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Ten years later: An update on the status of collections of endemic Gulf of Mexico fishes put at risk by the 2010 Oil Spill

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Abstract

The 2010 Gulf of Mexico Deepwater Horizon was the largest spill in human history that occurred during a 12- week period over ten years ago; however, after more than a decade of post-spill research little definitive remains known about the long-term impacts on the development and distribution of fishes in and around the region of the disaster. Here we examine endemic Gulf of Mexico fish species that may have been most affected by noting their past distributions in the region of the spill and examining data of known collecting events over the last twenty years (ten years prior to the spill, ten years post spill). In addition some observational data that did not result in specimen collections are also examined here. Five years post spill, it was reported that 48 of the Gulf's endemic fish species had not been collected, with expanded methods we now report that 29 (of the 78 endemic species) have not been reported in collections since 2010 (five of these are only known from observations post-spill). Although there is some cause to celebrate the good news that some previously 'missing' species have been found, the lack of information for many species remains a cause for concern.

Keywords

Oil spill, fishes, Gulf of Mexico, Macando, Deepwater Horizon

Introduction

The 2010 Gulf of Mexico Deepwater Horizon Oil Spill (DWH), MC 252 or Macondo blowout was the largest accidental oil spill in history (Crone and Tolstoy 2010, Rabalais 2014, Murawski et al. 2023). The tremendous amount of oil spilled during DWH was estimated at 134 million gallons (down from greater than 200 million reported in earlier sources), which, resulted in an immediate contamination area of 149,000 km and continued to spread through currents widely in the Gulf of Mexico (GOM) (Rabalais 2011, Ramseur and Hagerty 2014, MacDonald et al. 2015, Berenshtein et al. 2020).

Coupled with the fact that it occurred in the deep sea (>1000 m depth) and with the coordinated release of more than a million gallons of dispersant, which has been suggested to have made the DWH oil as much as 52% more toxic, more difficult to clean up, and increased its impact to wildlife (Rico-Martínez et al. 2013). It has been suggested almost 100 million gallons of DWH oil combined with dispersants remains in the Gulf and is one of the worst pollution events in history (Goodbody-Gringley et al. 2013, Ramseur and Hagerty 2014).

Even after a decade, the long-term effects of the spill are still not fully understood. Recent research has suggested there have been some persistent ecological effects including damage to deep ocean coral communities, harm to oyster fisheries, loss of marshlands, population declines of marine mammals, sea turtles, and seabirds (Barron et al. 2020).

Some fish species appear to have been particularly at risk and impacted by the 2010 Oil Spill with evidence of physical and developmental abnormalities reported and evidence of extirpations (Whitehead et al. 2012, Incardona et al. 2014, Dubansky et al. 2013, Brette et al. 2014, Mager et al. 2014, Alloy et al. 2016, Chakrabarty et al. 2016). Further, risks from oil production related polycyclic aromatic hydrocarbons (PAH) exposure and concentrations in fishes is widespread in the GOM and will likely continue as extraction of petrochemical intensifies (Turner and Rabalais 2019, Pulster et al. 2020). These include Taylor Energy's MC20 oil spill which began in 2004 and continues today (Schrope 2013, Mason 2019). Linardich et al. (2019) reported that habitat degradation is the leading cause of risk to endemic GOM species, and oil spills are certainly part of that equation.

The Gulf of Mexico is one of the most biologically rich and resilient marine environments in the world with 1541 fish species known from the region, 78 of which are reported to be endemic to the Gulf (i.e., found only in the Gulf; McEachran 2009, Chakrabarty et al. 2016). Although many commercially valuable fish species populations have been examined following DWH most Gulf ichthyofauna as a whole has received little attention (Fodrie et al. 2014, Murawski et al. 2023). The IUCN has suggested that upwards of 25% of the Gulf's endemic fishes may be threatened with extinction (Linardich et al. 2019, IUCN 2023). Chakrabarty et al. (Caruso et al. 2018, Chakrabarty et al. 2016 examined museum records

for the occurrence of all known endemic Gulf fish species (77 spp. thought to be endemic at the time) five years after the spill and reported that 48 species of fish had not been officially collected (i.e., vouchered in natural history collections) since the 2010 spill. Of these 14 species were designated as being of 'greatest concern' as they may have been most impacted by DWH because of their past distributions being largely (>35%) within the spill region.

In this current study we reexamine museum records (2000-2020) of the 78 endemic species (adding the recently described American Pocket shark, *Mollisquama mississippiensis*, as a Gulf endemic) using data from The Global Biodiversity Information Facility (GBIF: <https://www.gbif.org/>), FishNet2 (<http://www.fishnet2.net/>) and recent literature.

Material and methods

The documented occurrences of 78 species endemic to the Gulf of Mexico region were tallied using two databases: The Global Biodiversity Information Facility (GBIF) and FishNet2. To complementary specimen data from these databases, an extensive review of the literature on individual species was performed to determine if observations of these taxa were made (that were not part of digitized collections), population status as well as range expansion. The International Union for Conservation of Nature's Red List of Threatened Species (abbreviated "IUCN Red List" throughout) status was also reviewed and reported here when available (<https://www.iucnredlist.org/>).

GBIF recently changed their data algorithm to include observed species in addition to preserved specimens. To accurately measure the change in species populations, the data from the total identified specimens (preserved and observed in nature) from GBIF was graphed separately and compared to the total preserved specimens from FishNet2 from 2000 to 2020. Only species found in the Gulf of Mexico and Caribbean region were accounted for in the data, unless otherwise noted. We last gathered data from these websites on April 20, 2023.

A scatterplot graph was created in Microsoft Excel by plotting the Number of Occurrence(s) on the y-axis, and the Number of Years on the x-axis. Collections data from GBIF is denoted as "GBIF Preserved" when a voucher specimen was collected, human observation data from GBIF is denoted as "GBIF Observed", and collections data from FishNet2 is denoted by "FishNet2 Preserved" to indicate the type(s) of data that each database reported. No graph is included if species were not sampled between 2000-2020 (10 years before and 10 years after DWH).

Chakrabarty et al. (2016), Chakrabarty et al. (2012) listed fish species in need of conservation concern based on their known distribution within the spill zone or proximity to the DWH oil spill surface slick. Here we refer to these as "Species of Greatest Concern" (if over 35% of their range was in the spill zone) or "Lesser Concern" (if less than 35% of their range was in the spill zone, but they are still considered endemic) and their names are in

bold if they have not been observed or collected since 2010 and shown in Table 1 and 2, an asterisk denotes that it has only been observed and not vouchered (i.e., collected and cataloged in a museum). No scatterplot is included for species lacking collections in the 20 year period of our survey, but we include information about the last observations/collections events when that is known.

Eschmeyer's Catalog of Fishes (<https://www.calacademy.org/scientists/projects/eschmeyers-catalog-of-fishes>) was used to update taxonomic names and we also show the authority (authors of original description) and the family name from that catalog (Fricke et al. 2023). Please note that following taxonomic convention, the taxonomic-authority reference following the scientific name is only presented in parentheses if the species was described in a different genus than it is currently in, otherwise there are no parentheses.

