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CHANGES IN SPECIES COMPOSITION AND ABUNDANCE OF FISH LARVAE FROM THE GULF OF TEHUANTEPEC, MEXICO

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ABSTRACT. The larval fish abundance and species composition of the Gulf of Tehuantepec are described based on the analysis of samples obtained from oblique zooplankton tows during summer 2007 and spring 2008. Changes in species composition and abundance between both periods were also described. A total of 145 taxa were obtained from which 73 were identified to species level, 43 to genus and 29 to family. The larval fish assemblage of the Gulf of Tehuantepec showed distinctive characteristics from other regions of the American Pacific, such as: A) a dominance of coastal-pelagic species (mainly *Bregmaceros bathymaster*); B) high diversity and abundance of shallow demersal species even along the oceanic stations of the study area; and C) a low proportion of mesopelagic species, an unusual condition in areas with narrow continental shelf. The diversity estimations suggest that Gulf of Tehuantepec is one of the most diverse ecosystems of the American Pacific, even as compared with other regions considered of highest diversity such as the Gulf of California. The high abundance, as well as the presence of the larval, juvenile and adult stages of *B. bathymaster*, suggests the importance of this region as a reproductive, nursery and recruitment for this species.

Keywords: Fish larvae, Gulf of Tehuantepec, México.

Cambios en la composición de especies y abundancia de larvas de peces en el Golfo de Tehuantepec, México

RESUMEN. Se describen la composición de especies y abundancia de larvas de peces del Golfo de Tehuantepec a partir del análisis de muestras obtenidas en arrastres oblicuos de zooplancton. Así mismo, se describen los cambios en composición y abundancia entre un periodo de verano y uno de primavera. Se obtuvieron 145 taxa de los que 73 se identificaron a nivel especie, 43 a género y 29 a familia. La comunidad de larvas de peces del Golfo de Tehuantepec mostró rasgos distintivos de otras regiones similares del Pacífico Americano, tales como: A) dominancia de especies pelágico-costeras (particularmente *Bregmaceros bathymaster*); B) alta diversidad y abundancia de especies demersales someras aún en las estaciones mas oceánicas del área de estudio; y C) una proporción menor de especies de peces mesopelágicos, condición poco común en áreas con plataforma continental estrecha. Las estimaciones de diversidad ubican al Golfo de Tehuantepec como uno de los ecosistemas más diversos del Pacífico americano, aún comparándolo con regiones consideradas de alta diversidad a nivel mundial como es el caso del Golfo de California. La abundancia y la presencia de estadios larvales, juveniles y adultos de *B. bathymaster* reflejan la importancia de esta zona como área de reproducción, crianza y reclutamiento de esta especie.

Palabras clave: Larvas de peces, Golfo de Tehuantepec, México.

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INTRODUCTION

The Gulf of Tehuantepec is an area with intense fishery activity sustained since this is one of the three Central America areas of the eastern tropical Pacific with the highest primary productivity (Robles–Jarero & Lara–Lara, 1993; Ortega–García *et al*., 2000). The study area is known as a region of high diversity (Briggs, 1974), however there are few studies on the species composition of this region (Ortega–García *et al*., 2000), and most of them are limited to a few taxonomic groups such as copepods and euphausiids (Farber-Lorda *et al*., 1994; Fernández-Alamo *et al*., 2000).

The Gulf of Tehuantepec is also a key biogeographic area. Bahía Tangolunda (Fig. 1) is a transition area between two main biogeographic regions: the Panamic and Mexican provinces (Briggs, 1974). Although these biogeographic provinces were based mainly on fishes, the ichthyofauna of the Gulf of Tehuantepec is still not well known with only few descriptive studies in this area. The pioneer studies described a demersal fish fauna of around 292 species, and 38 more species in the coastal lagoon systems of Oaxaca and Chiapas (Anónimo, 1978; Acal & Arias, 1990; Bianchi, 1991; Tapia–García *et al*., 1994, Díaz–Ruiz *et al.,* 2004), but there are no assessments of epi-, bathy- or mesopelagic species. Estimations of the species richness in the Gulf of Tehuantepec contrast with those of the Gulf of California, with an estimated 850 to 900 species (Castro–Aguirre *et al*., 1995). Differences between the diversity in these areas have been explained as a result of the high number of microhabitats as well as by the presence of a combined fauna from temperate, subtropical and tropical species in the relative narrower area of the Gulf of California (Briggs,

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1974, Castro-Aguirre *et al*., 1995) besides a more intense and systematic sampling effort in the Gulf of California. However, differences on species diversity could be related also to a lack of relevant studies of the fish species composition in the Gulf of Tehuantepec.

Studies on the early life stages of fish provide evidence of the adult presence, as well as their reproduction; both are key elements in the biogeographical sense, and for recognizing reproductive and nursery habitats. At the present, there is no information at the species level concerning the fish larvae of this important area. The work by Ahlstrom (1972) during the EASTROPAC surveys included only two sampling stations in an oceanic area far from the Gulf of Tehuantepe. Whilst Ayala–Duval *et al*. (1998) studied larval fish distribution of the coastal region of the gulf, but they identified specimens only to family and order taxonomic levels.

