Terminos Lagoon Habitat and Ecosystem Report

First Draft

Fisheries Improvement Project Mexico Yucatan Peninsula blue crab-dipnet/pot/trap

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Content

List of Acronyms

Acronym	Description
SAV	Submerged Aquatic Vegetation
FIP	Fisheries Improvement Project
INEGI	National Institute of Statistics and Geography
SEMARNAP	Environment, Natural Resources and Fisheries Secretariat
INE	Ecology National Institute
m	meters
GOM	US Gulf of Mexico
psu	Practical salinity unit

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Introduction

The largest amount of crab in the FIP comes from Terminos Lagoon and its tributaries.

This lagoon was studied in depth in the 80's, however, various processes have caused important changes in it. Recently several institutions and projects had updated ecological information on this area, especially ECOSUR, Campeche. This report summarizes the most recent findings on general habitat and ecosystem issues at Laguna de Terminos, region that supplies the most of the blue-crab of the FIP.

Figure 1. Terminos Lagoon, Campeche, México.

Terminos Lagoon

Terminos Lagoon is located in the southwestern area of the Gulf of Mexico (Campeche State, Mexico). This is one of the largest lagoons in Mexico with a surface of 1660 km2, forming part of the Tropical North-Western Atlantic´s marine ecoregion 68 (Southern Gulf of Mexico). The lagoon is very shallow with a mean depth of 3.5 m.(Villéger, et al, 2010) Terminos Lagoon is actually an estuarine ecosystem as it is strongly influenced by freshwater discharges from three streams located on its southern part (respectively, from west to east: Palizada River, Chumpan River, and Candelaria River). The lagoon is delimited by Carmen Island (30 km long and 2.5 km wide) which separates it from the Gulf of Mexico and thus water exchanges with the sea take place through two inlets, one on its northeastern part (Puerto Real) and the other one on the northwestern part (Carmen)(Villéger, et al, 2010) with depth of 18 m and 14 m respectively (Romo-Ríos, 2013), receiving freshwater from three streams on its southern part: Palizada River, Chumpan River and Candelaria River (Ramos-Miranda, et al., 2005a). The mouth of Carmen, which is 3.9 km wide, has a fluvial influence derived from the Palizada River, which causes little transparency of the water due to the terrigenous material in suspension. (Borges Souza, 2004, en Romo-Ríos, 2013).

Water circulation in the lagoon generally follows a clockwise direction (David and Kjerfve 1998), with seawater going inside the lagoon through the Puerto Real inlet, mixing with freshwater inputs near the stream mouth, with the resulting brackish water going outside the lagoon through the Carmen inlet (Villéger, et al, 2010)

Climatic seasons

There are three climatic seasons in the area: dry, rainy and "norte" seasons. The rainy season goes from June to October with a precipitation of 100 mm/month. Starting in November, with a slight decrease in precipitation, the "nortes" season goes until February. From February to May, the minimum precipitation values are recorded corresponding to the dry season.

The contribution of sediment to the lagoon derives from the Palizada rivers (discharge of 238,126 m^3/s), flows into the Vapor and San Francisco lagoons through a small mouth of 7 m wide and 15 deep (Herrera Silveria et al., 2002), the Candelaria River with a discharge of 35.09 m^3/s that flows into the Panlau Lagoon and connects to the Terminos Lagoon through a 40 m wide mouth. Finally, the Chumpán and Mamantel rivers with a discharge of 1.67 m^3/s (BorgesSouza, 2004).

Winds

There are two dominant wind systems (Yáñez-Arancibia & Day, 1982 in Romo-Ríos, 2013):

a) northwest (October-March) with average speeds greater than 8 m / s, and

b) north-northeast and east-southeast (March-September), with an average speed that varies between 4 and 6 m/s.

Sediments

The spatial trends of the sediment textural parameters (mean grain size, selection and asymmetry) are indicators of the net transport trajectories and the final deposition destinations of the sedimentary material (Sánchez et al., 2009, 2010). The sediments in Terminos Lagoon are of biogenic and terrigenic origin, presenting spatio-temporal variations associated with the southwest-northeast circulation pattern present in the system, meteorological events, river discharges and the anthropogenic activity of the region. In a comparison of the composition and distribution of the sediments 1963 and 2001-2002, it only showed significant differences in the Central Basin (Borges-Souza, 2004). The main sources of terrigenous sediments are the basins of the Chumpán and Palizada rivers (through the Usumacinta river on the Gulf of Mexico slope); the sources of carbonate sediment contribution are the Gulf of Mexico through the Bocas de Puerto Real and Boca del Carmen, which are transported by tidal currents (Borges-Souza, 2004 in Romo-Ríos, 2013).

It is considered that the region presents three climatic seasons: dry (February-May), rains (June-September) and north (October-January), Yáñez-Arancibia and Day (1982), in (4) Throughout the years Various studies have been carried out that describe the main physical and chemical variables of water: temperature, salinity, transparency and depth (Yáñez-Arancibia et al., 1982; Flores Hernández et al., 2001; Herrera-Silveira (2002) and Villalobos Zapata (2002), Sosa López et al. (2005)) studies that reflect the salinity and transparency gradients in the region and the fact that it is a dynamic environment. In this regard, these studies show from five to seven "habitats", whose borders are apparently environmentally changing (taken from Ramos et. Al, 2015).

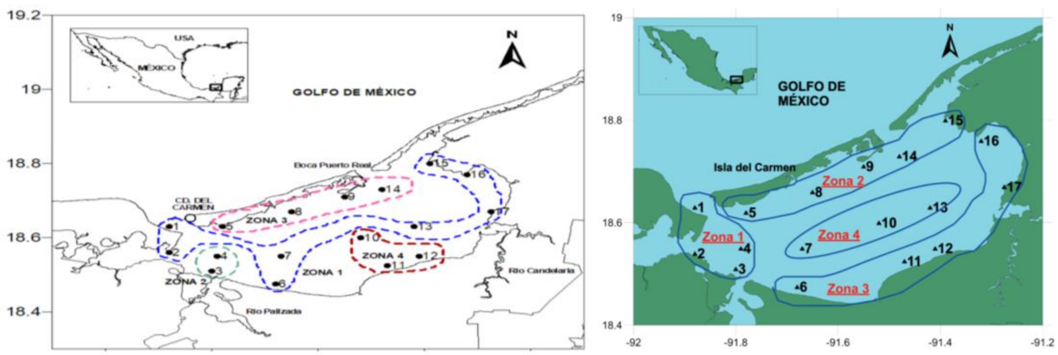
The changing environment of the Terminos Lagoon is the result of environmental variability, salinity being the main factor that explains the spatial distribution, directly influenced by the intrusion of brackish water due to hydrological inputs and the decrease in freshwater discharges from freshwater systems (Santos Santoyo, et al., 2021).

Tides

The tide in the Terminos Lagoon is of a mixed type (diurnal and semi-diurnal) being the diurnal components the dominant ones; the range between mean high tide and mean low tide in Isla del Carmen is 0.43 m and the average high tide is 0.40 m and -0.70 m. Spring tide and neap tide have an approximate period of 14 days (SEMARNAP-INE, 1997 in Romo-Ríos, 2013).