Results

Alosa alabamae Jordan and Evermann, 1896 - in Jordan and Evermann 1896 ; (Clupeidae), Alabama shad. Status listed as "Near Threatened" on the IUCN Red List (Anonymous 2021). (Fig. 1)

Alosa chrysochloris Rafinesque, 1820 in Rafinesque 1820; (Clupeidae), Skipjack shad. Status listed as "Least concern" on the IUCN Red List (Robertson and Caruso 2018). (Fig. 1)

Atherinella schultzi (Álvarez and Carranza, 1952) Álvarez del Villar and Carranza 1952; (Atherinopsidae), Chimalapa silverside. Status listed as "Data Deficient" on the IUCN Red List (Espinosa Pérez and Lambarri Martínez 2019). (Fig. 1)

Atractosteus spatula (Lacepède, 1803) Lacepède 1803; (Lepisosteidae), Alligator gar; note that this species is represented here by the Gulf of Mexico samples and that this species is predominantly found in freshwaters whose collections are not shown here. Status listed as "Least concern" on the IUCN Red List (Collette et al. 2019). (Fig. 1)

Bollmannia communis Ginsburg, 1942 in Ginsburg 1942; (Gobiidae), Ragged goby. Status listed as "Least concern" on the IUCN Red List (Anonymous 2015). (Fig. 2)

Bollmannia eigenmanni (Garman, 1896) Garman and 1896; (Gobiidae), Shelf goby. Status listed as "Least concern" on the IUCN Red List (Anonymous 2015). (Fig. 2)

Brevoortia gunteri Hildebrand, 1948 in Hildebrand 1948; (Clupeidae), Finescale menhaden. Status listed as "Least concern" on the IUCN Red List (Collette et al. 2019). (Fig. 2)

Brevoortia patronus Goode, 1878 in Goode 1878; (Clupeidae), Gulf menhaden. Status listed as "Least concern" on the IUCN Red List (Collette et al. 2019). (Fig. 2).

Calamus arctifrons Goode and Bean, 1882 in Goode and Bean 1882; (Sparidae), Grass porgy. Status listed as "Least concern" on the IUCN Red List (Collette et al. 2019). (Fig. 3)

Calamus campechanus Randall and Caldwell, 1966 in Randall and Caldwell 1966 (Sparidae), Campeche porgy. Last reported on GBIF in 2007, although Poot-López et al. (2017) reported 15 *C. campechanus* caught between Sept 2015-October 2016 off of the northern coast of the Yucatan Peninsula, Mexico. Borges-Ramirez et al. (2020) reported 40 *C. campechanus* caught in 2019 in Los Petenes Biosphere Reserve, Campeche Bay, Mexico. Status listed as “Data Deficient” on the IUCN Red List (Collette et al. 2019). (Fig. 3)

Chasmodes longimaxilla Williams, 1983 in Williams 1983; (Blenniidae), Stretchjaw blenny. Status listed as “Least concern” on the IUCN Red List (Anonymous 2014). (Fig. 3)

Citharichthys abbotti Dawson, 1969 in Dawson 1969; (Cyclopsettidae), Veracruz whiff. Species last reported in 2001 off the Texas coast. Status listed as “Least concern” on the IUCN Red List (Munroe et al. 2015). (Fig. 3)

Coryphaenoides mexicanus (Parr, 1946) in Parr 1946; (Macrouridae), Mexican grenadier. Status listed as “Least concern” on the IUCN Red List (Roa-Varón and Iwamoto 2019). (Fig. 4)

Coryphopterus punctipectophorus Springer, 1960 in Springer 1960; (Gobiidae), Spotted goby. Status listed as “Least concern” on the IUCN Red List (Anonymous 2015). (Fig. 4)

Ctenogobius claytonii (Meek, 1902) in Meek 1902; (Gobiidae), Black fin goby. The species was last reported off the Yucatan Peninsula, Mexico in 2015. Status is listed as “Vulnerable” on the IUCN Red List (Pezold 2019). (Fig. 4)

Cynoscion arenarius Ginsburg, 1930 in Ginsburg 1930; (Sciaenidae), Sand seatrout. Status listed as “Least Concern” on the IUCN Red List (Espinosa-Perez and Robertson 2020). (Fig. 4)

Dipturus olseni (Bigelow and Schroeder, 1951) in Bigelow and Schroeder 1951; (Rajidae), Spreadfin skate. The species was last reported in 2011 off the coast of Alabama. Status listed as “Least Concern” on the IUCN Red List (Kulka et al. 2020). (Fig. 5)

Dipturus oregoni Bigelow and Schroeder, 1958 in Bigelow and Schroeder 1958; (Rajidae), Hooktail skate. Status listed as “Least Concern” on the IUCN Red List (Crysler et al. 2020). (Fig. 5)

Eptatretus minor (Fernholm and Hubbs, 1981) in Fernholm and Hubbs 1981; (Myxinidae). The species was last reported in 2009 off the coast of Mississippi. Status listed as “Data Deficient” on the IUCN Red List (Anonymous 2011). (Fig. 5)

Eptatretus springeri (Bigelow and Schroeder, 1952) in Bigelow and Schroeder 1952; (Myxinidae), Gulf hagfish. Status listed as “Least Concern” on the IUCN Red List (Mincarone and Mok 2022). (Fig. 5)

Etmopterus schultzi Bigelow, Schroeder, and Springer, 1953 in Bigelow et al. 1953; (Etmopteridae), Fringe-fin lanternshark. The species was last reported in the GOM in 2009

off the coast of Alabama. Status listed as “Least Concern” on the IUCN Red List (Cotton et al. 2021). (Fig. 6)

Eustomias leptobolus Regan and Trewavas, 1930 in Regan and Trewavas 1930; (Stomiidae), Black dragonfish. The species was last reported in the GOM in 1960 off the coast of Louisiana and the species status is listed as “Data Deficient” by IUCN (Harold and Milligan 2019).

Exechodontes daidaleus DeWitt, 1977 in DeWitt 1977; (Zoarcidae), Outwordtoothed eelpout. The species was last reported in the GOM in 2007 off the coast of Florida. Status listed as “Least Concern” on the IUCN Red List (Vega-Cendejas et al. 2019). (Fig. 6)

Floridichthys carpio (Günther, 1866) in Günther 1866; (Cyprinodontidae), Goldspotted killifish. Status listed as “Least Concern” on the IUCN Red List (Chao et al. 2015). (Fig. 6)

Fundulus grandis Baird and Girard, 1853 in Baird and Girard 1853; (Fundulidae), Gulf killifish. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2019). (Fig. 6)

Fig. 6

Fundulus jenkinsi (Evermann, 1892) in Evermann 1892; (Fundulidae), Saltmarsh topminnow. Status listed as “Vulnerable” on the IUCN Red List (Collette et al. 2019). (Fig. 7)

Fundulus persimilis (Miller, 1955) in Miller 1955; (Fundulidae), Yucatan killifish. Species last reported in 2005 off of the Yucatán Peninsula, Mexico. Status listed as “Endangered” on the IUCN Red List (Jelks et al. 2019). (Fig. 7)

Fundulus pulvereus (Everman, 1892) in Evermann 1892; (Fundulidae), Bayou killifish. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2019). (Fig. 7)

Fundulus xenica Jordan and Evermann, 1896 (formerly *Adinia xenica*) in Jordan and Evermann 1896; (Fundulidae), Diamond killifish. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 7)

Gambusia yucatana Regan, 1914 in Regan 1914; (Poeciliidae), Yucatan gambusia. Species last reported on FishNet2 in 2010 the Yucatán Peninsula, Mexico. Rodríguez-Fuentes et al. 2016 reported collecting *G. yucatana* ($N = 38$) in Yucatan Peninsula wetlands during a monitoring campaign in May 2014. Aguilar et al. 2021 reported collecting juvenile *G. yucatana* (number not reported) from a small stream in San Francisco de Campeche City, Mexico in 2017. Aguilar et al. 2022 reported collecting *G. yucatana* (number not reported) from a small stream in San Francisco de Campeche City, Mexico in 2020. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2019). (Fig. 8)

Gobiosoma longipala Ginsburg, 1933 in Ginsburg 1933; (Gobiidae), Twoscale goby. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 8)

Gordiichthys ergodes McCosker, Böhlke, and Böhlke, 1989 in McCosker et al. 1989; (Ophichthidae), Irsone eel. Species last reported on FishNet2 in 2006 off the Florida coast. Status listed as “Data Deficient” on the IUCN Red List (McCosker 2015). (Fig. 8)

Gordiichthys leibyi McCosker and Böhlke, 1984 in McCosker and Böhlke 1984; (Ophichthidae), String eel. Species last reported in the GOM in 1973 off the Florida coast and reported off the Atlantic coast in 2004, 2001 and 2000. Caires and Fonseca (2010) reported a mature female *Gordiichthys leibyi* from the stomach of a Yellowtail snapper (*Ocyurus chrysurus*) collected 70 miles off the coast of Mucuri, Bahia, Brazil in 2005. Preserved specimens reported in GBIF and FISHNET2 were caught in the Atlantic Ocean (off of North Carolina), not the Gulf or Caribbean region, possibly due to being carried by the Gulf Stream. Status listed as “Data Deficient” on the IUCN Red List (McCosker 2015).