During the summer of 2007 (July 3rd-12th) and spring 2008 (May 26th-June 8th) the Secretaria de Marina made two oceanographic surveys in which zooplankton trawls were done. Analyzes of these samples allow us to obtain data in order to describe the larval fish species composition of the Gulf of Tehuantepec. The summer in this area corresponds with the dry season in which the Tehuano winds (which flow perpendicular to the coast) decrease significantly (Gallegos–García & Barberán–Falcón, 1998) and is characterized by a higher abundance of pelagic species (Tapia-García *et al*., 1994). Spring on the other hand corresponds to the rainy season and the strong Tehuano winds are almost over (Gallegos–García & Barberán–Falcón, 1998). During spring the abundance of demersal and estuarine-lacunar species increases (Tapia-García *et al*., 1994).

The objective of this work is to describe the larval fish species composition as well as the seasonal species change occurring between summer (July, 2007) and spring (May–June, 2008) in the Gulf of Tehuantepec.

MATERIALS AND METHODS

The Gulf of Tehuantepec is located in the southern tropical region of the Mexican Pacific. It is limited to the west by Puerto Ángel, Oaxaca and to the east by the mouth of the Suchiate river in Chiapas (Fig. 1). It has an area of 35,188 km² and a narrow continental shelf on the west side that increase toward the east side (Sosa–Hernández *et al*., 1980). The annual mean sea

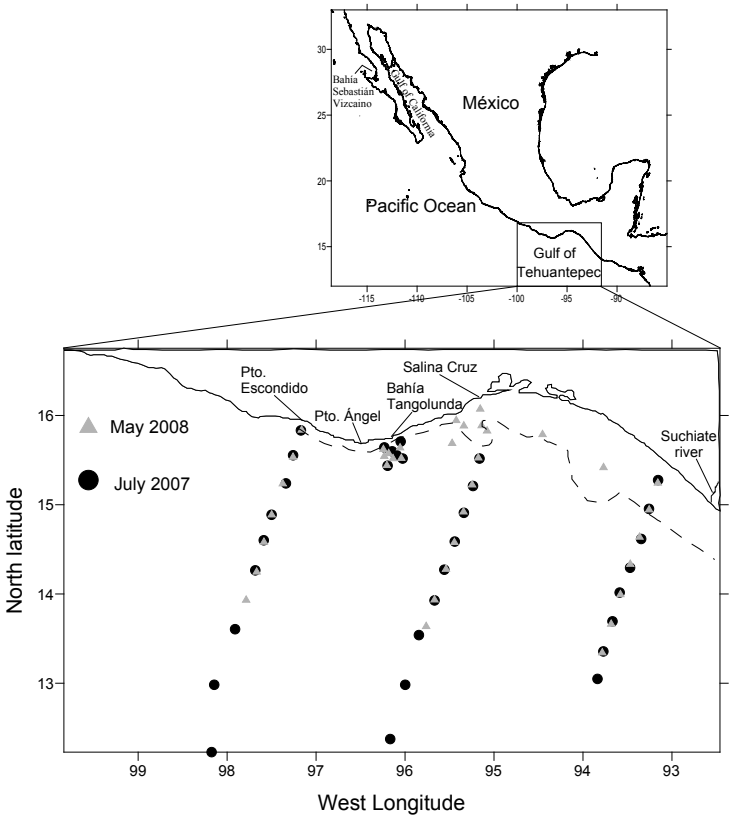

Figure 1. Study area and sampling stations during summer 2007 (dots) and spring 2008 (triangles). 200 m isobath is shown in dashed line.

surface temperature ranges between 25º and 30º C (Gallegos–García & Barberán-Falcón, 1998).

Two oceanographic surveys were conducted, one in summer (July 3rd to 12th, 2007) and one in spring (May 26th –June 8th, 2008). Zooplankton oblique tows were performed at 32 sampling stations in summer and 36 in spring (Fig. 1) using the Smith and Richardson (1979) standard method. Almost all the tows were done at a 200 m depth with an average towing time of 30 min but, in case stations were shallow, tows were then done 10 m above the sea floor. Nytex Bongo nets with 333 and 505-µm of mesh, 0.6 m in diameter, and flexible collectors were used. Each net was equipped with a digital flowmeter in the mouth to estimate the water volume filtered (in average 346 m³ in July and 297 m³ in spring). The zooplankton obtained with the 505-µm mesh net was preserved in a 4% formalin solution buffered with sodium borate, and that obtained with the 333-µm mesh net was preserved in 96% alcohol. Only the specimens collected with the 505-µm mesh net were used.

Fish larvae were sorted from all samples and identified to species when possible following Moser (1996). Identified organisms were counted and their abundance was standardized on each sampling station to 10 m² of sea surface (Smith & Richardson, 1979). When specimens could not be identified to species level in the absence of descriptions, they were identified to family or genus and the meristic and morphometric characteristics of each specimen were used to assign a type to each taxon. In this way, *Syacium* sp. 1 and *Syacium* sp. 2 for example, should be considered as different species. Percent abundance of families and taxa for each survey were calculated after adding adjusted numbers (organisms/10 m²). Due to the difference in the numbers of sampling stations as well as the non normal distribution in the ichthyoplankton data, we calculated de geometric mean of the larval abundance with its standard deviation in order to compare the larval abundance between both surveys as in Lavaniegos and Hereu (2009).

