

# Ichthyofaunal list of the continental slope of the southern Gulf of Mexico

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Academic editor: M. Elina Bichuette | Received 26 November 2018 | Accepted 3 January 2019 | Published 16 May 2019

<http://zoobank.org/D1A66290-1018-490B-9832-2E51ED42D66B>

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**Citation:** Ramírez JM, Vázquez-Bader AR, Gracia A (2019) Ichthyofaunal list of the continental slope of the southern Gulf of Mexico. ZooKeys 846: 117–132. <https://doi.org/10.3897/zookeys.846.31944>

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## Abstract

Four oceanographic cruises were carried out between April 2011 and May 2013 on the continental slope of the southern Gulf of Mexico (GoM) in a depth range of 290 to 1200 m on board the R/V JUSTO SIERRA. A total of 91 trawls covered a total swept area of 170.49 hectares. We recorded 177 fish species belonging to 80 families. Fifteen species extended their distribution into the south of the gulf and 37 increased their depth ranges. Five species could have commercial importance: *Aphanopus carbo* Lowe, 1839; *Hydrolagus mirabilis* (Collett, 1904); *Helicolenus dactylopterus* (Delaroché, 1809); *Lophius gastrophysus* Miranda Ribeiro, 1915, and *Merluccius albidus* (Mitchill, 1818). The most abundant species were *Polymixia lowei* Günther, 1859; *Parasudis truculenta* (Goode & Bean, 1896); *M. albidus*, *Chlorophthalmus agassizi* Bonaparte, 1840; *Dibranchius atlanticus* Peters, 1876; *Nezumia aequalis* (Günther, 1878); *Yarella blackfordi* Goode & Bean, 1896; and *Laemonema barbatulum* Goode & Bean, 1883. High values of fish species richness, diversity, and evenness were registered throughout the study area. A high percentage of the fish species (97%) collected during this project are distributed in the entire GoM. Most of the species showed a wide depth distribution; however, a vertical zonation of species can be observed.

## Keywords

Deep water, fishes, new records, species richness

## Introduction

The Gulf of Mexico (GoM) is one of the most productive and economically important ecosystems in the world (Cato 2009, Tunnell 2009), and its large biodiversity makes it one of the most diverse seawater bodies (Felder et al. 2009). Due to its ecological and economic importance, ichthyofauna studies initially focused on commercial species. Research on fish biodiversity in the GoM, which began in 1850 (Darnell and Defenbaugh 1990), became more systematic and extensive since 1950. A total of 1541 species has been reported in the GoM in the different types of habitats that exist in this large ecosystem (McEachran 2009). Nevertheless, more emphasis has been placed on coastal regions because they are more accessible and economical to survey compared to deeper areas and the open sea.

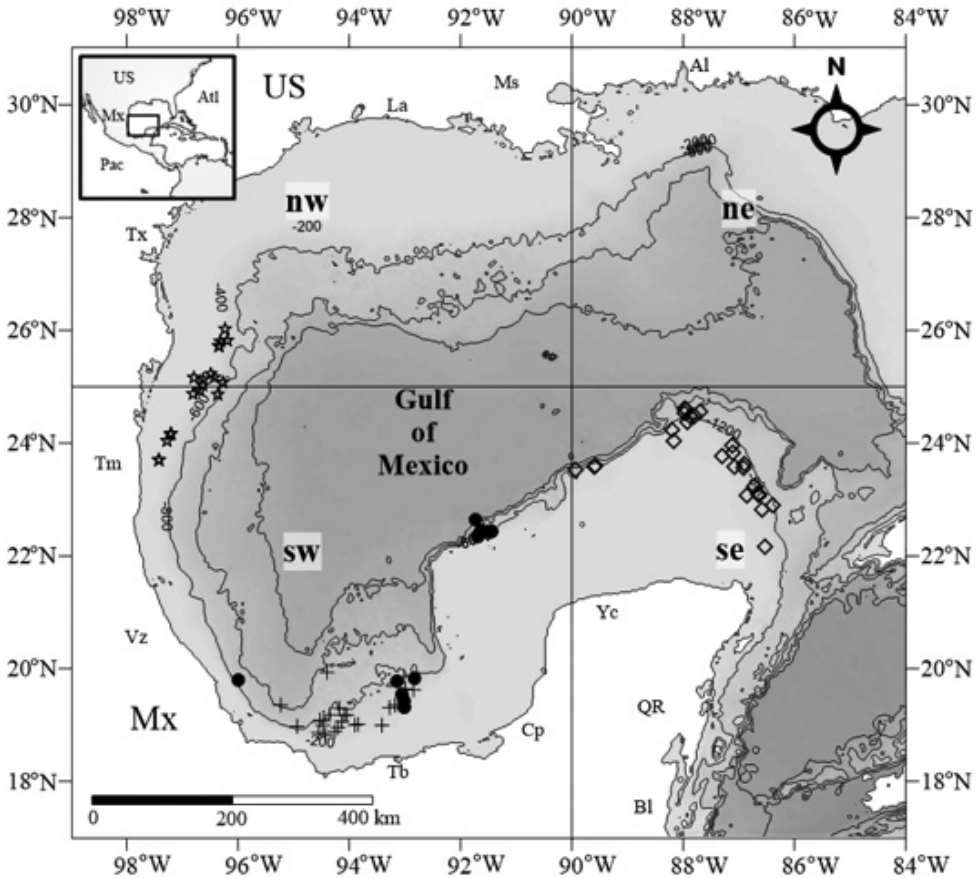
Few investigations about fish biodiversity have been conducted on the continental slope, and most have focused on different ecological aspects of demersal fish communities in the northern part of the GoM (Pequegnat et al. 1990, Powell et al. 2003). More than 126 mesopelagic fish species were found in this region by Ross et al. (2010), who compared the composition of mesopelagic fishes in three different habitats located at depths between surface and 1000 m. Sulak et al. (2007) documented 53 benthic fishes associated with deep water coral habitats in the north-central gulf. McEachran and Fechhelm (1998) produced one of the most complete ichthyological inventories for the GoM and for the Caribbean Sea's continental slope. In addition, Anderson et al. (1985), Saavedra-Díaz et al. (2004) and Paramo et al. (2015) issued complementary reports of 44 species in this region. Others studies of the deep-water fishes in the Caribbean, but concerning to deep reef fishes have been conducted by Colin (1974); Thresher and Colin (1986); Baldwin and Robertson (2014); Baldwin et al. (2016) and Quattrini et al. (2017).