*Gunterichthys longipenis** Dawson, 1966 in Dawson 1966; (Dinematichthyidae), Gold brotula. Observed twice in 2011 off the coast of Southern Florida. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 6)

Gymnachirus texae (Gunter, 1936) in Gunter 1936; (Achiroidae), Gulf of Mexico Fringed sole. Status listed as “Least Concern” on the IUCN Red List (Tornabene et al. 2015). (Fig. 9)

Halichoeres burekai Weaver and Rocha, 2007 in Weaver and Rocha 2007; (Labridae), Mardi Gras wrasse. Species listed as “Endangered” on the IUCN Red List (IUCN, 2022). Robertson et al. (2016) reported *H. burekai* to be abundant in the Cayo Arcas reefs off the Yucatan Peninsula in Mexico. Francisco and Fraco-Mej (2017) reported *H. burekai* as one of the most abundant species encountered at Enmedio Reef off of Veracruz, Mexico. Escarcega-Quiroga and Flores-Serrano (2020) reported *H. burekai* to be a frequently consumed species in the diet of the introduced Red lionfish (*Pterois volitans*) in coral reefs of Northern Veracruz, Mexico. Gonzalez-Gandara and Chavez (2020) reported the relative abundance of *H. burekai* as >30% in Veracruz Coast, 2-5% in Campeche bank, and <1 in the Mexican Caribbean. Status listed as “Endangered” on the IUCN Red List (Rocha et al. 2015).

Halieutichthys intermedius Ho, Chakrabarty, and Sparks, 2010 in Ho et al. 2010; (Ogcocephalidae), Louisiana Pancake batfish. Species collected three times in October, 2010 following DWH. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2019). (Fig. 9)

Heteroconger luteolus Smith, 1989 in Smith 1989; (Congridae), Yellow garden eel. *H. luteolus* has been GBIF observed seven times and preserved eight times off the Southeastern coast of Florida since 2014 but not in the Gulf of Mexico since 2010. Status listed as “Least Concern” on the IUCN Red List (Smith 2015). (Fig. 9)

*Hyperoglyphe bythites** (Ginsburg, 1954) in Ginsburg 1954; (Centrolophidae), Black driftfish. Observed once in 2019 off the coast of Texas. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2015). (Fig. 10)

Hypleurochilus caudovittatus Bath, 1994 in Bath 1994; (Blenniidae), Zebratail blenny. Last reported on FishNet2 in 2004. Schrandt 2018 reported collecting *H. caudovittatus* in the Big Bend Region of Florida during 2008-2015 trawls. Munnely et al. (2021) reported possible sightings of *H. caudovittatus* during 2013–2014 from remote video and diver surveys around 150 small oil platforms in nearshore federal waters off different points of the Louisiana coast at ≤ 18 m depth. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2014). (Fig. 10)

Hypleurochilus multifilis (Girard, 1858) in Girard 1858; (Blenniidae), Featherduster blenny. Status listed as “Least Concern” on the IUCN Red List (Smith-Vaniz et al. 2014). (Fig. 10)

Ijimaia antillarum Howell Rivero, 1935 in Howell Rivero 1935; (Ateleopodidae), Jellynose. Species last reported in GOM in 2004. A material sample of *J. antillarum* is reported in GBIF from 2011 off the coast of Belize. Syverson et al. (2014) reported observations of *J. antillarum* near Roatán, Honduras between 2012-2015. Status listed as “Least Concern” on the IUCN Red List (Roa-Varón and Iwamoto 2019). (Fig. 10)

Jordanella floridae Goode and Bean, 1879 in Goode and Bean 1879; (Cyprinodontidae), American flagfish. Status is not listed by the IUCN Red List. (Fig. 11)

*Jordanella pulchra** (Hubbs, 1936) in Hubbs 1936; (Cyprinodontidae), Progreso or Yucatan flagfish. Status listed as “Least Concern” on the IUCN Red List (Schmitter-Soto and Vega-Cendejas 2019). (Fig. 11)

Lepisosteus oculatus Winchell, 1864 in Winchell 1864; (Lepisosteidae), Spotted gar; note that this species is represented here by the Gulf of Mexico samples and that this species is predominantly found in freshwaters whose collections are not shown here. Status listed as “Least Concern” on the IUCN Red List (Collette et al. 2019). (Fig. 11)

*Leucoraja lentiginosa** (Bigelow and Schroeder, 1951) in Bigelow and Schroeder 1951; (Rajidae), Freckle skate. Species last reported in GOM on FISHNET2 in 2000. *L. lentiginosa* GBIF Observed twice in 2012 off the Western coast of Cozomel, Mexico by divers. Status listed as “Least Concern” on the IUCN Red List (Crysler et al. 2020). (Fig. 11)

*Lupinoblennius nicholsi** (Tavolga, 1954) in Tavolga 1954; (Blenniidae), Highfin blenny. Turner et al. 2022 reported range expansion of *L. nicholsi* to the Northern GOM and collected a single specimen in 2021 off of Dauphin Island, Alabama. Lima et al. 2015 reported *L. nicholsi* as the most abundant larvae sampled during trawling in 2012/13 along a floodplain across the north eastern coast of Brazil. Status listed as “Least Concern” on the IUCN Red List (Smith-Vaniz et al. 2014). (Fig. 12)

Lycenchelys bullisi Cohen, 1964 in Cohen 1964; (Zoarcidae), Gulf eelpout. Species last reported in 1999 off of the Florida Keys. Status listed as “Least Concern” on the IUCN Red List (Cobián Rojas et al. 2019).

Menidia clarkhubbsi Echelle and Mosier, 1982 in Echelle and Mosier 1982 (Atherinopsidae), Texas silverside. Species last reported in 2000 off of the Texas coast. Status listed as “Data Deficient” on the IUCN Red List (Collette et al. 2019). (Fig. 12)

Menidia colei Hubbs, 1936 in Hubbs 1936; (Atherinopsidae), Golden silverside. Species was last reported in 2009. Status listed as “Vulnerable” on the IUCN Red List (Schmitter-Soto et al. 2019). (Fig. 12)

Menidia conchorum Hildebrand and Ginsburg, 1927 in Hildebrand and Ginsburg 1927; (Atherinopsidae), Key silverside. Species was collected twice in 2019 of the Florida Keys and observed twice (2014, 2011) in the Cayman Islands by divers. Status listed as “Endangered” on the IUCN Red List (Anonymous 2015). (Fig. 12)

Fig. 12

Microdesmus lanceolatus Dawson, 1962 in Dawson 1962; (Microdesmidae), Lancetail wormfish. Species last reported in 1994. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015).

Mollisquama mississippiensis Grace, Doosey, Denton, Naylor, Bart, Maisey, 2019 in Grace et al. 2019; (Dalatiidae), American Pocket shark. Species was collected once in 2010 prior to DWH in the central GOM. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2020). (Fig. 13)

Monopenchelys acuta (Parr, 1930) in Parr 1930; (Muraenidae), Redface Moray Eel. Species was last reported in the GOM in 2007 with the most recent report being 2010 in French Polynesia. Status listed as “Data Deficient” on the IUCN Red List (McCosker 2010). (Fig. 13)

Mustelus sinusmexicanus Heemstra, 1997 in Heemstra 1997; (Triakidae), Gulf of Mexico smoothhound. Status listed as “Least Concern” on the IUCN Red List (Carlson et al. 2021). (Fig. 13)

Neopisthopterus cubanus Hildebrand, 1948 in Hildebrand 1948; (Pristigasteridae), Cuban Longfin herring. Species last reported in 1937. Status listed as “Vulnerable” on the IUCN Red List (Caruso et al. 2018).