The species list was done according to Nelson (2006) and includes biogeographic affinity (tropical, transitional), habitat of adult distribution (shallow demersal, deep demersal, epipelagic, mesopelagic or bathypelagic) based on Eschmeyer (2009). All specimens were preserved in borosilicate vials and included in the "Larval fish collection of the Mexican Pacific" of the Plankton and Marine Ecology Department of Centro Interdisciplinario de Ciencias Marinas (CICIMAR–IPN).

In order to do a comparative analysis of the species richness of the Gulf of Tehuantepec with other areas of the Mexican Pacific with high fish diversity, we performed cumulative species curves (Soberón & Llorente, 1993). For this propose the cumulative species adjusted curves of the Gulf of California (Aceves–Medina, 2003) and the raw data of Bahía Sebastián Vizcaino obtained from Jiménez-Rosenberg *et al*. (2007) and Jiménez-Rosenberg (2008) were used. Cumulative curves were performed until 68 samples were completed in order to make comparable the sampling efforts of both regions and the Gulf of Tehuantepec.

RESULTS

A total of 145 *taxa* were found, 73 were identified to species, 43 to genus and 29 to family (Table 1). From the 55 identified families, 15 represented at least 1% of the catches, totaling 92% of the collected larvae (Table 2). In the same way, 19 species had abundance ≥ 1% at least in one of both surveys, representing 84% of the total ichthyoplankton in July and 89% in May-June (Table 3).

The number of species was highest during spring 2008 (Table 4) and the number of shared species for both seasons was only 62 (44%). Of the 19 most abundant species for all the study period, only *Opisthonema* sp. 1 and *Eucinostomus dowii* were not present during summer. In both seasons most abundant species were *Bregmaceros bathymaster* and *Vinciguerria lucetia* (Table 3), which suggests a similar composition in the dominant fraction of the larval fish for both summer and spring.

The main differences between the larval fish assemblage of summer 2007 and spring 2008 were:

a) The fish larvae abundance was almost twice in the spring survey (Table 4).

b) The increase in the abundance of coastal pelagic species during spring (Table 4) was mainly an increase in the abundance of *B. bathymaster* and *Opisthonema* sp. 3 and sp.1 (Table 3).

c) There was an increase during the spring in both the abundance and the number of *taxa* of shallow demersal species (Table 4), particularly species of *Syacium* and *Symphurus* (Table 3).

d) A decrease in the abundance of mesopelagic species occurred during the spring.

The adjusted cumulative curve for the Gulf of Tehuantepec (Fig. 2), shows an expected value of 120 species from 68 samples, which indicates a higher species richness compared with the curves from the Gulf of California

Table 1. Fish larvae collected in the Gulf during July 2007 and May 2008 showing percent abundance. Order (O); Sub Order (S.O.); Family (F). Habitat (HA): shallow demersal (sd); deep demersal (dd); coastal pelagic (cp); ocean epipelagic (op); mesopelagic (mp); and bathypelagic (bp).