Since there were not studies of fish communities in the southern deep-water of the GoM, the ichthyological inventory of this ecosystem is not yet completed. The Mexican portion of the GoM deep water has recently become an area of interest because of its oil extraction potential (PEMEX 2016) and its potential fishing resources, where at least three important shrimp species have recently been discovered (Gracia et al. 2010). In a potential scenario of exploitation of both living and non-living resources of deep waters of the GoM, it is crucial to acquire more knowledge about this ecosystem. Biodiversity inventories need to be developed to understand, manage, and conserve these resources.

In this study we present information of the fish biodiversity of the scarce explored continental slope of the southern GoM. Our study is the first one that systematically analyzes the deep-water fish fauna in this region.

## Materials and methods

The GoM is in a subtropical region that measures 1600 km from east-to-west and 1300 km from north-to-south. It is influenced by the Caribbean Sea due to the transport of water masses via the Loop Current flowing into the gulf through the Yucatan



**Figure 1.** Locations of the oceanographic cruises: COBERPES 2; COBERPES 3; COBERPES 4; and COBERPES 5. Abbreviations: ne: north-east; nw: north-west; se: south-east; sw: south-west; Al: Alabama; Atl: Atlantic; Bl: Belize; Cp: Campeche; La: Louisiana; Ms: Mississippi; Mx: Mexico; Pac: Pacific; QR: Quintana Roo; Tb: Tabasco; Tm: Tamaulipas; Tx: Texas; US: United States; Vz: Veracruz; Yc: Yucatan. Gulf of Mexico division taken from Felder et al. (2009).

Channel and out of the gulf through the Straits of Florida. Winds, especially in winter also impact gulf circulation (Monreal-Gómez et al. 2004) (Fig. 1).

This research forms part of the project “Biodiversity and Potential Fishing Resources in Deep waters of the Gulf of Mexico,” through which oceanographic cruises (Benthic communities and potential fishing resources in the Gulf of Mexico deep waters, COBERPES) were conducted on the Mexican continental slope of the GoM on board the R/VJUSTO SIERRA of the Universidad Nacional Autónoma de México.

Four oceanographic cruises were carried out from April 2011 to May 2013: COBERPES 2 and COBERPES 3 on the Yucatan Slope; COBERPES 4, off the coast of Tamaulipas and COBERPES 5 on the Campeche Bank (Table 1). The benthic megafauna of soft bottom substrates was sampled in a depth range of 290–1200 m, using

**Table 1.** Geographic location and data on oceanographic cruises.

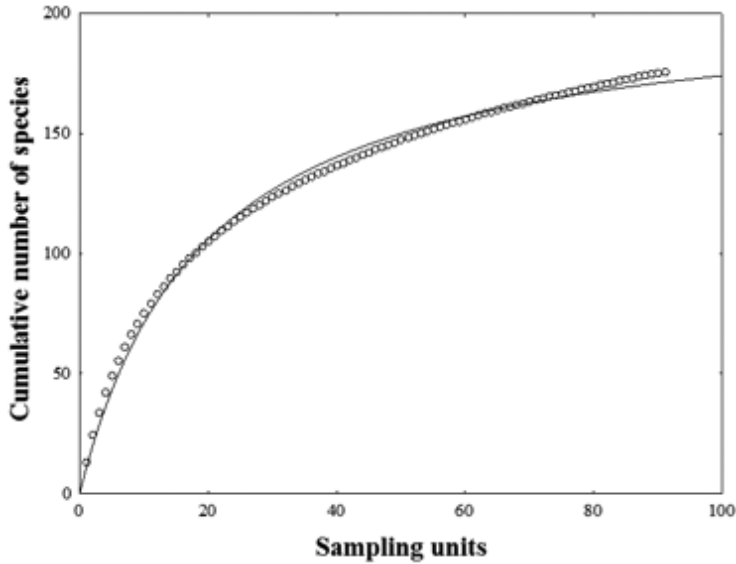
Cruise	Date	Geographic locations				Number of samples	Area (ha)
COBERPES 2	07–15 Apr 2011	23°02'46"N, 86°26'34"W	23°30'98"N, 89°49'42"W	24°22'60"N, 87°42'98"W	22°53'05"N, 86°15'49"W	28	46.79
COBERPES 3	13–19 Nov 2011	22°25'65"N, 91°26'49"W	19°19'38"N, 93°02'54"W	22°23'93"N, 91°37'41"W	19°33'82"N, 93°01'46"W	20	34.87
COBERPES 4	23–30 Aug 2012	23°30'73"N, 97°12'79"W	25°47'30"N, 96°14'83"W	24°54'93"N, 96°36'91"W	25°45'97"N, 96°13'05"W	20	38.58
COBERPES 5	22–31 May 2013	19°03'92"N, 94°05'53"W	18°45'66"N, 94°22'13"W	19°00'80"N, 93°50'35"W	19°48'22"N, 92°59'11"W	23	50.25

a semi-commercial shrimp trawling net with an 18m mouth, a 4.5cm mesh and a 1.5cm cod-end opening. Since information about sea bottom was lacking, sea bed was previously explored using a Multihaz EM 300 echo sounder and a Topas PS-18 sub-bottom profiler. After finding adequate substrate, 30-minute trawls were performed at an average velocity of 77.16 m/min. The distance of each tow was determined by GPS readings. Fauna samples were sorted by taxonomic groups, weighed, and preserved in 10% formalin on board.

In the laboratory, fishes were identified to species level. The names, authorities, and years of the descriptions were cross-referenced against the Eschmeyer database (2017), as well as the geographic and bathymetric distribution of the species was consulted in different web sites: Ocean Biogeographic Information System (OBIS 2018); Smithsonian National Museum of Natural History; Biodiversity of the Gulf of Mexico Database (Moretzsohn et al. 2017); Texas A & M University Corpus Christi, Harte Research Institute for Gulf of Mexico Studies (2017); FishNet 2 (2013); World Register of Marine Species (WoRMS 2017) and FishBase (Froese and Pauly 2017). Each individual was measured, weighed, preserved in 70% alcohol, and retained in the Reference Collection of the Laboratorio de Ecología Pesquera de Crustáceos del Instituto de Ciencias del Mar y Limnología, UNAM. Number of fish species vs. sampling effort was analyzed to determine sample size using the Clench model (Jiménez-Valverde and Hortal 2003) and the freeware Stimates v8 (Colwell 2006). With the biological data was examined the abundance (individuals/ha), richness (number of species), diversity (Shannon and Wiener 1963), and evenness (Pielou 1977) of the fish communities in different sampling areas. The bathymetric distribution of the species was recorded considering the average depth of each trawl.