Physicochemical variables of water

According to a comparative study between the behavior of the physicochemical variables of the water between 2021 and 2010, significant differences are observed and therefore an update of the regionalization of the Terminos Lagoon. The main differences are observed in the increase in the salinity of the lagoon. Following is the updated regionalization, according to Santos, et al., 2021. An increase in temperature and other parameters is also observed, however it does not yet affect its average values. Because these results are very recent, all the research found with reference to flora and fauna use previous regionalization. (Santos Santoyo, et al., 2021)



a b

Figure 2. Map illustrating the 4 hydrological zones defined in Terminos Lagoon after Santos, et al., 2021a (Illustration from Santos, et al., 2021) and Villeger et al., 2010 b

The pH varies from 7.04 to 8.5 depending on the climatic season (dry, rainy and "nortes"), with higher pH during the "nortes" season, according to what was found by Santos, et. al., 2021

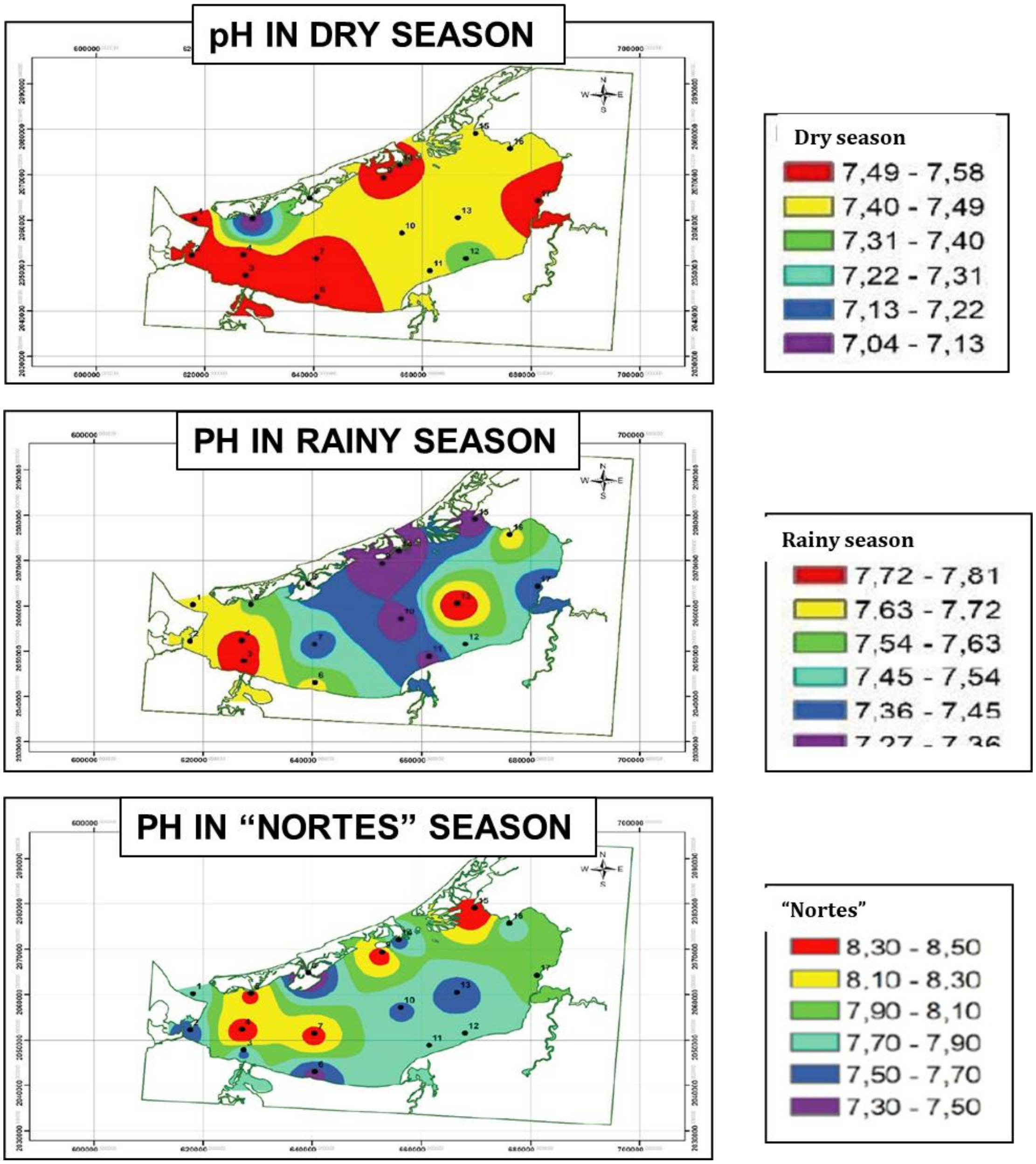


Figure 3. Spatial variability of pH by climatic seasons (dry, rainy and "nortes") after Santos et.al., 2021. (Illustration from Santos, et al., 2021)