Taxon	%	HA	Taxon	%	HA
O. Anguiliformes			*Ophidion* sp. 2	<0.1	sd
S. O. Congroidei			O. Lophiiformes		
F. Ophichthidae			S.O. Lophioidei		
Myrophis vafer Jordan and Gilbert, 1883	<0.1	sd	F. Lophiidae		
Ophichthus sp. 1	<0.1	sd	*Lophiodes* sp. 1	<0.1	dd
Ophichthus triserialis (Kaup, 1856)	<0.1	sd	F. Melanocetidae		
Ophichthus zophochir Jordan and Gilbert, 1882	<0.1	sd	Melanocetidae sp. 1	<0.1	bp
Ophichthus sp. 2	<0.1	sd	Melanocetidae sp. 2	<0.1	bp
F. Congridae			O. Mugiliformes		
Ariosoma gilberti (Ogilby, 1898)	<0.1	sd	F. Mugilidae		
Bathycongrus varidens (Garman,1899)	<0.1	sd	*Mugil cephalus* Linnaeus, 1758	<0.1	sd
Congridae sp. 1	<0.1	sd	O. Beloniformes		
Paraconger californiensis Kanazawa, 1961	<0.1	sd	F. Exocoetidae		
O. Clupeiformes			*Cheilopogon* sp. 1	<0.1	cp
S.O. Clupeoidei			*Cheilopogon* sp. 2	<0.1	cp
F. Clupeidae			*Cheilopogon* sp. 3	<0.1	cp
Etrumeus teres (DeKay, 1842)	<0.1	cp	*Fodiator rostratus* (Günther, 1866)	<0.1	cp
Harengula thrissina (Jordan and Gilbert, 1882)	<0.1	cp	*Prognichthys tringa* Breder, 1928	<0.1	cp
Opisthonema sp. 1	2.7	cp	F. Hemiramphidae		
Opisthonema sp. 3	4.2	cp	*Oxyporhamphus micropterus* (Valenciennes, 1847)	<0.1	cp
F. Engraulidae			O. Stephanoberyciformes		
Cetengraulis mysticetus (Günther, 1867)	1.8	cp	F. Melamphaidae		
O. Argentiniformes			*Melamphaes* sp. 1	<0.1	mp
S.O. Argentinoidei			Melamphaidae sp. 1	<0.1	mp
F. Microstomatidae			Melamphaidae sp. 2	<0.1	mp
Bathylagoides nigrigenys (Parr, 1931)	<0.1	bp	*Scopelogadus mizolepis* (Günther 1878)	<0.1	mp
Bathylagoides wesethi (Bolin, 1938)	<0.1	bp	O. Beryciformes		
O. Stomiiformes			S.O. Holocentroidei		
S.O. Phoschthyoidei			F. Holocentridae		
F. Phosichthyidae			*Myripristis leiognathos* Valenciennes, 1846	<0.1	sd
Vinciguerria lucetia (Garman, 1899)	14.3	mp	O. Scorpaeniformes		
F. Stomiidae			S.O. Scorpaenidae		
Idiacanthus antrostomus Gilbert, 1890	<0.1	mp	F. Scorpaenidae		
O. Aulopiformes			*Pontinus* sp. 1	3.3	sd
S.O. Synodontoidei			*Scorpaenodes xyris* (Jordan and Gilbert, 1882)	<0.1	sd
F. Synodontidae			F. Triglidae		
Synodus sp. 1	<0.1	sd	*Prionotus* sp. 1		sd
Synodus sp. 2	<0.1	sd	O. Perciformes		
S.O. Alepisauroidei			S.O. Percoide		
F. Scopelarchidae			F. Serranidae		
Scopelarchoides nicholsi (Parr, 1929)	<0.1	bp	*Cephalopholis panamensis* (Steindachner, 1877)	<0.1	sd
F. Paralepididae			*Diplectrum* sp. 1	<0.1	sd
Lestidiops neles (Harry, 1953)	<0.1	op	*Diplectrum* sp. 3	<0.1	sd
Lestidiops sp. 1	<0.1	op	*Epinephelus* sp.1	<0.1	sd
Paralepididae sp. 1	<0.1		*Paralabrax nebulifer* (Girard 1854)	<0.1	sd
O. Myctophiformes			*Paralabrax maculatofasciatus* Steindachner, (1868)	<0.1	sd
F. Myctophidae			*Serranus* sp. 1	<0.1	sd
Benthosema panamense (Tåning, 1932)	2.3	mp	*Serranus* sp. 3	<0.1	sd
Diaphus pacificus Parr, 1931	1.8	mp	F. Apogonidae		
Diogenichthys laternatus (Garman, 1899)	<0.1	mp	*Apogon* sp. 1	<0.1	sd
Hygophum atratum Garman, 1899	<0.1	mp	F. Coryphaenidae		
Lampanyctus parvicauda Parr, 1931	<0.1	mp	*Coryphaena hippurus* Linnaeus, 1758	<0.1	op
O. Lampriformes			F. Carangidae		
F. Trachipteridae			*Caranx caballus* Günther, 1868	<0.1	cp
Trachipterus altivelis Kner, 1859	<0.1	cp	*Caranx sexfasciatus* Quoy and Gaimard, 1825	1	cp
O. Gadiformes			*Chloroscombrus orqueta* Jordan and Gilbert, 1883	<0.1	cp
F. Bregmacerotidae			*Decapterus* sp. 1	<0.1	cp
Bregmaceros bathymaster Jordan & Bollman 1889	35.9	cp	*Naucrates ductor* (Linnaeus, 1758)	<0.1	cp
Bregmaceros sp. 1	<0.1	cp	*Oligoplites saurus* (Bloch and Schneider, 1801)	<0.1	cp
O. Ophidiiformes			*Selar crumenophthalmus* (Bloch, 1793)	<0.1	cp
S.O. Ophidioidei			*Selene peruviana* (Guichenot, 1866)	<0.1	cp
F. Ophidiidae			F. Bramidae		
Cherublemma emmelas (Gilbert, 1890)	<0.1	dd	Bramidae sp. 1	<0.1	op
Ophidion sp. 1	<0.1	sd	F. Lutjanidae		

Table 1. Continued. Order (O); Sub Order (S.O.); Family (F). Habitat (HA): shallow demersal (sd); deep demersal (dd); coastal pelagic (cp); ocean epipelagic (op); mesopelagic (mp); and bathypelagic (bp).