Ogcocephalus pantostictus Bradbury, 1980 in Bradbury 1980; (Ogcocephalidae), Spotted batfish. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 13)

Ogilbia cayorum Evermann and Kendall, 1898 in Evermann and Kendall 1898; (Bythitidae), Key brotula. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 14)

Oneirodes bradburyae Grey, 1957 in Grey 1957; (Oneirodidae), American Dreamer anglerfish. Collected once in 1954 off the coast of Western Florida. A genetic sample was

recorded in 2015 off the coast of Alabama by the DEEPEND Consortium (Schmutz 2022). Status listed as “Data Deficient” on the IUCN Red List (Carpenter et al. 2019).

Ophichthus omorgmus McCosker and Böhlke, 1984 in McCosker and Böhlke 1984; (Ophichthidae), Dottedline snake eel. Last reported in 1999 off of the Florida Keys. Status listed as “Data Deficient” on the IUCN Red List (Collette et al. 2022).

Ophichthus rex Böhlke and Caruso, 1980 in Böhlke and Caruso 1980; (Ophichthidae), Kingsnake eel. Status listed as “Least Concern” on the IUCN Red List (McCosker 2015). (Fig. 14)

Opsanus pardus Goode and Bean, 1882 in (Goode and Bean 1882); (Batrachoididae), Leopard toadfish. Status listed as “Least Concern” on the IUCN Red List (Polanco Fernandez et al. 2015 Fig. 14)

Parasaccogaster rhamphidognatha (Cohen, 1987) in Cohen 1987; (Bythitidae). Collected once in 1969 off of the coast of Alabama. Status listed as “Data Deficient” on the IUCN Red List (Cobián Rojas et al. 2019).

Parmaturus campechiensis Springer, 1979 in Springer 1979; (Pentanchidae), Campeche catshark. Collected once in 1970 in the continental slope off of Veracruz, Mexico. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2020).

Prionotus longispinosus Teague, 1951 in Teague 1951; (Triglidae), Bigeye searobin. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 14)

Prionotus martis Ginsburg, 1950 in Ginsburg 1950; (Triglidae), Gulf of Mexico Barred searobin. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 15)

Prionotus paralatus Ginsburg, 1950 in Ginsburg 1950; (Triglidae), Mexican searobin. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015). (Fig. 15)

Rostroraja texana (Chandler, 1921) formerly *Raja texana* in Chandler 1921; (Rajidae), Roundel skate. Status listed as “Least Concern” on the IUCN Red List (Dulvy et al. 2021). (Fig. 15)

*Sanopus reticulatus** Collette, 1983 in Collette 1983; (Batrachoididae), Reticulated toadfish. Observed once in 2015 off of the Yucatan Peninsula in Mexico. Status listed as “Endangered” on the IUCN Red List (Anonymous 2015). (Fig. 15)

Sphoeroides parvus Shipp and Yerger, 1969 in Shipp and Yerger 1969; (Tetraodontidae). Least puffer. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2014). (Fig. 16)

Sphoeroides spengleri (Bloch, 1785) in Bloch 1785; (Tetraodontidae), Bandtail puffer. Status listed as “Least Concern” on the IUCN Red List (Shao et al. 2014). (Fig. 16)

Springeria folirostris Bigelow and Schroeder, 1951 in Bigelow and Schroeder 1951 (formerly *Anacanthobatis folirostris*); (Anacanthobatidae), Leafnose skate. Species was last collected in 2004 off the coast of Louisiana. Status listed as “Least Concern” on the IUCN Red List (Crysler et al. 2020). (Fig. 16)

Stemonosudis bullisi Rofen, 1963 in Rofen 1963; (Paralepididae). Species was last collected in 2007 off the coast of Alabama. Status listed as “Data Deficient” on the IUCN Red List (Russell 2010). (Fig. 16)

Syngnathus texanus Gilbert, 2013 in Gilbert et al. 2013; (Syngnathidae), Texas pipefish. The species was last observed in 1983. Status is not assessed by the IUCN Red List.

Trichopsetta ventralis (Goode and Bean, 1885) in Goode and Bean 1885; (Bothidae), Sash flounder. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2021). (Fig. 17)

Varicus benthonis (Ginsburg, 1953) formerly *Chriolepis benthonis* in Ginsburg 1953; (Gobiidae), Deepwater goby. There are five reports of this species of GBIF collected off the Yucatan Peninsula, Mexico with no date given. Status listed as “Data Deficient” on the IUCN Red List (Anonymous 2015).

Varicus marilynae Gilmore, 1979 in Gilmore 1979; (Gobiidae), Orange belly goby. The species was last reported off the coast of Florida in 1974. Status listed as “Data Deficient” on the IUCN Red List (Gilmore et al. 2015).

Varicus vespa (Hastings and Bortone, 1981) formerly *Chriolepis vespa* in Hastings and Bortone 1981; (Gobiidae), Wasp goby. The species was last reported off the coast of Florida in 2006. Status listed as “Least Concern” on the IUCN Red List (Anonymous 2015).

Discussion

Understanding the impacts of catastrophic environmental events such as the 2010 Gulf of Mexico Oil Spill does not end when the wellhead is capped or when the last drops of oil cease to flow. The disaster only begins to end when the data no longer show impacts of the event. We are far from the beginning of the end for DWH. Lingering chemicals, lost generations of wildlife, a continued ecosystem imbalance may all be factors that prevent an environment from rebounding from such cataclysmic events (Turner and Rabalais 2019). However, the environment's ability to recover should also not be overlooked. This paper is the third in a series looking at distributions of endemic and threatened fishes that have distributions in the region of the 2010 Oil Spill. The first paper (Chakrabarty et al. 2012) mapped the surface oil slick from DWH and the distribution of fish species known to have specimens collected in the region; the second (Chakrabarty et al. 2016) reexamined those species to look for evidence of a continued impact; and here again we do a longer term (10 year) review of the populations of these species that may have been most impacted by DWH. Differently than those previous studies which exclusively used museum voucher

(reference specimens that are identified and cataloged in natural history collections) as the only evidence of a species existence or persistence in an area, this paper also included a literature search and other evidence that a species may be known from an area - even without a museum voucher. The need for museum vouchers as definitive evidence of a species existence in a given time and place should not be underestimated (Buckner et al. 2021) but we also recognize that qualified individuals can also make visual identifications that can be useful in expanding our knowledge of species distributions. GBIF recently added observational data (in the absence of a voucher) as part of its search tool, a feature not available for (Chakrabarty et al. 2016, Chakrabarty et al. 2012) which also relied on GBIF. To acknowledge that the observational data does not have the same weight as a physical specimen (i.e., it is difficult to check for misidentifications when a physical specimen is missing (Chakrabarty 2010) we separate those data in the results above. The addition of FishNet2, which is a database specific to fish collections, shows how there can be discrepancies even between partnering databases (much of the FishNet2 data is often uploaded to GBIF). At the time of writing, we are more than 13 years past the period of the spill, but it can take many years for the data to be merged and uploaded between individual databases. For that reason we focused our review for the time up to 10 years post DWH.