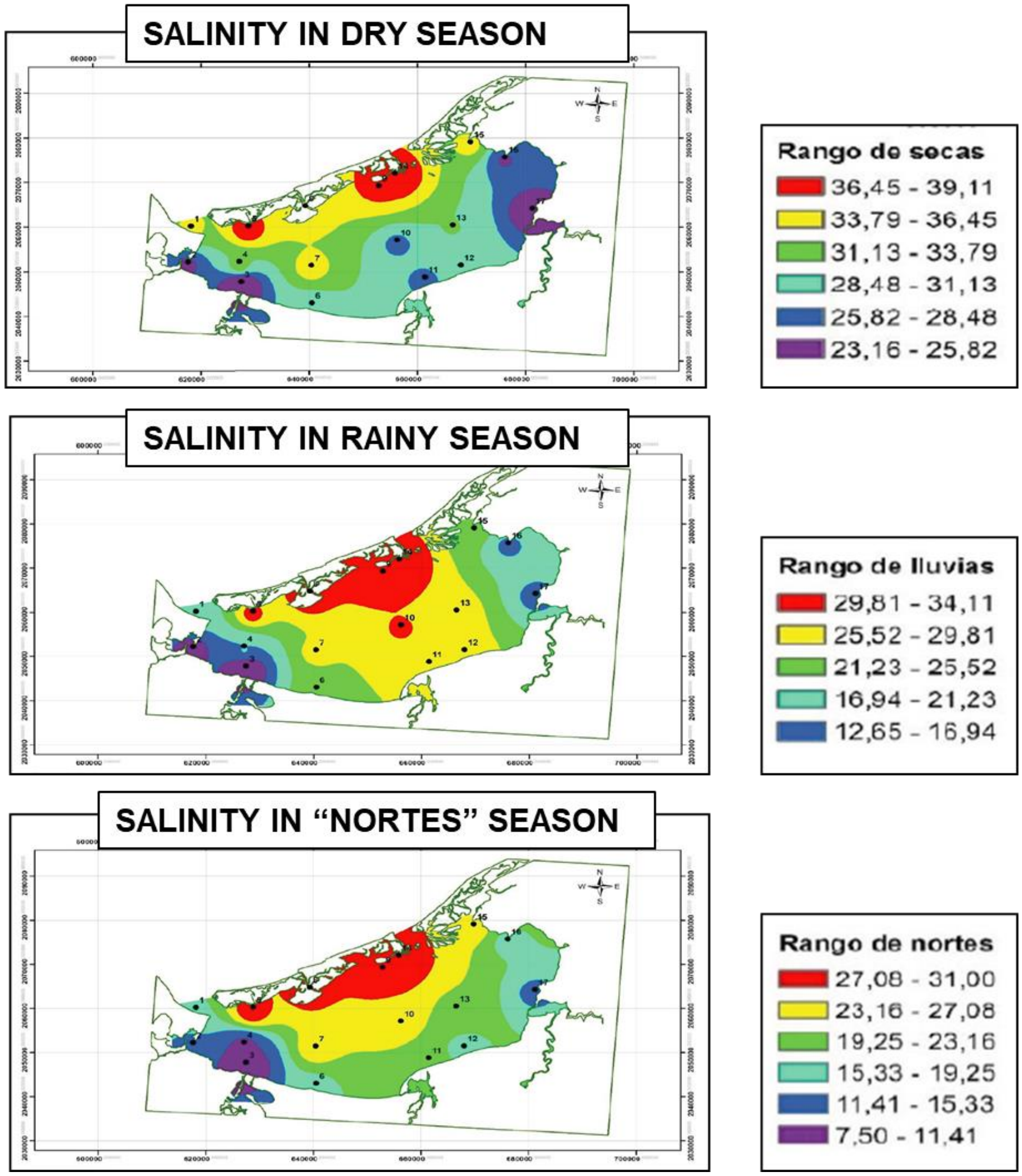


Figure 4. Spatial variability of salinity by climatic seasons (dry, rainy and "nortes"), after Santos et.al., 2021. (Illustration from Santos, et al., 2021)

Villéger et al. (2010) compared the results of previous studies and determined 4 zones, which are enclosed in this study since it encompass sediments and the type of vegetation (Figure 5). The trend of changes found in 2010 is a decrease in its depth and an increase in salinity. Zone 1 is located near the mouth of Carmen, and is influenced by the discharge of freshwater from the Palizada River, whose annual discharge is> 4 X 109 m3 year-1 and has a wide range of salinity (4 to 35 ups), presents a muddy substrate with fine sands and clays. Zone 2 covers the internal coastline of Isla del Carmen, up to the mouth of Puerto Real, this area is under marine influence with average salinities of 28.5 ups the substrate varies between muddy next to the mangrove strip (*Rhizophora mangle*) and sandy in seagrass areas (*Thalassia* *testudinum*). Zone 3 in the southeastern part of the lagoon, presents shallow waters close to mangrove swathes, it is influenced by the Candelaría and Chumpán rivers, with silty-clayey sediments. Zone 4 is the central part of the lagoon, with an average depth of 3.9 m, considered as a transition zone between the marine influence and the influence of fresh water, with a salinity range of 15 to 36 ups and an average of 26 ups. (Villeger et al., 2010)

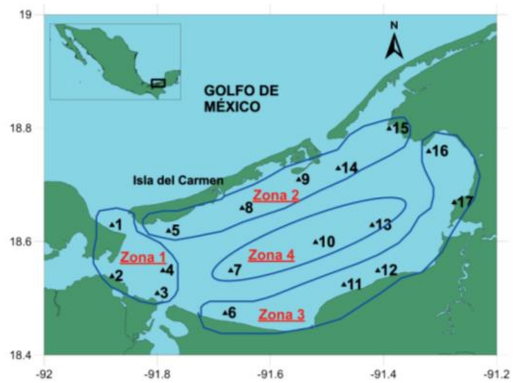


Figure 5. Map illustrating 4 zones after Villéger et al. (2010)

Comparisons between the 1980-1981 and 1998-1999 surveys showed that the four zones experienced severe modifications in their environmental conditions (Table 1). Depth and transparency were globally decreasing, particularly in Zones 1, 2, and 3, while salinity increased (Villéger et al., 2010).

Table I. Environmental conditions in four zones of the Terminos Lagoon (after Villeger, et al., 2010)

Zone	Depth (m)			Sechii (m)			Bottom salinity (psu)			Substrate
	1980-1981	1998-99	P	1980-1981	1998-99	P	1980-1981	1998-99	P	
1	2.8 (22 %)	2.1 (45 %)	***	0.6 (35 %)	0.5 (50 %)	*	21.3 (41 %)	23.1 (47%)	NS	Muddy with fine sand and clayed silt, riverine influence
2	2.6 (32 %)	1.6 (45 %)	***	1.1 (45 %)	0.9 (49 %)	**	28.5 (25 %)	31.7 (18 %)	***	Mud near mangrove swamps and sand with seagrasses and macroalgae
3	2.5 (24 %)	1.3 (35 %)	***	0.9 (38 %)	0.6 (39 %)	***	22.4 (28 %)	25.9 (22 %)	***	Silt-clay sediments, mangrove swamps, riverine influences
4	3.9 (11 %)	3.9 (9 %)	NS	1.1 (36%)	1.3 (44 %)	NS	26 (25 %)	31.1 (17 %)	***	Sand-silt sediments

Notes: For each zone, mean values are given for 1980-1981 and 1998-1999, with spatiotemporal coefficients of variation in parentheses. Results of pairwise Wilcowon rank tests between the two periods are shown as P levels. *P<0.005; *** P<0.01; P<0.001; NS, not significant.

Seagrass distribution (*Thalassia testudinum*)

The distribution of seagrasses and macroalgae is regulated by environmental conditions and affinity to textural groups of sediment. The seagrasses are distributed in sandy and muddy sediments mainly on the southern coast of Isla del Carmen at the entrance to Puerto Real near the coast (Raz Guzmán & Barba-Macias, 2000), while the macroalgae are located in sites with sandy sediment such as the central part of Terminos Lagoon. Seagrass productivity varies between 3 and 13 gr of dry weight / m 2 / day, with the highest rates occurring during spring in the Boca de Puerto Real area (Moore & Wetzel, 1988).

Yáñez-Arancibia et al. (1983), report a loss of T*. testudinum* of 37.5% of the coverage in the southeastern zone of Terminos Lagoon. In 1990, in the internal coastline of Isla del Carmen there was 58% coverage, while in Boca de Puerto Real (West-East zone 2) it was 40% and in the river discharge zone (South zone 3) of 12%. For the year 2000 it was reduced to 38%, 35% and 5% respectively (Figure 6) (Herrera-Silveira et al., 2011).

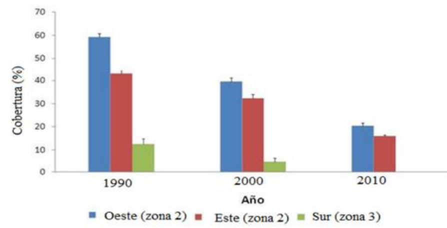


Figure 6. Distribution and coverage of *T. testudinum* in Terminos Lagoon (Herrera-Silveira., 2011; image from Rios-Romo, 2013).