Taxon	%	HA	Taxon	%	HA
Lutjanus peru (Nichols & Murphy, 1922)	<0.1	sd	F. Microdesmidae		
Lutjanus sp.1	<0.1	sd	*Clarkichthys bilineatus* (Clark, 1936)	<0.1	sd
F. Lobotidae			S.O. Acanthuroidei		
Lobotes surinamensis (Bloch, 1790)	<0.1	sd	F. Ephippidae		
F. Gerreidae			*Chaetodipterus zonatus* (Girard, 1858)	<0.1	sd
Eucinostomus currani Zahuranec, 1980	<0.1	sd	Ephippidae sp. 1	<0.1	sd
Eucinostomus dowii (Gill, 1863)	<0.1	sd	F. Luvaridae		
Eucinostomus gracilis (Gill, 1862)	<0.1	sd	*Luvarus imperialis* (Rafinesque, 1810)	<0.1	sd
F. Haemulidae			S.O. Scombroidei		
Haemulidae sp. 1	<0.1	sd	F. Sphyraenidae		
Haemulidae sp. 2	<0.1	sd	*Sphyraena ensis* Jordan & Gilbert, 1882	<0.1	cp
Haemulidae sp. 3	<0.1	sd	F. Scombridae		
Haemulidae sp. 4	<0.1	sd	*Auxis* sp. 1	1.7	op
Haemulidae sp. 5	<0.1	sd	*Euthynnus lineatus* Kishinouye, 1920	<0.1	op
F. Haemulidae			F. Istiophoridae		
Haemulon sp. 1	<0.1	sd	*Kajikia audax* (Philippi, 1887)	<0.1	op
F. Polynemidae			S.O. Stromateoidei		
Polydactylus approximans (Lay & Bennett, 1839)	<0.1	sd	F. Stromateidae		
F. Sciaenidae			*Peprilus* sp. 1	<0.1	sd
Sciaenidae sp. 1	<0.1	sd	F. Nomeidae		
Sciaenidae sp. 2	<0.1	sd	*Cubiceps pauciradiatus* Günther, 1872	<0.1	op
Sciaenidae sp. 3	<0.1	sd	Nomeidae sp. 1	<0.1	
Sciaenidae sp. 4	<0.1	sd	*Psenes sio* Haedrich 1970	<0.1	op
Sciaenidae sp. 5	<0.1	sd	O. Pleuronectiformes		
Sciaenidae sp. 6	<0.1	sd	S.O. Pleuronectoidei		
Sciaenidae sp. 7	<0.1	sd	F. Paralichthyidae		
Sciaenidae sp. 8	<0.1	sd	*Cyclopsetta panamensis* (Steindachner, 1876)	<0.1	sd
F. Kyphosidae			*Etropus* sp. 1	<0.1	sd
Kyphosidae sp. 1	<0.1	sd	Paralichthyidae sp. 1	<0.1	sd
S.O. Labroidei			*Syacium* sp. 1	3.5	sd
F. Pomacentridae			*Syacium* sp. 2	2.9	sd
Abudefduf troschelii (Gill, 1862)	<0.1	sd	F. Pleuronectidae		
Stegastes sp. 1	<0.1	sd	Pleuronectidae sp. 1	<0.1	sd
F. Labridae			F. Bothidae		
Thalassoma sp. 1	<0.1	sd	*Bothus leopardinus* (Günther, 1862)	1.8	sd
S.O. Zoarcoidei			*Bothus* sp. 1		sd
F. Stichaeidae			*Monolene asaedai* Clark, 1936	<0.1	sd
Stichaeidae sp. 1	<0.1	dd	F. Cynoglossidae		
S.O.Trachinoidei			*Symphurus atramentatus* Jordan & Bollman, 1890	<0.1	dd
F. Uranoscopidae			*Symphurus callopterus* Munroe & Mahadeva, 1989	<0.1	dd
Uranoscopidae sp. 1	<0.1	sd	*Symphurus chabanaudi* Mahadeva & Munroe, 1990	<0.1	sd
S.O. Blennioidei			*Symphurus elongatus* (Günther, 1868)	<0.1	sd
F. Blenniidae			*Symphurus melanurus* Clark, 1936	<0.1	sd
Hypsoblennius sp. 1	<0.1	sd	*Symphurus* sp. 1	<0.1	sd
Ophioblennius steindachneri Jordan & Evermann, 1898	<0.1	sd	*Symphurus* sp. 4	<0.1	sd
S.O. Gobioidei			*Symphurus* sp. 5	<0.1	sd
F. Eleotridae			*Symphurus* sp. 6	<0.1	sd
Dormitator latifrons (Richardson, 1844)	<0.1	sd	*Symphurus* sp. 7	<0.1	sd
Eleotridae sp. 1	<0.1	sd	*Symphurus* sp. 8	<0.1	sd
Erotelis armiger (Jordan & Richardson, 1895)	<0.1	sd	*Symphurus* sp. 9	<0.1	sd
F. Gobiidae			*Symphurus williamsi* Jordan & Culver, 1895	<0.1	sd
Ctenogobius manglicola (Jordan & Starks, 1895)	<0.1	sd	O. Tetraodontiformes		
Ctenogobius sagittula (Günther, 1862)	<0.1	sd	S.O. Balistoidei		
Gobiidae sp. 1	<0.1	sd	F. Balistidae		
Microgobius sp. 1	<0.1	sd	*Balistes polilepis* Steindachner, 1876	<0.1	sd
Microgobius sp. 2	<0.1	sd	*Sufflamen verres* (Gilbert & Starks, 1904)	<0.1	sd

(Aceves–Medina, 2003) and Bahía Sebastián Vizcaíno on the west coast of Baja California Sur (Jiménez–Rosenberg *et al*., 2007; Jiménez–Rosenberg, 2008).

The mode in the number of species by sampling station (18 taxa per sample) also shows a higher alpha diversity compared with other regions of the Eastern Pacific (Table 5).