## Results

Ninety-one trawls covering a 290–1200 m depth range were done in the different regions of the southern GoM during the four oceanographic cruises. The numbers of successful trawls at each depth stratum were 300 m: 17; 400 m: 11; 500 m: 16; 600 m: 8; 700 m:



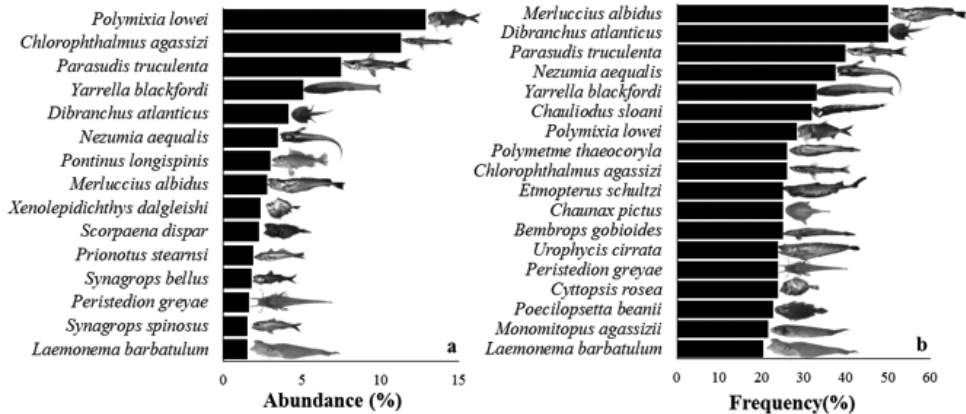
**Figure 2.** Plot for fish species accumulation for the total sample. Key: circles, random curve; continuous line, fit curve of Clench function ( $S_n = (10.79*n)/(1+(0.0520*n))$ ). Each sample unit consisted of 30 minutes trawl at an average speed of 77.16 m/min (2.5 knots).

11; 800 m: 11; 900 m: 6; and 1000 m: 4, corresponding to 170 hectares total swept area. Seven trawls failed (Table 1). A total of 9781 fishes was caught, belonging to 80 families and 177 species (Table 2). The species accumulation curve related to the number of samples did not reach a clear asymptote; however, data adjusted with a Clench model suggests that 91% species richness of the southern GoM continental slope was recorded (Fig. 2).

The most abundant species were *P. lowei* (1206 individuals), *P. triculenta*, *M. albidus*, *C. agassizi*, *D. atlanticus*, *N. aequalis*, *Y. blackfordi*, and *L. barbatulum*. Among these, *P. lowei* and *C. agassizi* are outstanding, with a relative abundance greater than 10%, and *D. atlanticus*, and *M. albidus* with a relative frequency of more than 50% (Fig. 3).

The lowest richness was found in the Yucatan slope area near the Caribbean Sea (COBERPES 2), with a total of 27 species and a mean of  $11.81 \pm 5.71$  (SD) species per trawl, whereas, the highest one was registered in the Campeche Bay (COBERPES 5) with 39 species ( $17.26 \pm 9.06$  species per trawl), however, a high fish species richness (>30 species) was recorded at different sites throughout the GoM (Fig. 4a). The highest fish abundance was registered in the Yucatan continental slope, close to the Caribbean Sea (COERPES 2), with 412.46 individuals/ha recorded and a sample mean of  $76.83 \pm 19.18$  individuals/ha (Fig. 4b). High fish diversity (Fig. 4c) and evenness (Fig. 4d) were recorded in several locations along the entire gulf, except in the area close to the Caribbean Sea (COBERPES 2).

Fifteen species extended their distribution into the continental slope of the southern GoM: *Eptatretus caribbeus* Fernholm, 1982; *Ventrifossa mucocephalus* Marshall, 1973; *L. barbatulum*; *Brotulotaenia nigra* Parr, 1933; *Lophiodes beroe* Caruso, 1981;



**Figure 3.** Abundance and frequency of the fish species: **a** Abundance (%) and **b** Frequency (%).

**Table 2.** List of the fish community. Presence and depth distribution ranges of fish species in the different cruises and literature reported (McEachran 2009, Ocean Biogeographic Information System (OBIS), Eschmeyer 2017, Moretzsohn et al. 2017, FishNet 2 2013, World Register of Marine Species 2017, and Froese and Pauly 2017). Key: \* species which extended their distribution into the south of the Gulf of Mexico; ne: north-east; nw: north-west; se: south-east; sw: south-west; Al: Alabama; Atl: Atlantic; Bh: Bahamas; Bl: Belize; Cp: Campeche; Cb: Caribbean; Cu: Cuba; La: Louisiana; Ms: Mississippi; Mx: Mexico; QR: Quintana Roo; Tb: Tabasco; Tx: Texas; Tm: Tamaulipas; US: United States; Vz: Veracruz; Yc: Yucatan. \*\* Species which extended their depth ranges.