Chakrabarty et al. (2012) reported that “Endemic species of greatest concern” which were species potentially impacted the most by the oil spill because greater than 35% of their historical records were from the spill zone: The species with the highest level of distribution overlap were, from highest to lowest: *Parasaccogaster rhamphidognatha* (formerly *Saccogaster rhamphidognatha*) (100 %), *Oneirodes bradburyae* (100 %), *Etmopterus schultzi* (90 %), *Gunterichthys longipenis* (88 %), *Hyperoglyphe bythites* (82 %), *Ophichthus rex* (82 %), *Dipturus oregoni* (80 %), *Springeria folirostris* (formerly *Anacanthobatis folirostris*) (79 %), *Halieutichthys intermedius* (68 %), *Bollmannia eigenmanni* (64 %), *Coryphaenoides mexicanus* (54 %), *Eptatretus springeri* (54 %), *Leucoraja lentiginosa* (53 %), *Lycenchelys bullisi* (50 %), *Prionotus longispinosus* (50 %), *Microdesmus lanceolatus* (43 %), *Mustelus sinusmexicanus* (43 %), *Bollmannia communis* (41 %), *Eustomias leptobolus* (40 %), and *Opsanus pardus* (39 %). One quarter of all endemics to the Gulf of Mexico were in this highest potential impact category reported by Chakrabarty et al. 2012.

Of these species of greatest concern six remain unsampled: *Eustomias leptobolus*, *Etmopterus schultzi*, *Lycenchelys bullisi*, *Microdesmus lanceolatus*, *Neoopisthopterus cubanus*, and *Parasaccogaster rhamphidognatha* (see Table 1). Notably, of these species, some have not been seen since their first description many years before the spill. It would be disingenuous to link their absence in the Gulf in recent years to DWH when many were “missing” from well before that time. However, the opportunity to rediscover these species while also monitoring the Gulf post-spill should not be lost.

Chakrabarty et al. (2012) also labeled “Endemic species of concern” as species with less than 35 % of historical records being from the spill zone (here called species of “lesser concern”). These included *Trichopsetta ventralis* (31 %), *Dipturus olsenii* (29 %), *Hypoleurochilus multifiliis* (25 %), *Eptatretus minor* (23 %), *Fundulus pulvereus* (18 %), *Gymnachirus texae* (16 %), *Adinia xenica* (13 %), *Fundulus grandis* (13 %), *Cynoscion*

arenarius (12 %), *Raja texana* (11 %), *Brevoortia patronus* (11 %), *Ijimaia antillarum* (8 %), *Prionotus martis* (5 %), *Fundulus jenkinsi* (4 %), *Ogcocephalus pantostictus* (3 %), *Brevoortia gunteri* (2 %), *Alosa chrysochloris* (2 %), *Alosa alabamae* (1 %), *Sphoeroides spengleri* (0.4 %), *Lepisosteus oculatus* (0.2 %) and here we also consider those with no overlap with the spill but that were recognized Gulf endemics. Several of these have yet to be collected post-spill, or have only been observed (Table 2).

Notably the newly described Pocket Shark, *Mollisquama mississippiensis*, (Grace et al. 2019), the newest endemic for the Gulf Of Mexico is only known from a single specimen, the holotype, collected in 2010. Several “missing” species reported in Chakrabarty et al. (2016) have now been observed or collected (see Table 3). Adding observations and conducting a literature search for species that had not been observed since 2010 has reduced the number of missing species; however, it should be noted that species only observed should still be considered imperiled until direct evidence (e.g., a voucher or a positive photo identification with location data can verify these results).

Although several endemic species of concern remain “missing” and the lack of samples may not be necessarily connected to the 2010 Oil Spill, their absence remains telling given how increased sampling efforts specifically looking at post-spill fish distributions, including GoMRI (the *Gulf of Mexico Research Initiative* <https://gulfresearchinitiative.org/>; Murawski et al. 2023). However, the efforts of those and other groups are yet fully included in global databases such as FishNet2 and GBIF.

The Gulf of Mexico continues to face many challenges from the Dead Zone, to climate change, loss of coast habitats and continued oil spills (Turner and Rabalais 2019). Efforts like this report aim to bring attention to vulnerable species that continue to be impacted by human activities and to the unique endemic fauna of the region.

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Conflicts of interest

The authors have declared that no competing interests exist.

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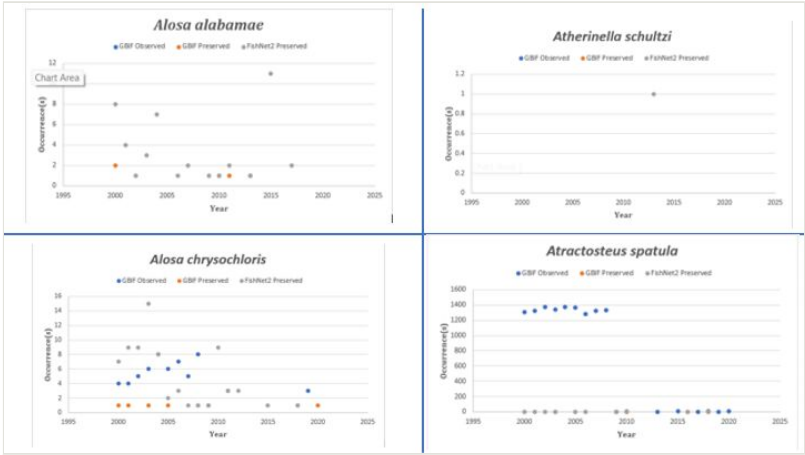


Figure 1.
Data records for *Alosa alabamae*, *Alosa chrysochloris*, *Atherinella schultzi*, and *Atractosteus spatula*

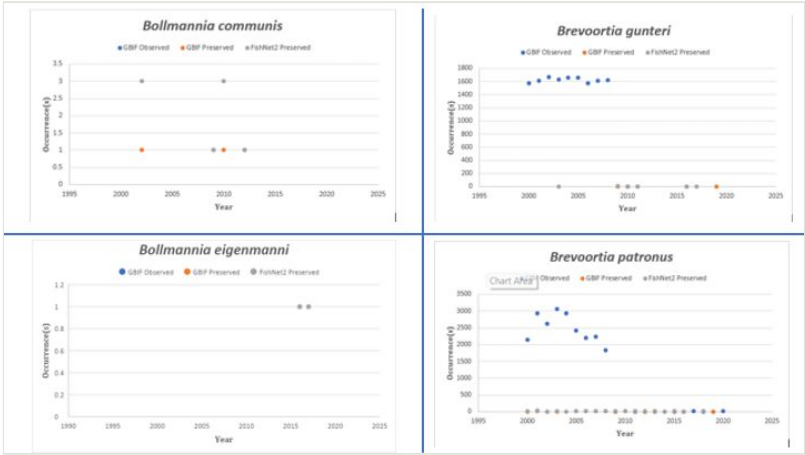


Figure 2.
Data records for *Bollmannia communis*, *Bollmannia eigenmanni*, *Brevoortia gunteri*, *Brevoortia patronus*

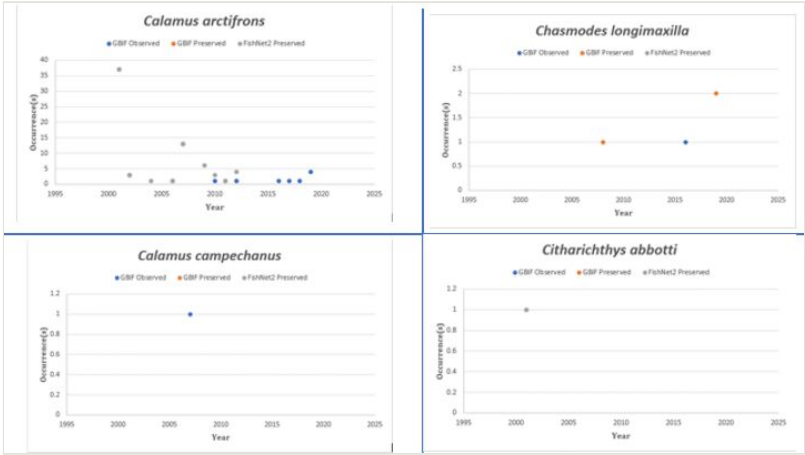


Figure 3.
Data records for *Calamus arctifrons*, *Calamus campechanus*, *Chasmodon longimaxilla*, *Citharichthys abbotti*