DISCUSSION

This is the first descriptive work on the larval fish assemblage of the Gulf of Tehuantepec which includes 145 taxa from the Eastern Tropical Pacific.

Table 2. Taxonomic list of families collected as larvae in the Gulf of Tehuantepec during July 2007 and May 2008, ordered by their relative abundance (%) and the number of taxa identified in each family (NT).

Family	%	NT	Family	%	NT	Family	%	NT
Bregmacerotidae	40	2	Eleotridae	0.4	3	Melanocetidae	<0.1	2
Phosichthyidae	14.3	1	Coryphaenidae	0.3	1	Triglidae	<0.1	1
Clupeidae	7.2	4	Sphyraenidae	0.3	1	Trachipteridae	<0.1	1
Paralichthyidae	7	5	Paralepididae	0.3	3	Bramidae	<0.1	1
Myctophidae	5.4	5	Balistidae	0.3	2	Microdesmidae	<0.1	1
Scorpaenidae	3.4	2	Melamphaidae	0.2	4	Labridae	<0.1	1
Sciaenidae	2.1	8	Ophichthidae	0.2	5	Istiophoridae	<0.1	1
Bothidae	2.1	3	Ophidiidae	0.2	3	Lobotidae	<0.1	1
Carangidae	2	8	Congridae	0.2	4	Stromateidae	<0.1	1
Engraulidae	1.8	1	Exocoetidae	0.2	5	Kyphosidae	<0.1	1
Cynoglossidae	1.8	13	Serranidae	0.1	8	Pleuronectidae	<0.1	1
Scombridae	1.7	2	Synodontidae	0.1	2	Uranoscopidae	<0.1	1
Gerreidae	1.4	3	Stomiidae	0.1	1	Apogonidae	<0.1	1
Lutjanidae	1.2	2	Pomacentridae	0.1	2	Luvaridae	<0.1	1
Nomeidae	1	3	Polynemidae	0.1	1	Holocentridae	<0.1	1
Hemiramphidae	0.9	1	Ephippidae	0.1	2	Stichaeidae	<0.1	1
Microstomatidae	0.6	2	Mugilidae	0.1	1	Lophiidae	<0.1	1
Haemulidae	0.4	6	Scopelarchidae	<0.1	1			
Gobiidae	0.4	5	Blenniidae	<0.1	2			

Only 50 % of the taxa (73) were identified to species, although almost all the specimens could be assigned to an equivalent category (types), using pigmentation patterns as well as meristic and morphometric characteristics. This allowed us to do a general description of the larval fish composition of this area, as well as a series of comparisons with other better known areas of the Eastern Pacific.

The larval fish assemblage of the Gulf of Tehuantepec consists of a group of dominant species found in both, summer and spring seasons. Contrasting with other areas of the Mexican Pacific Ocean, one of the dominant components is of coastal–pelagic species, the most abundant and frequent of which was *B. bathymaster*. In the California Current *B. bathymaster* is found in low abundances (Moser & Smith, 1993) and in the Gulf of California it constituted only 0.2% of the total abundance (Aceves–Medina *et al*., 2003). Abundance of this species increases off the coasts of Jalisco and Colima, México, where they represent more than 80% of the ichthyoplankton all year round (Franco–Gordo *et al*., 2001; Siordia-Cermeño *et al*., 2006). The abundance of the tropical–subtropical species

Table 3. Total collected fish larvae after the standardized routine and relative abundance by cruise (%) of the most abundant taxa collected in the Gulf of Tehuantepec during July 2007 and May 2008. Geometric mean (G.M) and standard deviation (S.D.) per sample.

Species	jul-07	(%)	may-08	(%)	G.M.	S.D.
Bregmaceros bathymaster	4462	31.4	10453	45.2	41	10.1
Vinciguerria lucetia	3427	24.1	1926	8.3	22.3	7.8
Syacium sp. 1	539	3.8	788	3.4	7.5	4.7
Pontinus sp. 1	625	4.4	623	2.7	4.6	5.5
Syacium sp. 2	212	1.5	868	3.8	3.7	5.5
Diaphus pacificus	488	3.4	185	1	3.1	4.4
Auxis sp. 1	517	3.6	135	0.6	3.1	4.4
Bothus leopardinus	361	2.5	335	1.5	2.9	4.3
Opisthonema sp. 3	170	1.2	1426	6.2	2.2	4.8
Benthosema panamense	412	2.9	481	2.1	2.2	4.5
Oxyporhamphus micropterus	107	0.8	227	1	2.1	3.3
Diogenichthys laternatus	98	0.7	263	1.1	2.1	3.4
Lutjanus peru	167	1.2	170	0.7	2	3.3
Psenes sio	93	0.7	206	1	1.9	3.2
Symphurus elongatus	61	0.4	215	1	1.9	3.2
Caranx sexfasciatus	191	1.3	208	0.9	1.7	3.4
Opisthonema sp. 1	0	0	1014	4.4	1.5	3.9
Cetengraulis mysticetus	29	0.2	663	2.9	1.5	3.3
Eucinostomus dowii	0	0	255	1.1	1.4	2.6

Table 4. Total collected larvae and number of species by adult habitat: shallow demersal (sd); deep demersal (dd); coastal pelagic (cp); ocean epipelagic (op); mesopelagic (mp); bathypelagic (bp); (nd) not determined; (CS) Taxa present in both months. Number in parentheses is the percentage by respective oceanographic survey. Bold numbers represent the geometric mean of the larval abundance by sample ± standard deviation.

