralepis spp.

	Lepidophanes guentheri		*Selar crumenophtalmus*	*Photostomias guernei*
	Lepidopus altifrons		*Selene vomer*	*Pronotogrammus aureorubens*
	Margrethia obtusirostre		*Sphyraena guachancho*	*Psenes arafurensis*
	Melanocetus johnsoni		Stegastes spp.	Psenes spp.
	Myctophum selenops		*Syngnathus louisianae*	*Scopelarchoides danae*
	Nannobrachium atrum		*Thunnus atlanticus*	*Scopelarchus guentheri*
	Nannobrachium lineatum			*Uncisudis advena*
	Nannobrachium spp.			Uncisudis spp.
	Notoscopelus caudispinosus			*Vinciguerria nimbaria*
	Notoscopelus resplendens			
	Omosudis spp.			
	Polydactilus spp.			
	Polyipnus spp.			
	Psenes pellucidus			
	Pterois spp.			
	Scopelarchus analis			
	Sigmops spp.			
	Stemonosudis rothschildi			
	Sudisatrox			
	Symphurus piger			
	Uroconger syringinus			
	Urophycis spp.			
	Vinciguerria poweriae			
	Vinciguerria spp.			

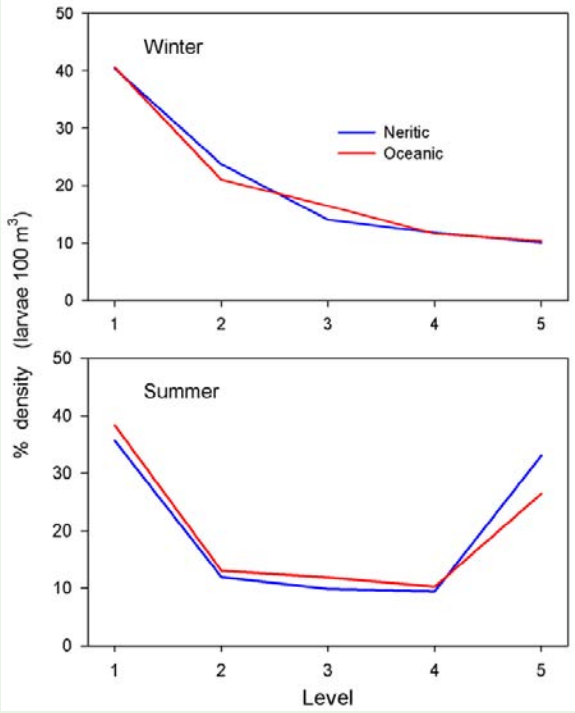

Figure 5: Percentage of larvae density by depth levels.

Vertical distribution

Distribution in the water column of the neritic and oceanic larvae was similar in winter and summer seasons; both groups of larvae presented greater density in the epipelagic layer, strongly declining towards the next level (200-400 m); the density continued descending up to 1000 m, except in the summer cruise in which after 800 m there was an increase to the next level (Figure 5).

The transport of larvae from the neritic to oceanic zones let us consider that this kind of larvae could remain in the epipelagic layer, but 31 from 85 neritic taxa occurred in the layers of 600 to 1000 m depth.

Most of these taxa were represented by one organism, except *Auxis thazard, Syacium papillosum* and *Bothus ocellatus*, occurring several times in such depths (Table 6).

Of the total taxa, 59 % occurred in only once, 85 oceanic and 55 neritic. This means that more than a half of neritic taxa were represented by a single organism and most of them were in the epipelagic layer, mainly in summer.

Discussion

Oceanic sub-regions

Differences in temperature and to a lesser extent of salinity allowed the recognition of three oceanic sub-regions in the Bay of

Campeche; in the two seasonal periods studied, these subdivision seem promoted by an almost permanent phenomenon, generated by two hydrographic facts: One is the semi-persistent cyclonic gyre which occurs in the bay [20,21]; and the other, the intrusion of neritic waters from the YSC that flow over the Bay [15,22].

The station groups resulting from the application of the similarity index [19] did not correspond to the oceanic regions determined from temperature and salinity; the differences in temperature and salinity are probably not so severe as to limit the passage of the larvae of a region to another. Richards et al., [16] in their study at the border of the Loop Current, had similar results applying a cluster analysis that might not support their hypothesis of front assemblages; however, in their study of families, they did distinguish coastal and oceanic groups.