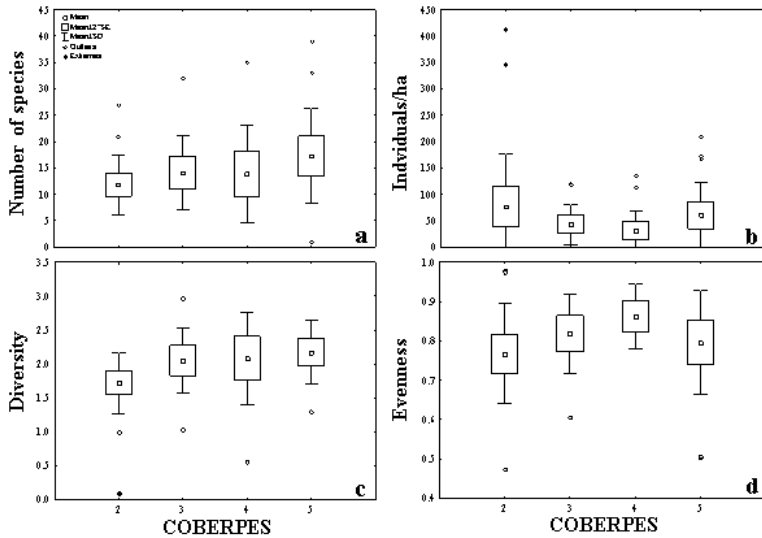
Specie	COBERPES cruises				Species depth range (m)	Reported distribution and depth range (m)
	2	3	4	5		
<i>Antigonia capros</i> Lowe, 1843		X			296	entire/50–900
<i>Antigonia combatia</i> Berry & Rathjen, 1959	X				308	Fl, Al, Bl/68–585
<i>Aphanopus carbo</i> Lowe, 1839			X		823	Atl, Vz/200–2300
<i>Apristurus laurussonii</i> (Saemundsson, 1922)	X				562–937	Ms, Al, Tx, Fl, Mx/500–1000
<i>Argentina georgei</i> Cohen & Atsides, 1969**	X	X	X	X	300–825	entire/220–457
<i>Argyrolepiscus aculeatus</i> Valenciennes, 1850	X		X	X	436–825	entire/100–2056
<i>Aristostomias tittmanni</i> Welsh, 1923	X				974	entire/100–2000
<i>Astronesthes similis</i> Parr, 1927				X	611	entire/0–800
<i>Atractodenchelys phrix</i> Robins & Robins, 1970**	X			X	534–600	Cb, Fl, Cu, Vz/385–425
<i>Baldwinella aureorubens</i> (Longley, 1935)			X	X	300–611	Mx/91–610
<i>Baldwinella vivanus</i> (Jordan & Swain, 1885)	X		X	X	300	Mx/20–610
<i>Barathronus bicolor</i> Goode & Bean, 1886					846	entire/366–1561
<i>Barbantus curvifrons</i> (Roule & Angel, 1931)			X		953	ne, nw, Fl/0–4500
<i>Bathylupea argentea</i> Goode & Bean, 1896**	X		X	X	300–677	entire/366–677
<i>Bathycongrus dubius</i> (Breder, 1927)				X	327	entire/120–886
<i>Bathycongrus vicinalis</i> (Garman, 1899)	X				477	Mx, US, Cb/101–503
<i>Bathygadus favosus</i> Goode & Bean, 1886	X	X			904–1068	entire/770–2745
<i>Bathygadus macrops</i> Goode & Bean, 1885**	X	X	X	X	494–1068	entire/200–777
<i>Bathygadus melanobranchus</i> Vaillant, 1888	X	X	X	X	602–1071	entire/400–2600
<i>Bathypterois bigelowi</i> Mead, 1958	X		X		534–780	entire/377–986
<i>Bathypterois gyallator</i> (Goode & Bean, 1886)		X			953	entire/878–4720
<i>Bathypterois quadrifilis</i> Günther, 1878	X				865	entire/462–1408

Specie	COBERPES cruises					Reported distribution and depth range (m)
	2	3	4	5	Species depth range (m)	
<i>Bathypterois viridensis</i> (Roule, 1916)	X		X	X	593–904	entire/476–1477
<i>Bathyraconger vicinus</i> (Vaillant, 1888)	X	X			477	ne, nw, Tm/100>1000
<i>Bembrops anatostris</i> Ginsburg, 1955**	X	X	X	X	300–611	entire/82–538
<i>Bembrops gobioides</i> (Goode, 1880)**	X	X	X	X	300–825	entire/82–740
<i>Bentholesmus simonyi</i> (Steindachner, 1891)*	X			X	436–500	ne/200–900
<i>Bentholesmus tenuis</i> (Günther, 1877)	X	X	X	X	300–825	nw, ne, Mx/200–850
<i>Bolinichthys supralatenalis</i> (Parr, 1928)	X		X	X	599–677	entire/40–850
<i>Bregmaceros atlanticus</i> Goode & Bean, 1886				X	300–462	entire/50–2000
<i>Bregmaceros cantori</i> Milliken & Houde, 1984***	X				812	ne/0–475
<i>Bregmaceros houdei</i> Saksena & Richards, 1986***	X		X		346–611	ne/>50
<i>Brotulotaenia nigra</i> Parr, 1933***			X	X	800–953	Atl/1000–1100
<i>Caulolatilus cyanops</i> Poey, 1866		X			300–500	entire/45–459
<i>Chascanopsetta lugubris</i> Alcock, 1894	X				358–426	entire/60–3210
<i>Chauliodus sloani</i> Bloch & Schneider, 1801	X	X	X	X	300–953	entire/0–4700
<i>Chaunax pictus</i> Lowe, 1846	X	X	X	X	321–865	ne, nw, Tb/200–978
<i>Chiasmodon</i> sp.				X	780	ne, Tb, QR
<i>Chlorophthalmus agassizi</i> Bonaparte, 1840	X	X	X	X	300–825	entire/50–3000
<i>Citharichthys dinoceros</i> Goode & Bean, 1886	X				336–423	ne, QR, Bl, Cu/180–2000
<i>Coccorella atlantica</i> (Parr, 1928)			X		995	entire/50–1000
<i>Coelorinchus caribbaeus</i> (Goode & Bean, 1885)**		X	X	X	300–825	entire/200–700
<i>Coelorinchus caelorbincus</i> (Risso, 1810)	X		X	X	436–800	entire/90–1485
<i>Coelorinchus occa</i> (Goode & Bean, 1885)	X	X	X	X	321–820	entire/400–2220
<i>Coelorinchus ventrilux</i> Marshall & Iwamoto, 1973	X	X	X	X	300–534	se, sw/300>500
<i>Coloconger meadi</i> Kanazawa, 1957		X	X		494–846	Tm, Vz, ne, nw/366–925
<i>Conocara macropterum</i> (Vaillant, 1888)**	X	X		X	354–1071	Mx/800–2200
<i>Coryphaenoides alateralis</i> Marsahl & Iwamoto, 1973	X				904	Mx/1035–1116
<i>Coryphaenoides mexicanus</i> (Parr, 1946)	X				534–937	Mx/110–1600
<i>Coryphaenoides zaniophorus</i> (Vaillant, 1888)	X		X	X	677–1065	entire/400–2775
<i>Cruvinaja rugosa</i> Bigelow & Schroeder, 1958	X	X	X		321–825	Mx/366–1007
<i>Cyttopsis rosea</i> (Lowe, 1843)	X	X	X	X	300–825	Mx/100>1000
<i>Dactylobatus clarkii</i> (Bigelow & Schroeder, 1958)	X				626	Mx/366–1000
<i>Diaphus dumerilii</i> (Bleeker, 1856)	X		X		423–823	entire/0–850
<i>Diaphus fragilis</i> (Taning, 1928)			X		823	entire/15–1313
<i>Dibranchius atlanticus</i> Peters, 1876	X	X	X	X	300–1071	entire/22–1300
<i>Dicrolene introniger</i> Goode & Bean, 1883		X	X	X	321–1071	entire/200–1785
<i>Diplacanthopoma brachysoma</i> Günther, 1887	X		X		494–766	entire/439–1670
<i>Dipturus oregoni</i> (Bigelow & Schroeder, 1958)		X			611	Mx/369–1079
<i>Dipturus teevani</i> (Bigelow & Schroeder, 1951)				X	540–800	Cp/311–940
<i>Directmoides pauciradiatus</i> (Woods, 1973)**	X	X	X	X	321–800	entire/0–600
<i>Epigonus denticulatus</i> Dieuzeide, 1950	X	X	X	X	354–800	Mx/130–830
<i>Epigonus macrops</i> (Brauer, 1906)			X		766–823	entire/550–1300
<i>Epigonus occidentalis</i> Goode & Bean, 1896	X			X	573–700	Vz, Tm/360–737
<i>Epigonus oligolepis</i> Mayer, 1974	X				540–619	Mx/380–660
<i>Epigonus pandionis</i> (Goode & Bean, 1881)		X	X	X	419–494	Cp/200–600
<i>Epigonus pectinifer</i> Mayer, 1974			X		346–677	Mx/100–1200
<i>Eptatretus caribbeaus</i> Fernholm, 1982***	X				597	Cb/300–400
<i>Espringeria foliostris</i> Bigelow & Schroeder, 1951		X	X	X	354–800	ne, nw, se, sw/50–1052
<i>Etmopterus schultzi</i> Bigelow, Schroeder & Springer, 1953	X	X	X	X	300–852	entire/200–1000
<i>Etmopterus virens</i> Bigelow, Schroeder & Springer, 1953	X	X	X	X	392–800	Mx/100–1000
<i>Gadella imberbis</i> (Vaillant, 1888)	X	X	X	X	300–974	Mx, Cb, Cu/70>900
<i>Gadomus arcuatus</i> (Goode & Bean, 1886)**	X	X	X	X	321–1068	entire/610–1370
<i>Gadomus dispar</i> (Vaillant, 1888)		X	X		611–677	Tm/548–1105
<i>Gadomus longifilis</i> (Goode & Bean, 1885)**	X	X	X	X	321–1071	entire/630–2168