Larval abundance								
survey	cp	mp	sd	op	bp	dd	nd	Total
July-07	5399(37.9) **30 ± 8.5**	4571(32.2) **63 ± 6.1**	3205(22.6) **56 ± 3.1**	791(5.6) **13 ± 3.9**	146(1.0) **2 ± 3.3**	58(0.4) **1.2 ± 2.3**	38(0.3) **1 ± 2**	14208 **280 ± 3**
may-08	14253(61.6) **187 ± 3.6**	2972(12.9) **29 ± 6.5**	5216(22.6) **91 ± 2.9**	504(2.1) **5 ± 4.5**	143(0.6) **2 ± 3.1**	28(0.1) **1 ± 1.8**	9(0.03) **1.1 ± 1.4**	23125 **452 ± 2.4**
Number of species								
survey	sd	cp	mp	op	bp	dd	nd	Total
July-07	57 (58.8)	19 (19.6)	10 (10.1)	5 (5.2)	3 (3.1)	1 (1)	2 (2.1)	97
may-08	68 (61.8)	19 (17.3)	9 (8.2)	5 (4.5)	5 (4.5)	3 (2.7)	1 (0.9)	110
Total	91	25	12	6	5	3	3	145
CS	34	13	7	4	3	1		62

B. bathymaster decreases south of the Jalisco and Colima area in the Gulf of Tehuantepec, where they represent between 31 to 45% of the total catches. There are no previous studies describing the seasonal or spatial variations in the abundance of this species. However, Aceves–Medina *et al*. (2003) found that *B. bathymaster* larvae were less abundant in the Gulf of California during the warm regime registered in the Pacific Ocean after 1975 than during the cold regime 1950–1975 Moser *et al*. (1974).

Distribution of *B. bathymaster* in the American Pacific Ocean has been determined from adult records in the Gulf of California and Panama (http://www.fishbase.org; Bianchi, 1991; Tapia–García *et al.*, 1994; Castro–Aguirre *et al*., 1999; Fröese & Pauly, 2009), and by the presence of larvae between both areas (Franco–Gordo *et al*., 2001; Siordia-Cermeño *et al*., 2006). In our surveys, several juveniles of *B. bathymaster* were collected in the Bongo nets from the coastal sampling stations off Bahía Tangolunda and Salina Cruz. In addition to these juvenile records, during the spring survey an adult specimen of 7 cm LP with a Petersen drag of 5 K off Puerto Escondido (15° 50' N; 97° 9' W) was collected at a 160 m depth (Bastida–Zavala, com. pers).

Although the juveniles were not included in the larval abundance data, because the ichthyoplankton protocol analysis excludes them (Smith & Richardson, 1979), the high abundance of *B. bathymaster* and the presence of juvenile and adults suggest the importance of the Gulf of Tehuantepec as a reproduction, nursery and recruitment area for this species, which although it has no commercial value, it is ecologically relevant in the oceanic trophic webs (Zavala–García & Flores–Coto, 1994; Siordia–Cermeño *et al*., 2006).

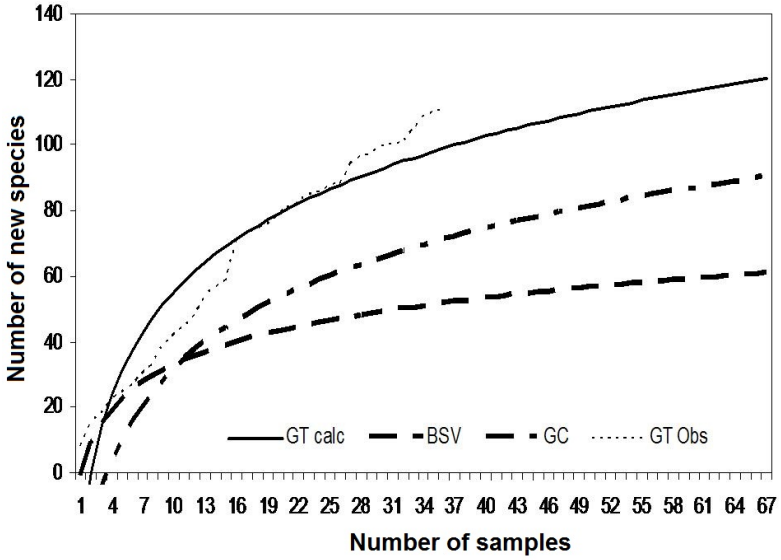

Figure 2. Cumulative curves for Bahía Sebastián Vizcaino (BSV; dashed-dot line); Gulf of California (GC; dashed line); observed data for the Gulf of Tehuantepec (GT Obs; dotted line) and adjusted curve for the Gulf of Tehuantepec (GT Calc; continuous line).

Table 5. Comparative list of species richness (R) and families (NF) by sampling region in the northern hemisphere of the Eastern Pacific including the total number of samples collected (NS) and the mode (M) of the number of taxa by positive station. (ND) = No available data.