For 2010, the highest coverage percentage was in the western region (Boca de Puerto Real) with 20%, and in the southern part of the river discharge (zone 3) there are practically no seagrasses. The loss of vegetation cover in the southeast may be related to the low salinity recorded in the area (<10 ‰), as well as low water transparency (<20%). Since this vegetation is associated with high salinity and transparency values and low levels of calcium carbonate (Yáñez-Arancibia et al., 1983; Raz-Guzman & Barba-Macías, 2000; Herrera Silveira et al., 2011 in Romo- Ríos, 2013)

Macroalgae and phytobenthos

The distribution of macroalgae in Terminos Lagoon and the adjacent continental shelf is characterized by occurring in the sandy or sandy-silty substratum where algae such as *Cladophora vagabunda*, *Vauceheria sp*. and *Enteromorpha lingulate* occur. In the sediments of coarse grains, shells or shell fragments, the following species were recorded: *Gracilaria verrucosa, Spyridia filamentosa, Acanthophora spicifera, Hypnea cervicornis, H. cornuta, H. musciformis, Polysiphonia sp, Enteromorpha lingulata, Aphanocapsa littoralis*; on large oyster shells: *Chondria baileyana, Gelidium pusillum* and *Dictyota ciliolata* (Conover, 1964 in Romo-Ríos, 2013), in 1995, 94 species of algae were identified (Ortega, 1995: Table II)

Table II. Observations of phytobenthos in Terminos Lagoon, Campeche (Ortega, 1995).

Algae	%	Genera	Species
Rhodophyceae	56.1	3	55
Chlorophyceae	22.4	12	22
Phaeophyceae	9.1	5	9
Cyanophyceae	7.1	5	7
Xanthophyceae	1	1	1

Ortega (2009) mentions the importance of shells as a low specific weight algal substrate, which is why it constitutes a mobile community due to the action of waves and currents. Specifically, epirrhizal algae (on mangroves) include *Bostrychia* *radicans, Caloglossa leprieurii*, and *Microleus chthonoplastes*, although they are present in silts.

An important part of the vegetation is made up of non-strict epiphytes, such as *Herposiphonia secunda, Polysiphonia ferulácea, Polysiphonia sp, Heterosiphonia crispella, Centroceras calvulatum*, *Enteromorpha flexuosa* sub *sp ,paraxa*. Among the algae not fixed on some substrate or floating algae are *Caulerpa fastigiata var. confervoides, Chaetomorpha linum, Rhizoclonium africanum, R. kerneri* (Ortega, 2009 in Romo-Ríos, 2013).

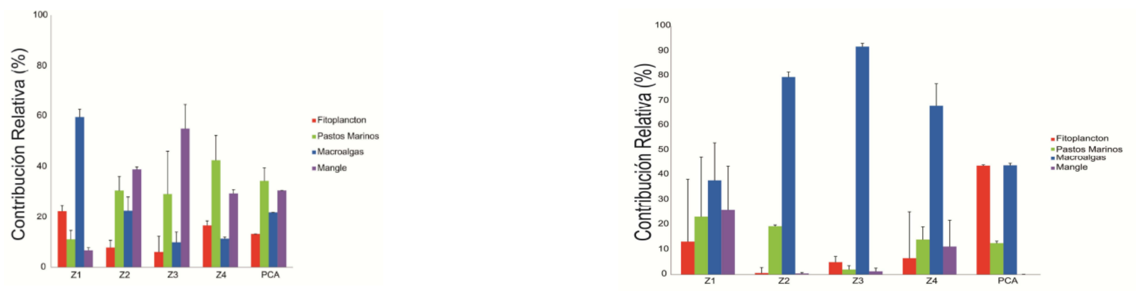
List of species can be found in Annex 1.

Mangrove

The four species reported for Mexico are present in Terminos Lagoon: *Rizhopora mangle* or red mangrove in the margins of rivers, lagoons and coasts, usually flooded soils, *Laguncularia racemosa* or white mangrove found in flooded soils with high levels of salinity, *Avicennia germinans* or black mangrove on sandy soils that are flooded only during part of the year or in years of maximum rainfall and *Conocarpus erecta* or buttonwood mostly on sandy and clay soils with low salinity that occasionally flooded during the rainy season (Agraz et al., 2012). The vegetation that border the Terminos Lagoon is attributed to the heterogeneous environmental conditions that characterize the lagoon system, since it receives large volumes of freshwater flows from the basin that drains into the Yucatán Peninsula, the lowlands of Tabasco and the Sierra de Chiapas. and Guatemala; as well as by the transport of terrigenic nutrients to the lagoon system, the type of soil and the anthropic activities that take place in the region (Agraz et al., 2012). Mangroves of the Terminos Lagoon continue to be responsible for the high productivity and biodiversity that is recorded (Agraz et al., 2012). On the other hand, the euryhaline water masses and the oxygen availability of the interstitial water from oxic to hypoxic prevailing in most of the Terminos Lagoon, determine the dominance of: black mangrove (*A. germinans*) with 77.4%, white mangrove (*L. racemosa*) presented a dominance of 22.2%,; The red mangrove (*R. mangle*), is a species with low tolerance capacity to salinity and low oxygen concentrations (Agraz et al., 2012 in Romo-Ríos, 2013).

It has been observed that during the rainy and northern seasons, the largest volume of litter is contributed to the lagoon, which fertilizes the waters favoring increases in the biomass of consumers (Barreiro-Güemes, 1999; Agraz et al., 2012).

Contribution of primary producers to ichthyofauna



(a) (b)

Figure 7. Contribution of primary producers to ichthyofauna in "nortes" season (a) and dry season (b) in Terminos Lagoon (Herrera-Silveira., 2011; image from Rios-Romo, 2013). Z1: zone 1, Z2: zone 2, Z3: zone 3, Z4: zone 4, PCA: Continental platform. Zones after Villager et al., 2010 zonification (Figure 5).

The spatial variations of the primary producers regulate the distribution of the fish and therefore the energy flow in terms of carbon and nitrogen of the organic matter in Terminos Lagoon and adjacent sea. The ichthyofauna present in the internal coastline of Isla del Carmen, Boca de Puerto Real presents more enriched values as a result of a trophic structure based on submerged vegetation (sea grasses and macroalgae) while the ichthyofauna of the fluvio-lagoon region (zone 3) presented less enriched values of δ 13C, as a result of a mangrove-based feeding source through detritus pathway (Romo-Ríos, 2013)

In Terminos Lagoon, the main origin of organic matter is autochthonous with high contributions from the mangroves in the river discharge area and it is an important component of the export of the lagoon system to the adjacent sea in the "nortes" season. (Romo-Ríos, 2013)

Fish

Terminos Lagoon is a tropical coastal aquatic system with high biodiversity and abundant natural resources (Rivera-Arriaga, et al. 2005), recognized in 1994 as a Flora and Fauna Protection Area. Along with the Campeche continental shelf it maintains numerous commercially important fisheries which employ thousands of people in the southern Gulf of Mexico. Therefore, understanding the long-term dynamics of this resource is essential in determining the present community assemblage and current magnitude species richness in order to support and maintain livelihoods in the region. (Paz-Ríos, et al, 2021)

This lagoon supports a great biodiversity: 117 species of fish, 69 of macro crustaceans (Raz, 2010), and 172 of mollusks (Reguero et al., 2010) among others. Of the species of fish and crustaceans registered, 43 are commercially exploited (Ramos Miranda, 2000; Ramos Miranda et al., 2005a & 2015).

The abundance of fish communities has notably decreased over the years (Sosa-López et al., 2006; Ramos-Miranda et al., 2015, Flores-Hernández, et al., 2021), showing a greater change in its structure (biomass) than in the loss of species composition (Villéger, et al, 2010). The increase in salinity is probably one of the causes that can explain the variation in the abundance of the species. (Flores-Hernández, et al., 2021) and has been interpreted as homogenization of the habitat (Ramos Miranda et al., 2015); pointing out that the greater intrusion of seawater and the pattern of circulation in the lagoon ecosystem have conditioned a reduction in the wide ranges of salinity observed in the 80's. (Flores-Hernández, et al., 2021). Thus, the composition and functioning of the ichthy community of Terminos Lagoon, given the increase in salinity, becomes a habitat more frequented by species of marine origin (Flores-Hernández, et al., 2021).