Specie	COBERPES cruises					Species depth range (m)	Reported distribution and depth range (m)
	2	3	4	5			
<i>Galeus arae</i> (Nichols, 1927)	X	X				358–780	Mx/250–750
<i>Gibberichthys pumilus</i> Parr, 1933	X					746	entire/300–1100
<i>Gigantura chuni</i> Brauer, 1901	X					540	entire/0–1830
<i>Gymothorax kolpos</i> Böhlke & Böhlke, 1980	X					336	entire/30–300
<i>Halieutichthys aculeatus</i> (Mitchill, 1818)		X				611	entire/8–820
<i>Halosaurus ovenii</i> Johnson, 1864	X	X	X	X		321–1068	entire/300>2000
<i>Helicolenus dactylopterus</i> (Delaroche, 1809)	X					426	Mx/50–1100
<i>Hemantias leptus</i> (Ginsburg, 1952)		X				611	entire/35–640
<i>Heptanchias perlo</i> (Bonnaterre, 1788)				X		436	entire/0–1000
<i>Hollandia hollardi</i> Poey, 1861	X	X		X		300–800	Mx/230–915
<i>Hoplostethus mediterraneus</i> Cuvier, 1829*	X		X	X		354–800	ne/100–1750
<i>Hoplunnis tenuis</i> Ginsburg, 1951**		X		X		302–611	entire/30>400
<i>Hydrolagus alberti</i> Bigelow & Schroeder, 1951		X	X	X		494–1068	entire/348–1470
<i>Hydrolagus mirabilis</i> (Collett, 1904)	X		X	X		462–812	entire/450–1933
<i>Hygophum reinhardtii</i> (Lütken, 1892)	X					611	entire/0–1100
<i>Hymenocephalus aterrimus</i> Gilbert, 1905		X				354–540	entire/340–1348
<i>Hymenocephalus billsam</i> Marshall & Iwamoto, 1973	X					573–711	entire/400–900
<i>Hymenocephalus italicus</i> Giglioli, 1884	X	X	X	X		428–800	entire/100–1400
<i>Ijimaia antillarum</i> Howell Rivero, 1935**	X	X	X	X		462–1068	entire/439>700
<i>Laemonema barbatulum</i> Goode & Bean, 1883*	X	X	X	X		426–937	QR/50–1620
<i>Leptoderma macrops</i> Vaillant, 1886	X	X	X	X		700–1065	Mx/500–2000
<i>Leuconaja garmani</i> (Whitley, 1939)**	X	X	X	X		300–800	Mx/37–530
<i>Leuconaja lentiginosa</i> (Bigelow & Schroeder, 1951)**	X	X	X	X		346–852	entire/53–538
<i>Lophiodes beroe</i> Caruso, 1981*	X	X		X		462–735	ne/347–860
<i>Lophiodes monodi</i> (Le Danois, 1971)**	X	X		X		419–800	ne, se/366–549
<i>Lophiodes reticulatus</i> Caruso & Surtkus, 1979	X					590–619	entire/64–820
<i>Lophius gastrophysus</i> Miranda Ribeiro, 1915	X					599	entire/40–700
<i>Luciobrotula corethromycter</i> Cohen, 1964	X	X				606–846	Mx/220–1830
<i>Macroramphosus scolopax</i> (Linnaeus, 1758)*	X					308	ne, nw, Cu/25–600
<i>Malacocephalus laevis</i> (Lowe, 1843)	X	X	X	X		300–800	entire/200–1000
<i>Malacocephalus occidentalis</i> Goode & Bean, 1885	X	X	X	X		308–800	entire/140–1495
<i>Merluccius albidus</i> (Mitchill, 1818)	X	X	X	X		300–852	entire/80–1170
<i>Monolene sessilicauda</i> Goode, 1880	X	X				336–1046	ne, nw, sw/0>3000
<i>Monomitopus agassizii</i> (Goode & Bean, 1896)	X	X	X	X		300–1071	entire/48–1125
<i>Myctophum nitidulum</i> Garman, 1899			X			823	entire/0–1537
<i>Nemichthys scolopaceus</i> Richardson, 1848		X				321	ne, nw, Yc, Cu/100–4337
<i>Neopinnula americana</i> (Grey, 1953)			X	X		300–370	Yc/0–600
<i>Neoscopelus macrolepidotus</i> Johnson, 1863*	X	X	X	X		300–852	ne, nw, Cu, Tb/300–1180
<i>Neoscopelus microchir</i> Matsubara, 1943*	X			X		300–814	ne, nw, Cu, Bh/60>900
<i>Nettastoma melanurum</i> Rafinesque, 1810	X	X	X	X		300–852	entire/37–1647
<i>Nezumia aequalis</i> (Günther, 1878)	X	X	X	X		321–973	entire/200–2320
<i>Nezumia cyrano</i> Marshall & Iwamoto, 1973**	X	X	X	X		321–1071	entire/400–1324
<i>Nezumia suilla</i> Marsahll & Iwamoto, 1973	X					904–1046	entire/860–1500
<i>Oxinotus caribbaeus</i> Cervigón, 1961**				X		800	Yc/402–457
<i>Parasudis truculenta</i> (Goode & Bean, 1896)	X	X	X	X		300–846	entire/0>1000
<i>Parazen pacificus</i> Kamohara, 1935	X					300	Cp, Cu/145–512
<i>Peristedion ecuadorensis</i> Teague, 1961*	X	X				392–814	ne, nw/324–910
<i>Peristedion greyae</i> Miller, 1967**	X	X	X	X		300–1071	entire/60–914
<i>Peristedion longispatha</i> Goode & Bean, 1886	X			X		302–553	entire/101–787
<i>Peristedion miniatum</i> Goode, 1880		X	X	X		300–500	entire/64–910
<i>Peristedion thompsoni</i> Fowler, 1952*	X					358–423	ne, nw, Cu/115–475