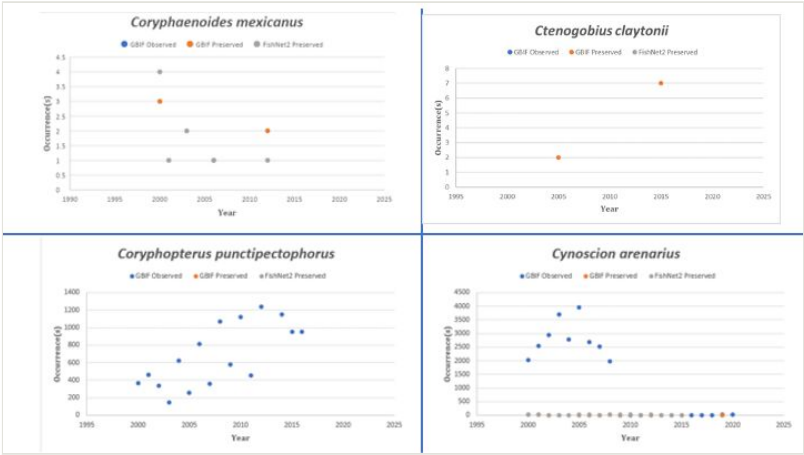


Figure 4.
Data records for *Coryphaenoides mexicanus*, *Coryphopterus punctipectophorus*, *Ctenogobius claytonii*, and *Cynoscion arenarius*.

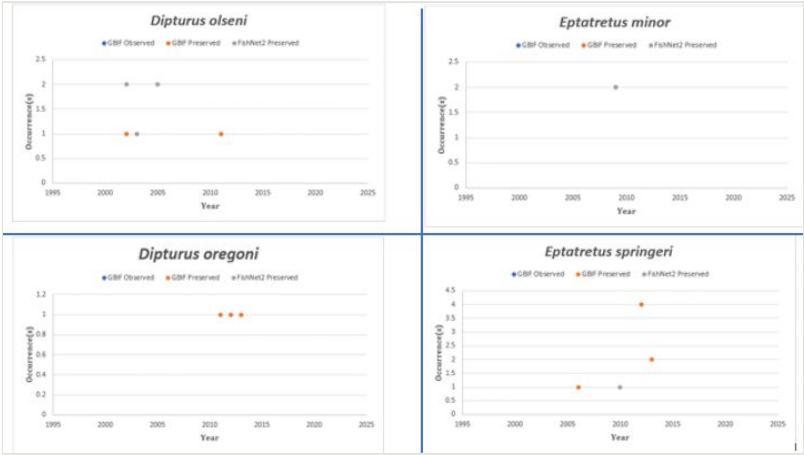


Figure 5.
Data records for *Dipturus olseni*, *Dipturus oregoni*, *Eptatretus minor*, *Eptatretus springeri*.

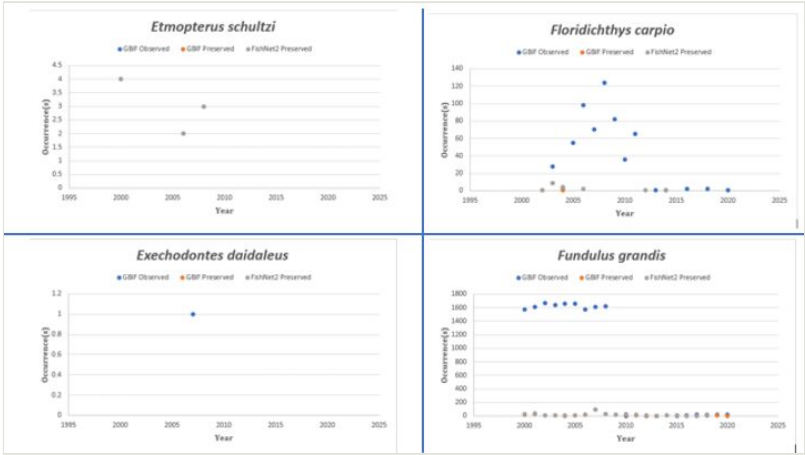


Figure 6.

Data records for *Etmopterus schultzi*, *Exechodontes daidaleus*, *Floridichthys carpio*, *Fundulus grandis*.

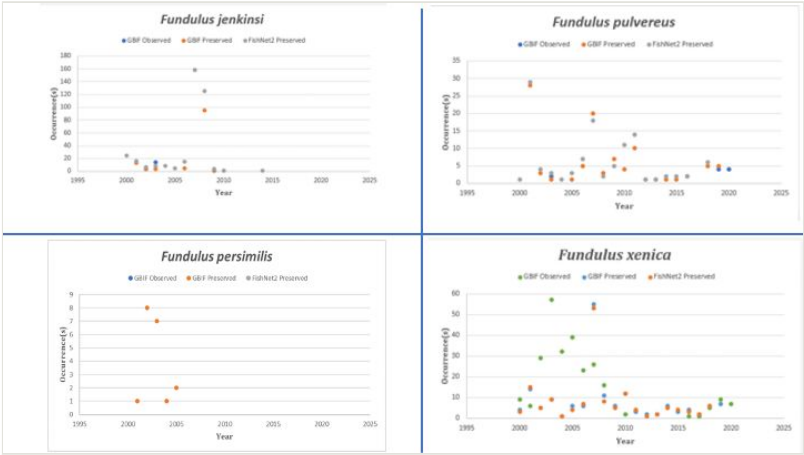


Figure 7.
Data records for *Fundulus jenkinsi*, *Fundulus persimilis*, *Fundulus pulvereus*, and *Fundulus xenica*.

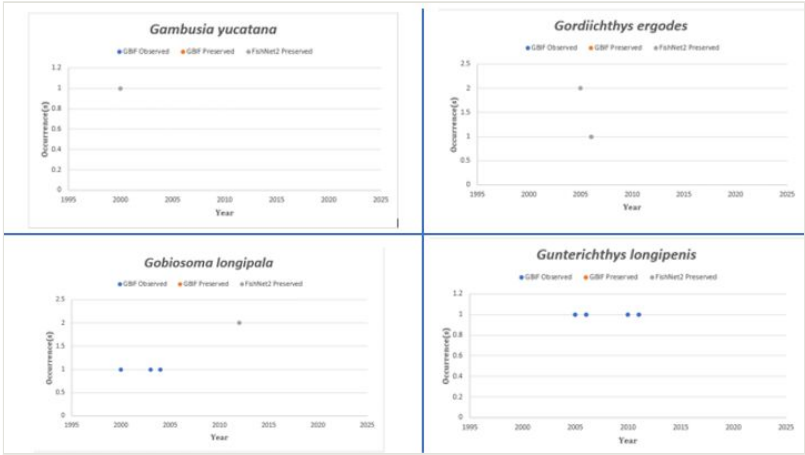


Figure 8.

Data records for *Gambusia yucatana*, *Gobiosoma longipala*, *Gordiichthys ergodes*, and *Gunterichthys longipenis*.

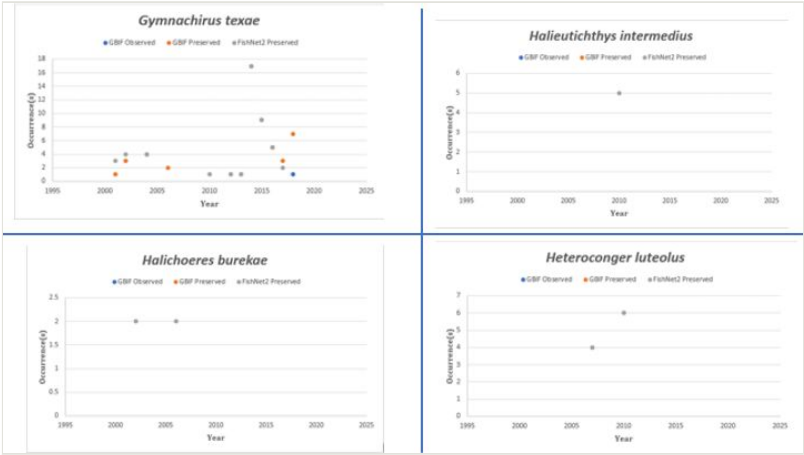


Figure 9.