The studies carried out suggest a trend towards a more generalist fish community, under a regime of sharing resources rather than competition (Flores-Hernández, et al., 2021). Among the four largest zones studied after Villéger et al., 2010, three did not show strong functional changes; in the northern coast of the lagoon, they found an increase in fish richness but a significant decrease of specialized species, functional divergence and functional specialization. The decline of specialized species were those with particular combinations of traits linked to seagrass habitats, while newly occurring species are redundant with those already present. Seagrass habitats regressed consecutively to increasing eutrophication (Villéger, et al, 2010)

In 2021, a spatio-temporal analysis of the behavior of biodiversity presented the rainy season with the highest values in terms of diversity and richness, while from a spatial perspective, region 1 (adjacent area of Boca Atasta and Palizada river) was the most representative throughout the three climatic seasons for both index. Region 2 was the one characterized by presenting the highest values of abundance. Thus, regions 1 and 2 represent areas of great ecological importance for the balance of biodiversity, which is why they are key areas that should be protected in Terminos Lagoon. (Irola-Sansores, 2021). List of species can be found in Annex 3.

As part of the fish community recorded for the Terminos Lagoon, 45 spp. Are considered commercially important. Occurrence and abundance data on this resource showed that most of the species display a highly dynamic distribution through the sampling years and zones, but in general, zone 4 presented lower species abundance values. Several fish species were poorly represented and recorded at one or two sampling campaigns with low abundance, suchas *Brevoortia gunteri*, *Sardinella aurita*, *Centropomus poeyi*, *Centropomus undecimalis* or *Ocyurus chrysurus*. Other locally exploited species were maintained relatively consistently through the sampling years, such as some *Clupeidae* (e.g. *Herengula jaguana*), Ephippida (*Chaetodipterus faber*), *Sciaenidae* (e.g. *Bairdiella chrysoura*, *Bairdiella ronchus*, *Cynoscion arenarius*, *Cynoscion nebulosus*) or *Ariidae* (e.g. *Ariopsis felis*, *Bagre marinus*, *Cathorops melanopus*).

Blue crab habitat description

The life history of the estuarine-dependent blue crab involves a complex cycle of planktonic, nektonic, and benthic stages which occur throughout the estuarine-nearshore marine environment. A variety of habitats within the estuarine environment are occupied depending upon the particular physiological requirements of each life history stage (Perry et al. 1984). These habitats can be divided into offshore and estuarine phases. Female blue crabs are catadromous; they migrate from hyposaline waters to higher salinity water to spawn and hatch their eggs. The high salinity, oceanic water not only serves as habitat for the spawning female but ensures larval development, increases dispersal capabilities, decreases osmoregulatory stress, and reduces predation. Fertile eggs hatch into free swimming larvae (zoeae) which pass through a series of molts. Newly-hatched blue crab larvae normally develop through seven zoeal stages before transforming into a megalopal stage. Megalopae return to the estuary where they metamorphose into the first crab stage. The estuarine phase is perhaps the most critical because all postsettlement growth and the major components of the reproductive cycle occur there. Male blue crabs usually remain within the estuary during their entire postsettlement life. Juvenile and adult blue crabs exhibit wide seasonal and areal distribution within estuaries. (VanderKooy, 2013)

The partitioning of estuarine habitat among size classes of blue crabs is thought to be related to predator avoidance (including cannibalism), food availability and nutritional requirements, reproductive success, and growth (Millikin and Williams 1984, Perry et al. 1984, Hines et al. 1987, Thomas et al. 1990 in VanderKoov, 2013).

Female *C. sapidus* spawn near the offshore barrier islands in the northern GOM (Perry 1989, Adkins 1972) or in high-salinity waters near bay mouths. After hatching, first stage zoeae move into surface waters where they remain for the duration of larval development and are exported from estuaries on an ebbing tide. Subsequent zoeal development and metamorphosis to the megalopal stage takes place on the adjacent continental shelf. (VanderKooy, 2013)

Stuck and Perry (1981) reported that peak numbers of blue crab megalopae in plankton samples occurred from July through September. Morgan et al. (1996) found that settlement of megalopae in Mobile Bay, Alabama occurred from June through November with a peak during July to mid-October. If a preferred habitat is not present when molting to the first crab stage becomes obligatory, settlement and metamorphosis can occur anywhere (Orth and van Montfrans 1990). In the northcentral GOM, megalopae settle in shoreline habitats (Guillory et al. 2001) and prefer vegetated habitats to unvegetated habitats (Morgan et al. 1996) Several studies show vegetated habitats are important nursery areas for estuarine dependent species such as the blue crab, with higher overall abundances of blue crabs and lower predation rates than were non-vegetated habitats (Orth and van Montfrans, 1990). Unvegetated substrates with drift algae or attached macroalgae also provide important habitat in some areas. An association of juvenile blue crabs with soft mud sediments has been noted in several GOM studies suggesting that unvegetated soft-sediment habitats also provide protection from predation. Although juvenile blue crabs occur over a broad range of salinities, they are most abundant in low to intermediate salinities characteristic of middle and upper estuarine waters which may explain the wide range of habitat usage. (VanderKooy, 2013)

Throughout the GOM, adult blue crabs are widely distributed and occur on a variety of bottom types in fresh, estuarine, and shallow oceanic waters. Adult blue crabs use submerged vegetation (including macroalgae), unvegetated sediments, and Spartina marsh for refuge and foraging (Wilson et al. 1990). Although adult blue crabs are ubiquitous throughout an estuarine system, they are distributed seasonally with respect to salinity and sex (Steele and Bert 1994). Three subhabitats (spawning, wintering, and maturation) were recognized in the Barataria, Louisiana, estuary by Jaworski (1972). The spawning habitat for females included tidal passes and nearshore GOM waters, while the lower bays where juvenile and male crabs concentrated after water temperatures fell below 15ºC comprised the wintering habitat. The maturation habitat included the shallow, brackish marshes of the upper estuaries. (VanderKooy, 2013)

Daud (1979) concluded that shallow, brackish to saline waters are the major habitat for the early crab stages (5-10 mm). As they grow to a larger size, these blue crabs move into fresher waters. Daud (1979) observed a movement of crabs into low salinity Louisiana marshes with growth. Juvenile crabs in Christmas Bay, Texas, were larger in salt marshes than in seagrass or on sand and mud bottoms (Thomas et al. 1990); possible reasons for the observed habitat-related size patterns included differential predation, differential recruitment of megalopae, inability of small crabs to effectively move with tides in and out of salt marshes, and active selection. Several authors found maximum abundance for larger juveniles in salinities blue crabs were associated with salinities >14.9 ppt. Steele and Bert (1994) found maximum abundance for subadult males and adult females in salinities >20.0 ppt in Tampa Bay, Florida. High salinity waters (>30.0 ppt) are occupied almost exclusively by mature crabs, particularly females. (VanderKooy, 2013)

Economical and social development

Terminos Lagoon has great ecological, social and economic relevance, as an area of intense economic development with population growth and industrial or extractive activities that have led to the modification of the ecosystem and habitats (Flores-Hernández, et al., 2021). Traditionally, the area has been exploited based in the idea of abundance and the possibility of endless capacity of extraction until its exhaustment. (Villegas & Solís, 2015).