Specie	COBERPES cruises					Reported distribution and depth range (m)
	2	3	4	5	Species depth range (m)	
<i>Peristedion truncatum</i> (Günther, 1880)	X	X	X		336–852	Vz, Yc/155–910
<i>Photostomias guernei</i> Collett, 1889	X				540–772	entire/500–3100
<i>Poecilopsetta beanii</i> (Goode, 1881)	X	X	X	X	300–825	entire/155–1636
<i>Polyipnus asteroides</i> Schultz, 1938*	X			X	300–820	ne, nw/0>1000
<i>Polymetme thaeocoryla</i> Parin & Borodulina, 1990	X	X	X	X	300–953	entire/165–1400
<i>Polymixia lowei</i> Günther, 1859	X	X	X	X	300–825	entire/0>2000
<i>Pontinus longispinis</i> Goode & Bean, 1896**	X	X		X	300–611	entire/50–440
<i>Prionotus alatus</i> Goode & Bean, 1883**		X			611	Yc/35–457
<i>Prionotus stearnsi</i> Jordan & Swain, 1885	X	X	X		308–346	entire/11–549
<i>Pristipomoides macrophthalmus</i> (Müller & Jelks, 1848)**		X			611	ne, nw, Cp/110–550
<i>Promethichthys prometheus</i> (Cuvier, 1832)	X			X	540–609	ne, Cu, Yc/80–800
<i>Pseudomyrophis frio</i> (Jordan & Davis, 1891)**		X			494	sw, Atl, Yc/0–180
<i>Pseudonaja fischeri</i> Bigelow & Schroeder, 1954	X				534–580	Yc/412–576
<i>Rinoctes nasutus</i> (Koefoed, 1927)		X			1068	ne, nw, Yc/1000–4337
<i>Rouleinia maderensis</i> Maul, 1948	X	X	X		852–1068	ne, Cu/595–1450
<i>Saurida caribbaea</i> Breder, 1927	X	X	X		308–422	entire/4–460
<i>Saurida normani</i> Longley, 1935	X	X		X	300–611	entire/25–550
<i>Scopelosaurus smithii</i> Bean, 1925			X		953	ne, Vz/50>3000
<i>Scorpaena dispar</i> Longley & Hildebrand, 1940**	X	X	X	X	300–812	entire/0>500
<i>Scyliorhinus retifer</i> (Garman, 1881)	X			X	300–812	entire/36–750
<i>Setarches guentheri</i> Johnson, 1862	X				392	ne, nw, Yc, QR/150–780
<i>Sigmops elongatum</i> (Günther, 1878)	X	X	X	X	494–1068	entire/25–1463
<i>Sphagemacrusus grenadae</i> (Parr, 1946)**	X	X	X	X	820–1071	entire/1000–1960
<i>Squalogadus modificatus</i> Gilbert & Hubbs, 1916	X	X	X		865–995	entire/50–1740
<i>Squalus cubensis</i> Howell Rivero, 1936**	X	X	X	X	300–608	entire/60>500
<i>Squatina dumeril</i> Lesueur, 1818			X		354–370	entire/0–1375
<i>Steindachneria argentea</i> Goode & Bean, 1886			X	X	300–370	entire/350–550
<i>Stephanoberyx monae</i> Gill, 1883	X	X	X		628–953	entire/945–4777
<i>Sternoptyx diaphana</i> Hermann, 1781	X	X	X		577–1065	entire/300–3676
<i>Sternoptyx pseudobscura</i> Baird, 1971	X	X	X		628–953	entire/0>3000
<i>Stomias affinis</i> Günther, 1887	X	X	X		611–772	entire/0–3180
<i>Symbolophorus rufinus</i> (Täning, 1928)				X	327	entire/0–3000
<i>Synagrops bellus</i> (Goode & Bean, 1896)	X	X	X	X	300–974	entire/00>900
<i>Synagrops spinosus</i> Schultz, 1940**	X	X	X	X	300–825	entire/0–544
<i>Synaphobranchus affinis</i> Günther, 1877					820	entire/290–2400
<i>Synaphobranchus oregoni</i> Castle, 1960	X	X	X	X	377–1071	entire/45–1900
<i>Synchiropus agassizii</i> (Goode & Bean, 1888)	X	X	X		336–426	Mx, Cb, Cp/0–500
<i>Tetronarce nobiliana</i> (Bonaparte, 1835)				X	540	ne, nw, Cp, Yc/0–530
<i>Thaumatichthys binghami</i> Parr, 1927**	X				820	ne, nw, Cb/1100–4032
<i>Trachonurus sulcatus</i> (Goode & Bean, 1885)**	X	X	X	X	626–1068	entire/700–1500
<i>Trachyscorpia cristulata</i> (Goode & Bean, 1896)					619–628	ne, Cb, Mx/130–1100
<i>Urophycis cirrata</i> (Goode & Bean, 1896)**		X	X	X	300–825	entire/27>700
<i>Venefica procera</i> (Goode & Bean, 1883)	X	X	X	X	327–953	ne, nw, Tm, Vz/326–2340
<i>Ventrifossa macropogon</i> Marshall, 1973**	X	X	X		300–846	Tm, Yc/439–1000
<i>Ventrifossa mucocephalus</i> Marshall, 1973***	X	X	X	X	300–814	ne, Cb/450–732
<i>Xenopcephalus egegius</i> (Jordan & Thompson, 1905)	X	X	X		370–423	entire/180–440
<i>Xenodermichthys copei</i> (Gill, 1884)	X		X		590–865	ne, nw, Vz, Tb/100–2650
<i>Xenolepidichthys dalgleisbi</i> Gilchrist, 1922	X	X	X		346–547	Tm, Cp/90–900
<i>Yarrella blackfordi</i> Goode & Bean, 1896	X	X	X	X	321–1071	entire/350–1000
<i>Zalieutes mcgintyi</i> (Fowler, 1952)	X				300–394	entire/70–500
<i>Zenion hololepis</i> (Goode & Bean, 1896)**	X	X	X	X	300–825	Cp, Tb/180–700