The hydrodynamics of Campeche Bay is consistent with the hydrographic sub-regions described in our results. Thus, the WOR is located where the cyclonic gyre takes place [20,21]. It is, the region with the lower temperatures and salinities caused by the upwelling of deep water; while the NOR, which had warmer temperatures and high salinity are formed in the area under the direct influence of the YSC with the east-west direction [15,22,23]. The EOR, on the other hand, with average values of temperatures and salinities strictly intermediate is also influenced by the same current, after flowing through the Campeche-Tabasco shelf.

Neritic and oceanic larvae in the oceanic sub-regions

In the pelagic zone of Campeche Bay predominated larvae from oceanic parents, epipelagic, mesopelagic, bathypelagic or demersal; the families Myctophidae, Gonostomatidae, Sternoptychidae, Bregmacerotidae regularly were the most abundant and frequent [2,18].

The distribution of oceanic species did not appear limited by temperature or salinity differences among the three recorded oceanic sub-regions.

The low densities of neritic larvae 13.1 % in winter and 26.5 % in summer shows the small influence of neritic communities on the oceanic area as it has already been mentioned by Flores-Coto et al., [11]. This is consistent with its neritic origin [6-10] and their dispersion generated by the warm current that flows over the Yucatan shelf which reaches the oceanic zone.

The higher neritic larvae concentration on the NOR and EOR concerning the WOR fits the trajectories of the surface currents described by Zavala-Sansón et al., [24].

The larval distribution of neritic species confirms the low connectivity that exists between Yucatan and Veracruz reefs [25]. That is to say, those planktonic organisms transported by YSC towards Campeche Bay, do not to reach the Western area off Veracruz. However, possibly some of the neritic larvae identified come from the Veracruz reefs, particularly in the most western stations, since many species of this work also have been recorded in this reef area [26-28].

The hydrodynamics of Campeche Bay explains the differences in the proportion of neritic and oceanic larvae among the three oceanic sub-regions.

In the WOR there were a low number of neritic larvae because it was the area with less influence of the neritic communities swept away by YSC; and also, because in this sub-region the most important physical feature is the cyclonic gyre which, closely occupies the center of the Campeche Bay and generates a boundary in its outer limit for the other two regions [22].

In contrast, the EOR presented the greatest number of neritic larvae, due to the significant influence of the communities coming from the Yucatan shelf, particularly of taxa whose parents are linked to the existing local reefs [26].

On the other hand, in addition to the low number of neritic larvae in the WOR and the low number of common taxa shared with the other two sub-regions, it demonstrated its significant difference with other two sub-regions. In contrast, NOR and EOR were more similar.

In the studied area, larval fish distribution, as observed in another world environment, depend on the parents habit mainly the spawning season and areas and larvae concentration or dispersion by the hydrodynamic regime [4-10,29,30].

Vertical distribution

The high density of larvae both oceanic and neritic in the epipelagic zone seems to be attributed to the increased availability of food in that layer, decreasing to the next depthlevels [31,33]. The increase in density of larvae between 800 and 1000 m recorded during the summer cruise corresponded to juvenile and adult mesopelagic and bathypelagic species. However, the increase in larvae of neritic species has no explanation.

On the other hand, the concentration the larvae of neritic species in the surface layer of the water column, usually at depths less than 50 m is a common feature. However, the presence at depths of 600-1000 m larvae from neritic species, coming from areas with depths less than 200 m, suggests a vertical migration process by the larvae, not strictly to a turbulence mechanism. These considerations are based on the fact that 31 of the 85 neritic taxa, more one-third, were at greater depths, in all sub-regions during the two cruises, except in the summer when there were no neritic taxa at those depths in the WOR.

The presence of species represented by a single specimen in the oceanic waters seems a common fact. Richards et al., [18] reported 21.8 %, and we recorded 59 % in our study: 55 neritic and 85 oceanic taxa.

Many neritic species form schools as adults and larvae, as part of their life strategy, including reproduction and spawning; the shoals of larvae swept away by currents are highly dispersed in oceanic waters. Therefore, the capture of a single specimen of a species in the oceanic area could be considered normal. However, the presence of an individual of an oceanic species, particularly mesopelagic must obey to other causes, such as that not all species form dense schools during the reproduction process, or by a high mortality rate of larvae by inanition or predation.

The presence of the same three oceanic sub-regions in the Campeche Bay, in two different seasonal periods, winter and summer, recorded here, underlines the high relevance of its hydrographic regime upon zooplankton communities. We conclude that the distribution of taxa is not limited by salinity or temperature differences

between the ocean's three sub-regions. However, the distribution of neritic larvae is determined by the mesoscale hydrographic stressors that characterize the area, mainly the YSC and the cyclonic gyre.

The presence of neritic larvae in deep layers seems to obey to a vertical migration process, rather than to an advection mechanism.

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