For example, the urban population of Ciudad del Carmen increased almost 29 times from 1940 to 2010 (INEGI, 2016). The oil industry developed, with impacts on fauna (Gold-Bouchot et al., 1995) and agriculture with the use of pesticides and fertilizers (Rendon-von Osten et al., 2005). On the other hand, natural phenomena such as hurricanes have modified the composition of channels. The sandy islands inside the lagoon have spread, modifying the movement of the water and consequently the salinity. (Flores-Hernández, et al., 2021)

In the last 20 years the hydraulic management in the basin and global warming stand out, which modifies the physicochemical characteristics of the water (temperature, salinity and pH) and as a consequence modifies the regionalization. (Santos Santoyo, et al., 2021)

In summary, in the region four economic, social and cultural processes are established with a worldview linked to extensive extraction: that of the dye stick for 250 years, which as a colorant had great importance in the European textile industry of the second half of the 18th century (Contreras, 1990 at 12). Later, 57 years of extensive and intensive exploitation of chicle. The chicle extraction industry generated a dynamic that marked the economy of the state of Campeche and the Terminos Lagoon region throughout the first forty years of the twentieth century, although the activity is recognized since 1890 (Vadillo, 2001). Both processes allowed the reconformation of the regional oliarchy closely linked to the commercial capital of the United States, contributing during its exploitation to the deforestation of the Campeche forests (Vadillo, 2001). Later, in 50 years of intensive shrimp exploitation in El Carmen, its origins, evolution and situation at the time of the transfer of the shrimp fleet from the private sector to the cooperatives in 1982, represents an outward-oriented development model, although their degree of vulnerability and dependence are lower by virtue of the provisions of the Federal Government that stimulated the growth of an industry and promoted in the locality the establishment of manufacturing institutions to process, freeze and pack shrimp, and to build and repair fishing vessels (Leriche, 2001); and until now, the last extractive stage with 35 years of intensive exploitation of hydrocarbons and gas with the installation of platforms in the marine area. These two social events throughout the twentieth century: the arrival of deep-sea fishing and later the oil industry, both are confronted with the millenary riverine culture of the region, presenting themselves as modernization processes, giving rise to conflicts and tensions between the different social groups –those who inhabit and those who arrive– that are confronted by the appropriation of the territory and with it in time their spatial and sociocultural reconfiguration is observed. (Villegas & Solís, 2008)

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Annex I. List of species of phytobenthos found in Terminos Lagoon by Ortega (1995).

	Class	Species
Algae	Cyanophiceae	*Aphanocapsa litoralis*
		Lyngbya aestuarii
		Lyngbya confervoides
		Lyngbya majuscula
		Microcoleus chthonoplastes
		Phromidium sp
		Calothrix longifila
	Rhodophyceae	*stylonema alsidii*
		Erythrocladia irregularis
		Erythrocladia sp
		Audouinella hypneae
		Gelidium americanum
		Gelidium pusillum
		Fosliella farinosa
		Fosliella lejolisii
		Jania adhaerens
		Hypnea cervicornis
		Hypnea valentiae
		Hypnea musciformis
		Hypnea spinella
		Hypneocolax stellaris
		Agardhiella ramosissima
		Agardhiella subulata
		Eucheuma gelidium
		Eucheuma inerme
		Eucheuma isiforme
		Gracilaria caudata
		Gracilaria cervicornis
		Gracilaria curtissiae
		Gracilaria cylindrica
		Gracilaria damaecornis
		Gracilaria domingensis
		Gracilaria lemaneiformis
		Gracilaria tikvahiae
		Gracilaria venezuelensis
		Gracilaria verrucosa
		Gracilaria sp
		Gymnogongrus tenuis
		Champia parvula
		Chrysymenia sp
		Anotrichium tenue
		Callithamnion sp

	Class	Species
Algae	Rhodophyceae	*Centroceras clavulatum*
		Ceramium diaphanum
		Ceramium fastigiatum
		Ceramium flaccidum
		Spyridia filamentosa
		Wrangelia argus
		Caloglossa leprieurii
		Heterosiphonia crispella
		Acanthophora spicifera
		Bostrychia radicans
		Chondria baileyana
		Chondria sedifolia
		Chondria tenuissima
		Digenea simplex
		Herposiphonia secunda
		Laurencia gemmifera
		Laurencia papillosa
		Lophocladia trichoclados
		Polysiphonia ferulacea
		Polysiphonia sp
	Xanthophyceae	*Vaucheria sp*
	Phaeophyceae	*Ectocarpus? rhodochortonoides*
		Feldmannia elachistaeformis
		Giffordia indica
		Hincksia mitchelliae
		Hincksia sp
		Dictyota bartayresii
		Dictyota ciliolata
		Padina boergesenii
		Padina gymnospora
	Chlorophyceae	*Entocladia ventriculosum*
		Entocladia viridis
		Phaeophyla dendroides
		Enteromorpha flexuosa
		Entheromorpha lingulata
		Ulva fasciata
		Cladophoropsis membranacea
		Chaetomorpha aerea
		Chaetomorpha antenninna
		Chaetomorpha linum
		Cladophora vagabunda
		Rhizoclonium africanum
		Rhizoclonium kerneri

	Class	Species
Algae	Chlorophyceae	*Bryopsis plumosa*
		Bryopsis ramulosa
		Codium isthmocladum
		Caulerpa fastigiata
		Caulerpa mexicana
		Caulerpa prolifera v zosterifolia
		Caulerpa prolifera v zosterifolia
		Caulerpa racemosa peltata
		Caulerpa racemosa occidentales
		Caulerpa sertularioides
		Caulerpa sertularioides
		Caulerpa sertularioides longiseta
		Acetabularia crenulata
Seagrass	Monocotyledoneae	*Halophyla aschersonii*
		Halophyla decipiens
		Thalassia testudinum
		Halodule wrightii
		Syringodium filiforme

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Annex II. Systematic list of benthos species found in Terminos Lagoon 2016-2017 (taken from Irola, et al, 2021)

	Family	Species
Bivalva	Ostreidae	Crassostrea virginica
Gastrópoda	Cassidae	Semicassis granulata
	Fasciolariidae	Triplofusus giganteus
	Buccinidae	Sinistrofulgur perversum
		Fulguropsis sipirata
	Strombidae	Strombus alatus
Cephalopoda	Loliginidae	Lolliguncula brevis
	Squillidae	Squilla empusa
Crustacea	Peneidae	Penaeus aztecus
		Penaeus (Farfantepenaeus) duoraru
		Penaeus (Litopenaeus) setiferus
		Rimapenaeus similis
		Xiphopenaeus kroyeri
	Sicyoniidae	Sicyonia brevirostris
	Menippidae	Menippe mercenaria
	Portunidae	Callinectes bocourti
		Callinectes danae
		Callinectes rathbunae
		Callinectes sapidus
		Callinectes similis
Rayas	Rhinobatidae	Pseudobatos lentiginosus
	Dasyatidae	Dasyatis sabina
		Himantura schmardae
		Hypanus americanus
	Urotrygonidae	Urobatis jamaicensis
	Gymnuridae	Gymnura micrura
Teleosti	Clupeidae	Dorosoma anale
		Harengula jaguana
		Opisthonema oglinum
	Engraulidae	Anchoa hepsetus
		Anchoa lamprotaenia
		Anchoa mitchilli
		Cetrengraulis edentulus
	Synodontidae	Synodus foetens
	Ariidae	Ariopsis felis
		Arius melanopus
		Bagre marinus
	Batrachoididae	Opsanus beta
	Hemiramphida	Chriodorus atherinoides
	Syngnathidae	Hippocampus zosterae
		Hippocampus erectus
		Syngnathus floridae
		Syngnathus louisianae
		Syngnathus scovelli
	Triglidae	Prionotus carolinus
		Prionotus scitulus
		Prionotus tribulus
	Serranidae	Diplectrum formosum