Data records for *Gymnachirus texae*, *Halichoeres burekai*, *Halieutichthys intermedius*, and *Heteroconger luteolus*.

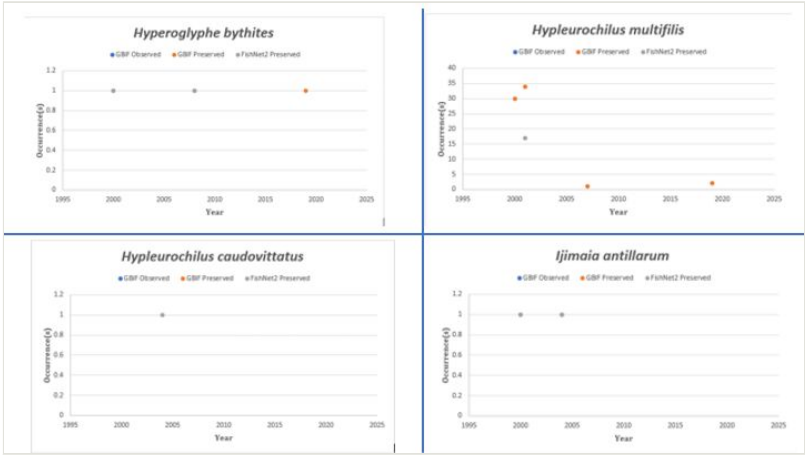


Figure 10.

Data records for *Hyperoglyphe bythites*, *Hyleurochilus caudovittatus*, *Hyleurochilus multifilis*, and *Ijimaia antillarum*.

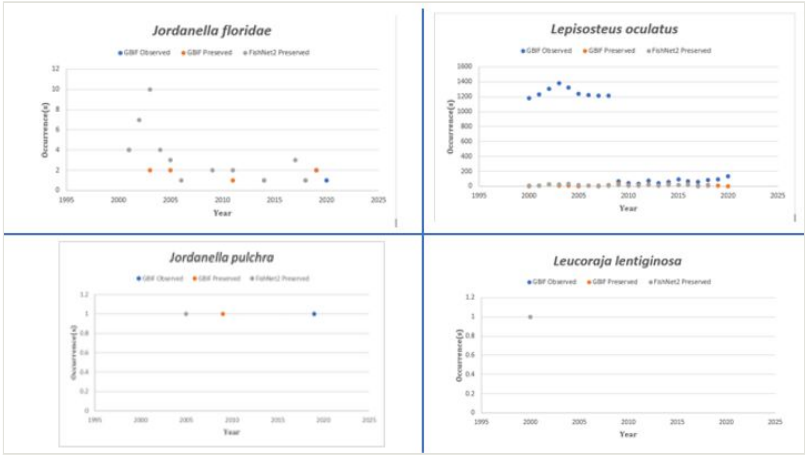


Figure 11.
Data records for *Jordanella floridae*, *Jordanella pulchra*, *Lepisosteus oculatus*, and *Leucoraja lentiginosa*.

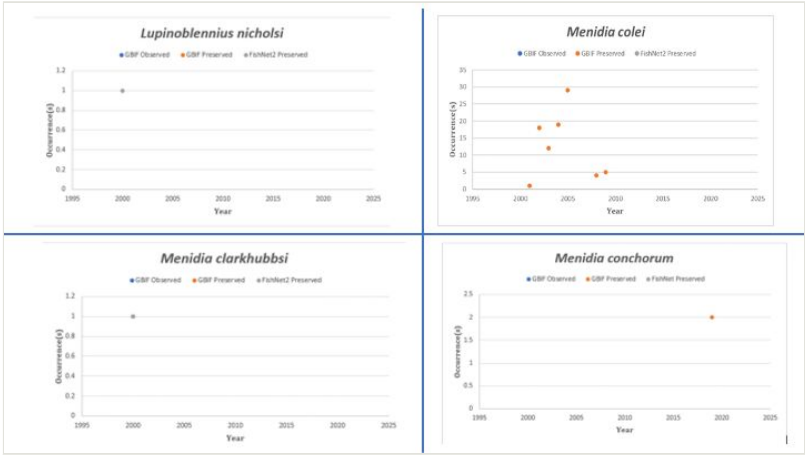


Figure 12.

Data records for *Lupinoblennius nicholsi*, *Menidia clarkhubbsi*, *Menidia coleii*, and *Menidia conchorum*.

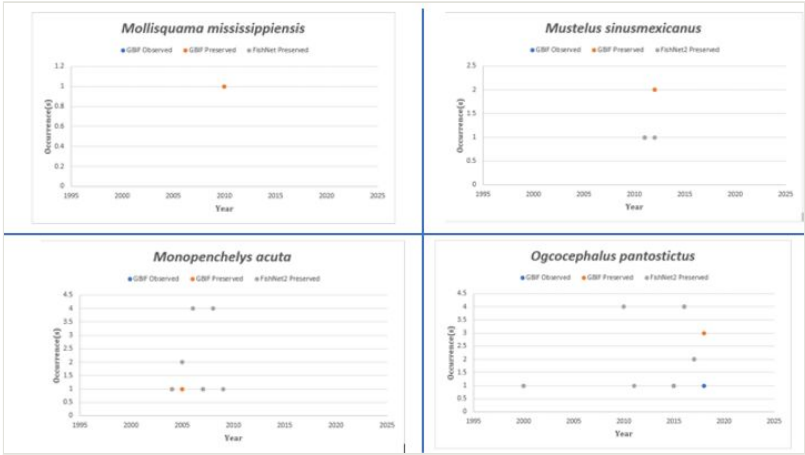


Figure 13.

Data records for *Mollisquama mississippiensis* , *Monopenchelys acuta*, *Mustelus sinuMexicanus*, and *Ogocephalus pantostictus*.

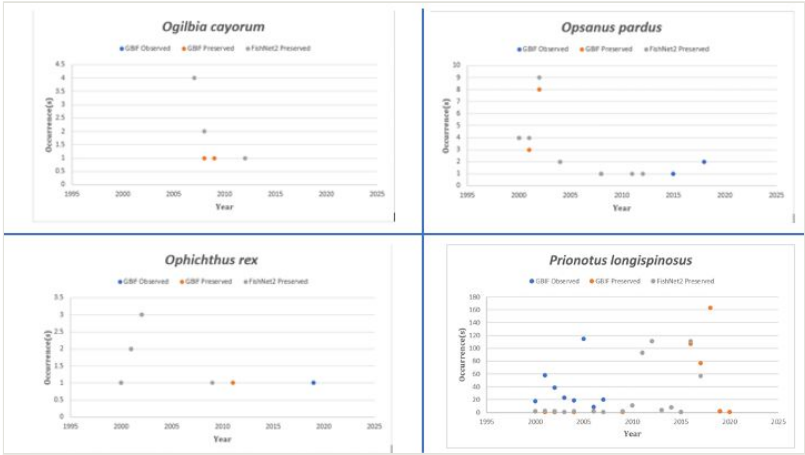


Figure 14.
Data records for *Ogilbia cayorum*, *Ophichthus rex*, *Opsanus pardus*, and *Prionotus longispinosus*.