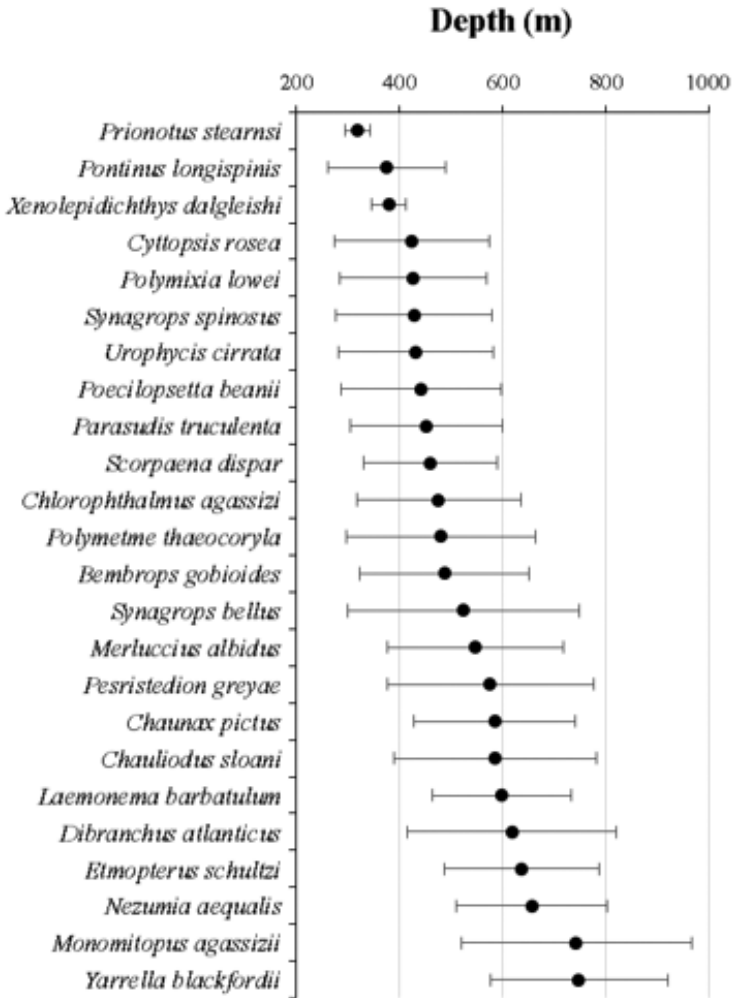
**Figure 4.** Community parameters for each cruise (COBERPES): **a** Species richness (number of species); **b** Abundance (individuals/ha); **c** Diversity (Shannon-Wiener); **d** Evenness (Pielou).

*Hoplostethus mediterraneus* Cuvier, 1829; *Benthodesmus simonyi* (Steindachner, 1891); *Macroramphosus scolopax* (Linnaeus, 1758); *Bregmaceros cantori* Milliken & Houde, 1984; *Bregmaceros houdei* Saksena & Richards, 1986; *Peristedion ecuadorensis* Teague, 196; *Peristedion thompsoni* Fowler, 1952; *Polyipnus asteroides* Schultz, 1938; *Neoscopelus microchir* Johnson, 1863, and *Neoscopelus macrolepidotus* Matsubara, 1943 (Table 2).

Thirty seven species increased its depth range distribution (Table 2). Three of the most abundant species recorded an average depth lower than 400 m (Fig. 3): *Prionotus stearnsi* Jordan & Swain, 1885 ( $318 \pm 24.57$  m); *Xenolepidichthys dalgleishi* Gilchrist, 1922 ( $379 \pm 33.05$  m) and *Pontinus longispinis* Goode & Bean, 1896 ( $376 \pm 114.03$  m). Many of the species showed a wide depth range distribution ( $400 > 800$ ); however, only two of them presented the highest average depth: *Monomitopus agassizii* (Goode & Bean, 1896) and *Y. blackfordi* ( $743 \pm 223.92$  m and  $749 \pm 172.95$  m, respectively) (Fig. 5).

