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SpeciesMap: a web-based application for visualizing the overlap of distributions and pollution events, with a list of fishes put at risk by the 2010 Gulf of Mexico oil spill

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Abstract The 2010 Gulf of Mexico oil spill was the largest in history outside of warfare and because the spill occurred in the deep sea, its impact on the biota will be difficult to assess. To help address this problem we have created SpeciesMap (http://speciesmap.org), a web-based application (web app) that allows a user to synthesize data on the oil spill with distributional records and other information on marine species. We have combined satellite image data collected over the course of the oil spill with locality data from historical collection records of fish species in a geographic information system. In doing so, we have created maps to assess which species were potentially in the region of the spill and to what degree their range was exposed to pollution. To evaluate the impact of the spill, we examined and categorized various levels of overlap between the observed surface range of the 2010 spill with collections records for 124 fish species including all 77 endemic to the Gulf of Mexico. More than half of all species examined (including more than half of all endemics) were found to have population records in the region of the spill. SpeciesMap contains interaction maps for all the species examined and these data can be used to target post-spill collections, to evaluate changes in habitat, and to discover extirpations or extinctions in response to environmental disturbances.

Keywords Deepwater Horizon · Macondo blowout · Deep sea

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Introduction

Potential impacts of the 2010 Gulf of Mexico oil spill on the native fish fauna include: diverted spawning grounds, concentrated bioaccumulation of pollutants, altered migration routes, depleted populations, extirpations and extinctions. We have created a web-based application (web app) called SpeciesMap that enables layered mapping of distributions and other data of organisms in conjunction with maps of the range of the 2010 Gulf of Mexico oil spill. SpeciesMap enables users to assess the level of overlap between populations and the oil spill over time and space (Fig. 1). This program and the results we present here will allow researchers to estimate the impact of the oil spill in a regionally, temporally, and species-specific manner. The interaction maps we provide can be used to discover which species are most vulnerable and to aid in prioritizing further studies and conservation efforts. Because SpeciesMap users can make maps for any species for any region, the tool can be used for other studies of environmental disturbances around the world.

The Deepwater Horizon blowout event occurred at nearly 1,500 m depth over nearly 3 months (Fodrie and Heck 2011). It is possible that due to the use of dispersants (nearly two million gallons) that some portion of the spilled oil (more than 200 million gallons; Deepwater Horizon Unified Command 2010) remains suspended below the surface (Schrope 2010; Stockstad 2010; Mascarelli 2010). The lingering effects of this dispersed oil on fishes are still at the early stages of being examined, although dramatic effects have been recorded (Whitehead et al. 2011). Post spill assessments on biota made by submersible are few and can only address a small fraction of the area of the spill (Orcutt et al. 2010). As a result of these factors, it is very difficult to measure the overall impact of the oil and dispersants on the fauna beneath the ocean's surface (Jernelöv 2010; Collette et al. 2011; Campagna et al. 2011).

As this spill was unique in its depth of occurrence, sheer volume, and use of dispersants, novel approaches are required to better understand its effects (Safina 2011). Researchers from government, industry, and academia will need to compare post-spill data with

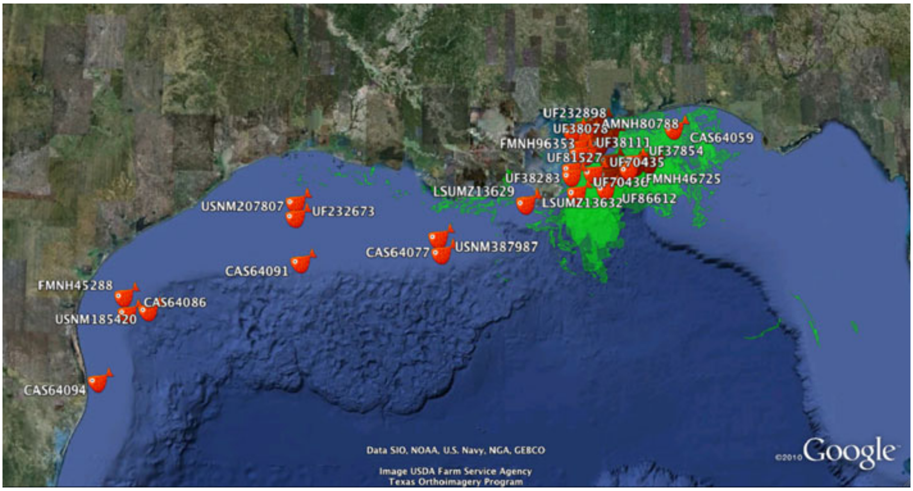

Fig. 1 SpeciesMap screen shot showing distributional data for the Gulf of Mexico endemic, the Louisiana Pancake Batfish, *Halieutichthys intermedius,* shown as *red* fish adjacent to museum catalog numbers of known holdings. The Gulf of Mexico oil spill is shown in *green* and is based on NOAA data for the extent and duration of the spill from its location at the surface of the ocean

pre-spill information in order to better assess the spill. Unfortunately, information about the distribution of fish species of the northern Gulf and information on the extent of the oil spill are located in disparate databases. These data are also not available in a format that can be easily accessed, compared, or visualized. SpeciesMap allows researchers to make pre- and post-spill comparisons of distributions and to make assessments about which Gulf species potentially interacted with the oil. With SpeciesMap one can gather collections data from disparate sources and satellite views of the oil spill from the duration of the blowout from the National Oceanic and Atmospheric Administration (NOAA).