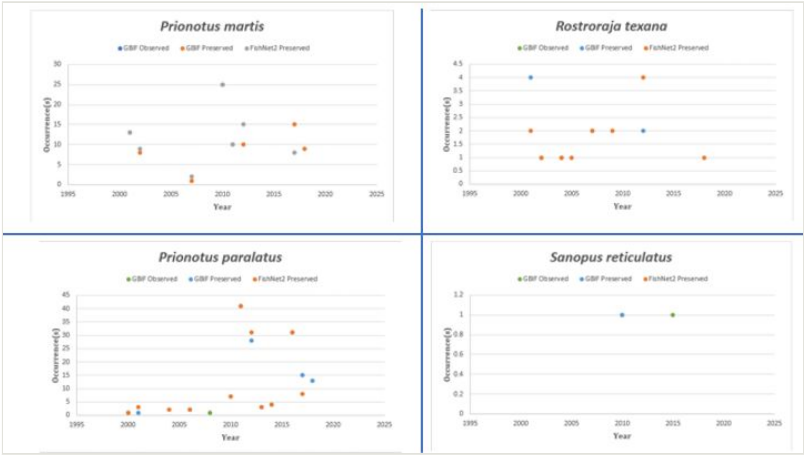


Figure 15.
Data records for *Prionotus martis*, *Prionotus paralatus*, *Rostroraja texana*, and *Sanopus reticulatus*.

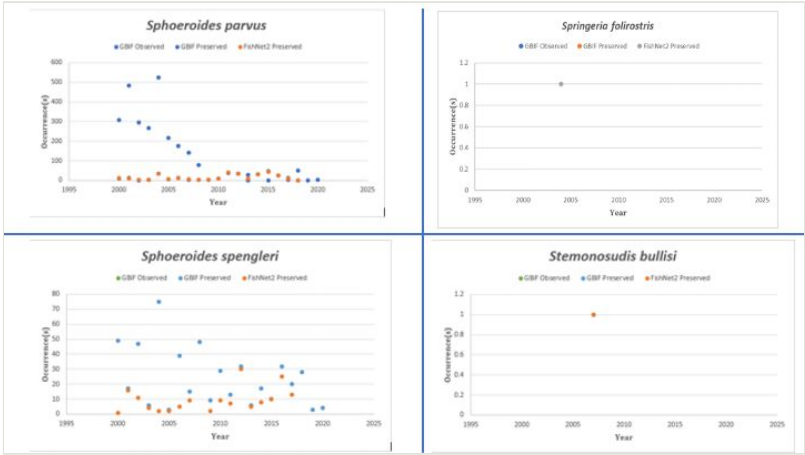


Figure 16.

Data records for *Sphoeroides parvus*, *Sphoeroides spengleri*, *Springeria folirostris*, and *Stemonosudis bullisi*.

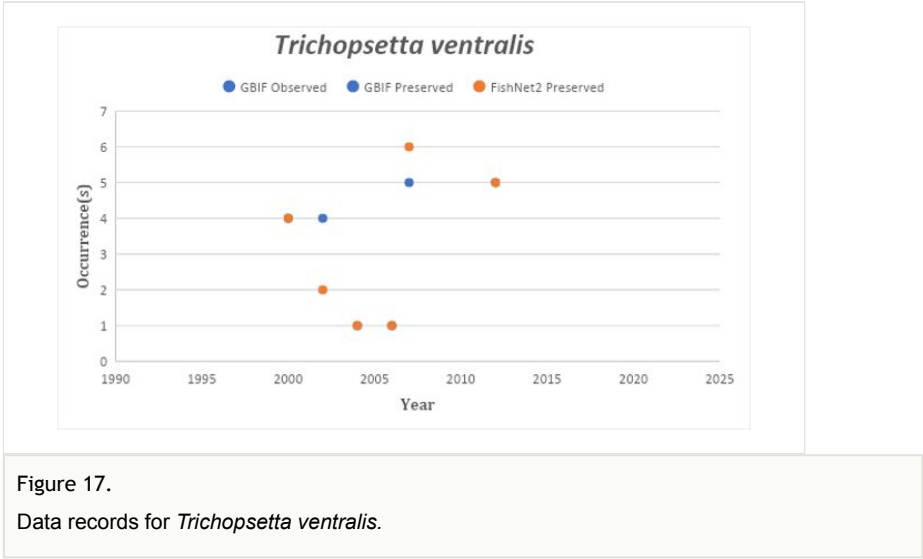


Table 1.
Species of Greatest Concern not collected or observed since the DWH (and their last identification date).

Species of Greatest Concern from the Gulf of Mexico	Last Identification Date
<i>Etmopterus schultzi</i>	2009
<i>Lycenchelys bullisi</i>	1999
<i>Microdesmus lanceolatus</i>	1994
<i>Parasaccogaster rhamphidognatha</i>	1969
<i>Springeria folirostris</i>	2004

Table 2.
Endemic species of Lesser Concern (less than 35% of their distribution was noted to be in the region of the spill) not collected in the GOM following DWH (and their last identification date)

Missing Gulf of Mexico Endemics	Last Seen/Collected
<i>Eptatretus minor</i>	2009
<i>Exechodontes daidaleus</i>	2007
<i>Fundulus persimilis</i>	2005
<i>Gordiichthys ergodes</i>	2006
<i>Gordiichthys leibyi</i>	2005
<i>Gunterichthys longipenis</i> *	observed 2011
<i>Hyperoglyphe bythites</i> *	observed in 2019
<i>Jordanella pulchra</i> *	observed in 2019
<i>Leucoraja lentiginosa</i> *	observed in 2012
<i>Menidia clarkhubbsi</i>	2000
<i>Menidia colei</i>	2009
<i>Mollisquama mississippiensis</i>	2010
<i>Monopenchelys acuta</i>	2007
<i>Neoopisthopterus cubanus</i>	1937
<i>Ophichthus omorgmus</i>	1999
<i>Parmaturus campechiensis</i>	1970
<i>Sanopus reticulatus</i> *	observed 2015
<i>Stemonosudis bullisi</i>	2007
<i>Syngnathus texanus</i>	1983
<i>Varicus benthonis</i>	no specific year available
<i>Varicus marilynae</i>	1974
<i>Varicus vespa</i>	2006

Table 3.
Recently reported “found” (once “missing”; **Chakrabarty, 2016**) species in the GOM following DWH and the number of reportings (**collected or observed**).

Gulf of Mexico Species Once "Missing", Now Found	Last Collected/Reported
<i>Calamus campechanus</i>	reported 2+ times since 2010
<i>Chasmodes longimaxilla</i>	observed and collected 2 times since 2010
<i>Coryphopterus punctipectophorus</i>	observed more than 5 times since 2010
<i>Ctenogobius claytonia</i>	collected 1 time since 2010
<i>Dipturus olseni</i>	collected 1 time since 2010
<i>Dipturus oregoni</i>	collected 3 times since 2010
<i>Fundulus jenkinsi</i>	collected 1 time since 2010
<i>Gunterichthys longipenis</i>	observed 2 times since 2010
<i>Halichoeres burekae</i>	observed and collected more than 50 times since 2010
<i>Heteroconger luteolus</i>	observed and collected more than 5 times since 2010
<i>Hyperoglyphe bythites</i>	observed 1 time since 2010
<i>Hypleurochilus caudovittatus</i>	reported 2 times since 2010
<i>Hypleurochilus multifilis</i>	collected 2 times since 2010
<i>Ijimaia antillarum</i>	observed 2 times since 2010
<i>Jordanella pulchra</i>	observed 1 time since 2010
<i>Lupinoblennius nicholsi</i>	observed 1 times since 2010
<i>Menidia conchorum</i>	observed and collected 2 times since 2010
<i>Ogilbia cayorum</i>	observed and collected 2 times since 2010
<i>Oneirodes bradburyae</i>	collected 1 time since 2010
<i>Ophichthus rex</i>	observed and collected 2 times since 2010
<i>Sanopus reticulatus</i>	observed 1 time since 2010