## Discussion

The species accumulation curve suggests that we registered most of the fish species found on soft bottoms of the continental slope of the southern GoM. Nevertheless, since the species accumulation curve continued to increase, the inventory still appears to be inconclusive. This situation is congruent with the fact that the sampling effort in the GoM deep waters has been low, particularly in the south. We identified 177 species which represent 12% of the total fish species (1541) reported for all habitats in continental shelf and deep waters including demersal and pelagic fishes of the GoM



**Figure 5.** Depth of occurrence of the most abundant fish species: average depth  $\pm$  standard deviation (SD).

(McEachran 2009). The only previous systematic study using a similar sampling gear was conducted in the northern GoM by Powell et al. (2003) who recorded 93 demersal fish species for the upper (315–785 m) and mid slope (686–1369 m).

Based on the fish list elaborated by McEachran (2009) we counted 335 benthic and demersal fishes for the continental slope of the GoM. This number is 30 % higher than the 235 summed from this paper and Powell et al. (2003) study. It must be noted that McEachran list includes fishes collected with other gears and also in other habitats, like hard bottoms. Nonetheless, three fish species can be added to McEachran list: *Kali indica* Lloyd, 1909, following Powell et al. (2003) and two species found in this research *E. caribbeus* and *B. nigra*. In this way, a total compilation of 338 species of benthic and demersal

fishes can be listed for this ecosystem. Additionally, 15 species extended their distribution into the south of the GoM (Table 2). It must also be noted that 37 species extended their depth ranges, nine of them were recorded in deeper ranges and 28 species in shallower depths than previously reported in literature. Most of the species showed a wide distribution depth range which is consistent with the distribution pattern of deep water fishes.

The highest species richness recorded in the continental slope of the Campeche Bay (COBERPES 5), is probably influenced by the high freshwater discharge of the largest hydrological system in the southern GoM: Grijalva-Usumacinta during summer, which inputs 62% of the total freshwater to the Mexican GoM (Day et al. 2004), similar to what Powell et al. (2003) found in the northern GoM, near the mouth of the Mississippi River. Likewise, the upwelling produced by cyclonic gyres in the Campeche Bank (De la Lanza-Espino and Gómez-Rojas 2004, Durán-Campos et al. 2017), could be playing an important ecological role. These factors together incorporate large concentrations of nutrients which may trigger local productivity, and subsequently the diversity of demersal fishes on the continental slope in this region. Fish richness and diversity difference between COBERPES 3 and COBERPES 5 could also be influenced by seasonal productivity variations due to current pattern change in the area.

Five species captured in this survey are of commercial importance in other parts of the world. *M. albidus* was one of the second most frequent species (50%) which accounted greatly to total biomass (72.296 kg) and presented relatively large sizes (total length = 103–555 mm). This species could have a fishing potential in the GoM, as it was an important fishing resource in the US Atlantic in the early 1990s, but its production decreased significantly over a 10-year period of exploitation (Traver et al. 2012). Other taxa of commercial interest in the Atlantic such as *H. mirabilis*, *H. dactylopterus* and particularly *A. carbo* (one individual), are important fishing resources in the central and northern regions of the eastern Atlantic Ocean (Bensch et al. 2009, Pajuelo et al. 2010). Another species registered in the present study was *L. gastrophysus*, which was a significant deep water fishing resource in Brazil from 2000 to 2007 (Álvarez et al. 2009). However, the fishing potential of these species in the GoM is still to be defined with further studies.

Compiling data of fish species of this study as well as from the literature (McEachran and Fechhelm 1998, Powell et al. 2003 and McEachran 2009), we found that the north and south parts of the GoM share 97% of the species recorded on soft bottoms of the continental slope of the whole gulf. On the other hand, more than 63% of the species ( $n = 44$ ) recorded for the Caribbean Sea ( $n = 69$ ) (Anderson et al. 1985, Saavedra-Díaz et al. 2004, Paramo et al. 2015) also occur in the GoM. McEachran (2009) pointed out that this fish similarity is influenced by fauna from the central Atlantic (the region between North Carolina and the Great and Lesser Antilles, including The Bahamas, Bermuda islands, and South America) due to the Loop Current effect that connects the Yucatan and Florida currents (Monreal-Gómez et al. 2004, NOAA 2016).

This result is consistent with the distribution of deep water fishes inhabiting large bathymetric areas due to more stable environmental conditions in these habitats (Clark et al. 2010). A similar distribution pattern has been recorded in several studies done in the world, for example in the Mediterranean Sea (Moranta et al. 1998), in the Atlantic (Menezes et al. 2006, 2015; Magnussen 2002; Bergstad et al. 2012; Koslow 1993;

Quattrini et al. 2015); in the Caribbean (Quattrini et al. 2017), and in the northern of the GoM (Powell et al. 2003).

Our results suggest that a high number of species dwelling on the continental slope are shared between the north and south of the GoM. We recorded an extension in distribution into the south of the GoM and also bathymetrically of several fish species. New records are highly likely to be increased if sampling effort continues both geographically and bathymetrically, since the species cumulative curve did not reach an asymptote. This research contributes to the knowledge of the deep water fish community of the GoM, never studied before in the southern region. However, information needs to be enhanced since deep water natural resources of the southern GoM could be subject to increasing human pressures in the near future.

## Acknowledgements

Our acknowledgements are due to Programa de Apoyo a Proyectos de Investigación e Innovación Tecnológica (PAPIIT), Proyecto IN223109-3 of the Universidad Nacional Autónoma de México (UNAM) and to the crew of the R/V *Justo Sierra* for their support in conducting the cruises. The Consejo Nacional de Ciencia y Tecnología (CONACyT) is greatly appreciated for the PhD scholarship. Particularly, we extended thanks to our colleagues of the laboratory of Ecología Pesquera de Crustáceos, ICML, UNAM: Rosa María Hernández Díaz, Diana Torres Galíndez, Magaly Galván Palmerín, Linda Trejo Torres, Sandra Antonio Bueno, Andrea Yazmín López Chávez, León Felipe González Morales, and Iván Martínez Romero. Thanks also to the staff of the Department of Hidrobiología of the Universidad Autónoma Metropolitana-Iztapalapa (UAM-I): Verónica Escobar Morales, Araceli Soto Ávila, Obeth Ayala Medina, Luis Arturo Ponza Ramos, and David Herrera Olayo.

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