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	Family	Species
	Carangidae	Caranx hippos
		Chloroscombrus chrysurus
		Hemicaranx amblyrhinchus
		Selene vomer
	Lutjanidae	Lutjanus analis
		Lutjanus griseus
		Lutjanus synagris
	Gerreidae	Diapterus auratus
		Diapterus rhombeus
		Eucinostomus argenteus
		Eucinostomus gula
		Eucinostomus melanopterus
		Eugerres plumieri
		Stenotomus caprinus
	Pomadasydae	Anisotremus virginicus
		Conodon nobilis
		Haemulon aurolineatum
		Haemulon bonariense
		Haemulon plumieri
		Orthopristis chrysoptera
	Sparidae	Archosargus probatocephalus
		Archosargus rhomboidalis
		Lagodon rhomboides
	Sciaenidae	Bairdiella chrysura
		Bairdiella ronchus
		Corvula batabana
		Cynoscion arenarius
		Cynoscion nebulosus
		Cynoscion nothus
		Menticirrhus americanus
		Menticirrhus saxtilis
		Mentcirrhus littoralis
		Micropogonias undulatus
		Stellifer lanceolatus
	Polynemidae	Polydactylus octonemus
	Cichlidae	Cichlasoma urophthalmus
	Gobiidae	Gobioides broussonnetti
		Gobionellus oceanicus
	Ephippidae	Chaetodipterus faber
	Trichiuridae	Trichiurus lepturus
	Bothidae	Citharichthys spilopterus
	Soleidae	Achirus lineatus
		Trinectes maculatus
	Cynoglossidae	Symphurus civitatium
		Symphurus plagiusa
	Monacanthidae	Aluterus schoepfii
		Monacanthus ciliatus
	Ostraciidae	Stephanolepis hispidus
	Tetraodontidae	Acanthostracion quadricornis
		Sphoeroides greeleyi
		Sphoeroides nephelus
		Sphoeroides parvus
		Sphoeroides spengleri
		Sphoeroides testudineus
	Diodontidae	Chilomycterus schoepfi

Annex III. Fish species richness in Terminos Lagoon: An occurrence data compilation of four sampling campaigns along a multidecadal series. (Paz Ríos et al., 2021)

Class	Order	Family	Species	1980-1981	1998-1999	2010-2011	2016-2017
Elasmobranchii	Myliobatiformes	*Dasyatidae*	*Dasyatis hastata* (DeKay, 1842)	●			
			**Hypanus americanus* (Hildebrand & Schroeder, 1928)			●	●
			~*Hypanus sabinus* (Lesueur, 1824)	●	●	●	●
		Gymnuridae	*Gymnura micrura* (Bloch & Schneider, 1801)			●	●
		Potamotrygonidae	*Styracura schmardae* (Werner, 1904)		●		●
		Urotrygonidae	*Urobatis jamaicensis* (Cuvier, 1816)	●	●	●	●
	Rhinopristiformes	*Rhinobatidae*	*Pseudobatos lentiginosus* (Garman, 1880)			●	●
Actinopteri	Acanthuriformes	Ephippidae	*~Chaetodipterus faber (Broussonet, 1782)	●	●	●	●
		Lobotidae	*~Lobotes surinamensis (Bloch, 1790)		●		
	Anguilliformes	Muraenidae	Gymnothorax nigromarginatus (Girard, 1858)			●	
			Gymnothorax saxicola Jordan & Davis, 1891		●		
		Ophichthidae	Ophichthus gomesii (Castelnau, 1855)	●	●		
	Aulopiformes	Synodontidae	Synodus foetens (Linnaeus, 1766)	●	●	●	●
	Batrachoidiforme	Batrachoididae	~Opsanus beta (Goode & Bean, 1880)	●	●	●	●
			Porichthys porosissimus (Cuvier, 1829)	●	●	●	
	Beloniformes	Belonidae	~Strongylura notata (Poey, 1860)		●		
		Hemiramphida	~Chriodorus atherinoides Goode & Bean, 1	●			●
	Blenniiformes	Blenniidae	Hypleurochilus geminatus (Wood, 1825)				●
		Labrisomidae	Paraclinus fasciatus (Steindachner, 1876)				●
	Carangiformes	Achiridae	~Achirus lineatus (Linnaeus, 1758)	●	●	●	●
			~Trinectes maculatus (Bloch & Schneider, 1	●	●	●	●
		Bothidae	Bothus ocellatus (Agassiz, 1831)	●			
		Carangidae	*Caranx crysos (Mitchill, 1815)		●	●	
			*~Caranx hippos (Linnaeus, 1766)	●	●	●	●
			~Caranx latus Agassiz, 1831			●	
			Caranx ruber (Bloch, 1793)			●	
			*Chloroscombrus chrysurus (Linnaeus, 176	●	●	●	●
			Hemicaranx amblyrhynchus (Cuvier, 1833)		●	●	●
			~Oligoplites saurus (Bloch & Schneider, 18	●	●	●	
			*Selene setapinnis (Mitchill, 1815)		●	●	
			Selene vomer (Linnaeus, 1758)	●	●	●	●
			*Trachinotus carolinus (Linnaeus, 1766)		●		
			Trachinotus falcatus (Linnaeus, 1758)		●		
			Trachinotus goodei Jordan & Evermann, 1896		●		
		Centropomidae	*~Centropomus parallelus Poey, 1860		●	●	
			*~Centropomus poeyi Chávez, 1961		●		
			*~Centropomus undecimalis (Bloch, 1792)	●			
		Cynoglossidae	*Symphurus civitatum Ginsburg, 1951		●		●
			~Symphurus plagiusa (Linnaeus, 1766)	●	●	●	●
		Paralichthyidae	Ancylopsetta quadrocellata Gill, 1864	●		●	
			~Citharichthys spilopterus Günther, 1862	●	●	●	●
			Etropus crossotus Jordan & Gilbert, 1882	●	●	●	●
			Syacium gunteri Ginsburg, 1933			●	
		Polynemidae	Polydactylus octonemus (Girard, 1858)	●	●	●	●
		Sphyraenidae	Sphyraena barracuda (Edwards, 1771)			●	
	Cichliformes	Cichlidae	~Mayaheros urophthalmus (Günther, 1862)	●	●	●	●