	NS	R	M	NF.	Source
California Current	31,214	249	6	ND	Moser & Smith, 1993
Sebastián Vizcaíno	377	208	8	78	Jiménez-Rosenberg *et al*., 2007
Gulf of California	464	283	4	53	Aceves-Medina 2003
Jalisco-Colima	132	102	ND	ND	Franco-Gordo *et al*., 1999
Gulf of Tehuantepec	68	145	18	55	This work
Eastern Tropical Pacific	482	ND	ND	56	Ahlstrom, 1971; Ahlstrom, 1972
Costa Rica Dome	ND	ND	ND	37	Aguilar-Ibarra & Vicencio-Aguilar, 1994

Other coastal pelagic species also included between the most abundant species of the Gulf of Tehuantepec, were *Opisthonema* sp. 1, *Opisthonema* sp. 3 and *Cetengraulis mysticetus*; all of them have commercial and/or ecological relevance. The *Opisthonema* morpho-types (sp. 1 and sp. 2) were identified according to Funes–Rodríguez *et al*. (2004) and based on the number of miomers and the pigmentation pattern in the cephalic region as well as in the caudal region below the notochord. During the identification processes of fish larvae from the Gulf of Tehuantepec, we observed a number of larvae different from *Opisthonema* sp. 1 and *Opisthonema* sp. 2, because of the presence of a group of pigments in the anal region. These specimens were designated as *Opisthonema* sp. 3.

Opisthonema sp. 1 was present only during the spring survey, while *Opisthonema* sp. 3 was found in both seasons. Three *Opisthonema* species are distributed in the area (*O. libertate*, *O. bulleri* and *O. medirastre*) However, until now it is not possible to assign the species name to any of the three types found (Funes–Rodríguez *et al*., 2004). The finding of a third morphotype of *Opisthonema* offers a possibility to obtain meristic and morphometric data useful in future work in the description of these larvae at species level.

The second most abundant species in the Gulf of Tehuantepec was *Vinciguerria lucetia,* which together with other mesopelagic species such as *Benthosema panamense, Diaphus pacificus* and *Diogenichthys laternatus* are characteristics of the oceanic ecosystem of the Gulf of Tehuantepec and other regions of the Pacific Ocean (Moser & Smith, 1993; Aceves–Medina *et al*., 2004; Funes–Rodríguez *et al*., 2006).

An important characteristic of the larval fish assemblage of the Gulf of Tehuantepec is the high larval abundance of shallow demersal species such as *Syacium*, *Bothus* and *Pontinus* along with many others, which together represented 22 % of the abundance. This feature, along with the lower abundance of larvae of mesopelagic species during spring, is relevant since in other regions of the Eastern Pacific, including the Gulf of California, the abundance as well as the number of species from demersal environments is lower than that of mesopelagic species. That is the case off the west coast of the Baja California Peninsula, where larvae of demersal species are the most abundant, reaching 18% of the total (Jiménez–Rosenberg *et al*., 2000). In the Gulf of California demersal species larvae may represent 16 % of the total catches (Aceves–Medina *et al*., 2003).

High abundance of shallow demersal species is remarkable since most of the sampling stations are far from the continental shelf in the Gulf of Tehuantepec. Presence of this kind of larvae in the oceanic region suggests oceanographic processes that transport fish larvae of neritic species off the Gulf of Tehuantepec, and could explain also the lower abundance of larvae of mesopelagic species. These processes may play a key role in the recruitment to the adult fish populations and should be studied in a multidisciplinary context.

Cumulative curves show that with the same sampling effort it is possible to obtain larvae of almost 33% more species than in the Gulf of California (Aceves–Medina *et al*., 2003), and 60% more species than in Bahía Sebastián Vizcaíno (Jiménez–Rosenberg *et al.,* 2007). Alpha diversity is also higher since the number of species per sample in the Gulf of Tehuantepec is more than twice than in any other region studied in the Eastern Pacific. These results indicate that the Gulf of Tehuantepec is an important reproduction area, mainly of species of coastal pelagic and demersal environments.

Even to family level, the Gulf of Tehuantepec has a higher diversity than that found in the Domo de Costa Rica and is quite similar to that found in the whole area of the Eastern Tropical Pacific between 20º N and 20º S (Table 5). The species richness found showes the importance of this region, and diversity indices suggest that the area could be considered one of the areas

of highest diversity in the Mexican Pacific, even when compared with the Gulf of California, considered one of the most diverse ecosystems in the Eastern Pacific (Walker, 1960; Thompson *et al*., 1979; Castro–Aguirre *et al*., 1995; Aceves–Medina *et al*., 2003).

Although the primary production of the Gulf of Tehuantepec is lower than that found in the upwelling ecosystems of middle latitudes of the Eastern Pacific (Ortega–García *et al*., 2000), this region, together with the Gulf of Papagayo and the Domo de Costa Rica, represents the only known source of enrichment by nutrients supply to the surface along the entire area of the Central America Pacific coast (Ortega–García *et al*., 2000). This together with the high species richness found, make the Gulf of Tehuantepec a key area in the understanding of the oceanic ecosystems from low latitudes, which are poorly studied.

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