Class	Order	Family	Species	1980-1981	1998-1999	2010-2011	2016-2017
Actinopteri	Clupeiformes	Clupeidae	*~Brevoortia gunteri Hildebrand, 1948		●		
			~Dorosoma anale Meek, 1904			●	
			~Dorosoma petenense (Günther, 1867)		●	●	
			*Harengula clupeola (Cuvier, 1829)				●
			*~Harengula jaguana Poey, 1865	●	●	●	●
			*Opisthonema oglinum (Lesueur, 1818)	●	●	●	●
			*Sardinella aurita Valenciennes, 1847		●		
		Engraulidae	~Anchoa hepsetus (Linnaeus, 1758)	●	●	●	●
			Anchoa lamprotaenia Hildebrand, 1943	●			●
			Anchoa lyolepis (Evermann & Marsh, 1900)			●	
			~Anchoa mitchilli (Valenciennes, 1848)	●	●	●	●
			Cetengraulis edentulus (Cuvier, 1829)	●	●	●	●
	Cyprinodontiform	Fundulidae	~Lucania parva (Baird & Girard, 1855)				●
	Elopiformes	Elopidae	Elops saurus Linnaeus, 1766		●		
	Gobiiformes	Eleotridae	~Eleotris pisonis (Gmelin, 1789)				●
		Gobiidae	~Bathygobius soporator (Valenciennes, 1837)		●		
			~Gobionellus oceanicus (Pallas, 1770)	●	●	●	●
			Gobiosoma longipala Ginsburg, 1933				●
	Mugiliformes	Mugilidae	*~Mugil cephalus Linnaeus, 1758		●		
			*~Mugil curema Valenciennes, 1836		●	●	
	Perciformes	Scaridae	Nicholsina usta (Valenciennes, 1840)	●	●		
		Scorpaenidae	Scorpaena brasiliensis Cuvier, 1829			●	
			Scorpaena plumieri Bloch, 1789	●		●	●
		Triglidae	Prionotus beanii Goode, 1896	●			
			Prionotus carolinus (Linnaeus, 1771)	●	●	●	
			Prionotus martis Ginsburg, 1950			●	
			Prionotus punctatus (Bloch, 1793)	●		●	
			Prionotus rubio Jordan, 1886			●	●
			Prionotus scitulus Jordan & Gilbert, 1882	●	●	●	●
			Prionotus tribulus Cuvier, 1829	●		●	●
		Gerreidae	~Diapterus auratus Ranzani, 1842		●	●	●
			~Diapterus rhombeus (Cuvier, 1829)	●	●	●	●
			~Eucinostomus argenteus Baird & Girard, 1	●	●	●	●
			~Eucinostomus gula (Quoy & Gaimard, 182	●	●	●	●
			~Eucinostomus melanopterus (Bleeker, 186	●	●		●
			*~Eugerres plumieri (Cuvier, 1830)	●	●	●	●
		Haemulidae	Anisotremus virginicus (Linnaeus, 1758)				●
			*~Conodon nobilis (Linnaeus, 1758)		●		
			Haemulon aurolineatum Cuvier, 1830		●	●	●
			*Haemulon bonariense Cuvier, 1830	●	●	●	●
			*Haemulon plumierii (Lacepède, 1801)	●	●	●	●
			*~Orthopristis chrysoptera (Linnaeus, 1766)	●	●	●	●
		Lutjanidae	*~Lutjanus analis (Cuvier, 1828)	●	●		●
			*Lutjanus apodus (Walbaum, 1792)		●		
			*~Lutjanus griseus (Linnaeus, 1758)	●	●	●	●
			*Lutjanus synagris (Linnaeus, 1758)	●	●	●	●
			*Ocyurus chrysurus (Bloch, 1791)		●		

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Actinopteri	Perciformes	Sciaenidae	*~Bairdiella chrysoura (Lacepède, 1802)	●	●	●	●
			*Bairdiella ronchus (Cuvier, 1830)	●	●	●	●
			Corvula batabana (Poey, 1860)				●
			*~Cynoscion arenarius Ginsburg, 1930	●	●	●	●
			*~Cynoscion nebulosus (Cuvier, 1830)	●	●	●	●
			*Cynoscion nothus (Holbrook, 1848)	●		●	●
			*Menticirrhus americanus (Linnaeus, 1758)	●	●	●	●
			*Menticirrhus littoralis (Holbrook, 1847)				●
			Menticirrhus saxatilis (Bloch & Schneider, 1	●	●	●	●
			~Micropogonias furnieri (Desmarest, 1823)			●	●
			*~Micropogonias undulatus (Linnaeus, 1766	●	●	●	●
			Odontoscion dentex (Cuvier, 1830)	●			
			~Stellifer lanceolatus (Holbrook, 1855)	●	●	●	●
		Serranidae	Diplectrum bivittatum (Valenciennes, 1828)			●	
			*Diplectrum formosum (Linnaeus, 1766)			●	●
			Epinephelus itajara (Lichtenstein, 1822)		●		
			*Mycteroperca bonaci (Poey, 1860)		●	●	
		Sparidae	*~Archosargus probatocephalus (Walbaum	●	●	●	●
			Archosargus rhomboidalis (Linnaeus, 1758	●	●	●	●
			Calamus penna (Valenciennes, 1830)		●		
			*~Lagodon rhomboides (Linnaeus, 1766)		●	●	●
			Stenotomus caprinus Jordan & Gilbert, 1882				●
	Scombriformes	Stromateidae	Peprilus paru (Linnaeus, 1758)		●	●	
		Trichiuridae	*Trichiurus lepturus Linnaeus, 1758	●	●	●	●
	Siluriformes	Ariidae	*~Ariopsis felis (Linnaeus, 1766)	●	●	●	●
			*Bagre marinus (Mitchill, 1815)	●	●	●	●
			*~Cathorops melanopus (Günther, 1864)	●	●	●	●
	Syngnathiformes	Dactylopteridae	Dactylopterus volitans (Linnaeus, 1758)			●	
		Syngnathidae	Hippocampus erectus Perry, 1810	●	●	●	●
			Hippocampus zosterae Jordan & Gilbert, 1882				●
			Syngnathus floridae (Jordan & Gilbert, 1882)				●
			~Syngnathus fuscus Storer, 1839			●	
			Syngnathus louisianae Günther, 1870	●	●		●
			~Syngnathus scovelli (Evermann & Kendall,	●	●	●	●
	Tetraodontiforme	Diodontidae	Chilomycterus schoepfii (Walbaum, 1792)	●	●	●	●
		Monacanthidae	Aluterus schoepfii (Walbaum, 1792)	●		●	●
			Monacanthus ciliatus (Mitchill, 1818)		●	●	
			Stephanolepis hispida (Linnaeus, 1766)	●	●	●	●
		Ostraciidae	Acanthostracion quadricornis (Linnaeus, 17	●	●	●	●
		Tetraodontidae	Lagocephalus laevigatus (Linnaeus, 1766)	●	●	●	
			Sphoeroides greeleyi Gilbert, 1900	●	●	●	●
			Sphoeroides maculatus (Bloch & Schneider, 1801)			●	
			Sphoeroides marmoratus (Lowe, 1838)	●			
			Sphoeroides nephelus (Goode & Bean, 18	●	●	●	●
			Sphoeroides pachygaster (Müller & Troschel, 1848)			●	
			Sphoeroides parvus Shipp & Yerger, 1969			●	●
			Sphoeroides spengleri (Bloch, 1785)	●	●	●	●
			~Sphoeroides testudineus (Linnaeus, 1758	●	●	●	●