For example, pre-spill data on the distribution of species can be gathered from a number of sources that focus on the Gulf of Mexico, including: the Louisiana State University Museum of Natural Science (LSUMNS), Tulane University, Southeast Area Monitoring and Assessment Program (SEAMAP), Louisiana Wildlife and Fisheries, Dauphin Island Sea Lab plankton databases, as well as other resources in the region and nation. Historical collection's information has been aggregated from many sources (including those listed above) by the Global Biodiversity Information Facility (GBIF; http://www.gbif.org) and FishNet2 (http://www.fishnet2.net). SpeciesMap produces files in Keyhole Markup Language (KML) that can be viewed with virtual globe software to show ocean surface views of known distributions. For some species for which depth-of-capture data are available, views below the surface are possible with the "altitude mode" capabilities afforded by Google Earth (version 5). In our analyses we used SpeciesMap to superimpose distributions of 124 fish species with aggregate satellite data from the duration of the oil spill to assess the potential impact of this event on the Gulf of Mexico's ichthyofauna. The results are a set of interactive maps (http://speciesmap.org) that we use to assess which populations may have been put at risk due to their co-occurrence with the spilled oil. Our maps provide visual formats, temporal animations, and pop-up windows linking back to collections data providers such that researchers can study and communicate their results. The "create-your-own SpeciesMap" portion of the application (speciesmap.org) allows users to leverage our efforts for other species of interest in the Gulf or elsewhere. Furthermore, the interoperability of the KML format enables researchers to add additional layers to a SpeciesMap. For example, these additional layers could include life history information so that shifts in distributions and collections of eggs, larvae, young-of-the-year, and spawning adults can be studied. These layers can also allow comparisons of reproductive success during pre- and post-spill time periods. Data such as depth of capture and fish counts over time will allow comparisons of population structure and community dynamics. Similarly, KML allows researchers to add environmental data found by ongoing oceanographic research. Layers of interest could include: information on dissolved oxygen concentrations over space and time, the persistence and distribution in the water column of droplets of oil caused by dispersant use, and oil potentially remaining on the sea floor.

In this paper and the accompanying web app, we illustrate how to collect and utilize records about fish species such that baseline data can be made available to measure and illustrate the impact of the spill. We provide example interaction maps for 77 fish species that are endemic (restricted) to the Gulf of Mexico and for 47 other fish species that are also found in the Gulf (and elsewhere) that are of ecological and economic interest (http://speciesmap.org).

Methods

The SpeciesMap web app (http://speciesmap.org) was built using the Ruby on Rails (http://rubyonrails.org) web development framework and is available with a tutorial.

The web application runs on an Nginx http server (http://wiki.nginx.org) and uses MySQL (http://mysql.org) as the data store for user accounts, data files, and results.

We used satellite data on the oil spill collected by the National Oceanic and Atmospheric Administration (NOAA; http://www.ssd.noaa.gov/PS/MPS/about.html–about). Dates were sampled from the beginning of the spill (April 22, 2010) to its eventual abatement (July 25, 2010). One date per week in this 16 week time period was sampled. We converted shape files provided by NOAA (ftp://satepsanone.nesdis.noaa.gov/OMS/disasters/DeepwaterHorizon/mpsr/2010) to KML files with SHP2KML (www.zonums.com/shp2kml.html) and merged data across dates for animation in KML. We combined the merged spill dates KMLs with species collection's data to create SpeciesMaps.

The content portion of the SpeciesMap site includes a tree control based on a taxonomic hierarchy as well a search box for Classes Elasmobranchii (cartilaginous fishes) and Actinopterygii (bony fishes). Both the tree control and the search box dynamically pulls information from GBIF (http://data.gbif.org) and adds it to the merged satellite data on the oil spill to create new KML files on demand. Alternatively, the user can upload distributional data of their own in comma separated values (CSV) format. The user is directed by the site to create an individual account to use this function.

We examined 77 endemic fish species from the Gulf of Mexico (McEachran 2009; IUCN 2011) and 47 other (non-endemic) species for potential exposure to the spill. We prioritized our choice of non-endemic species around economically and ecologically important taxa (e.g. anchovy, menhaden, croaker) as well as species that are important in food webs including large sharks, flatfishes, and batfishes (Hoese and Moore 1998; McEachran 2009). Most historical collections records were obtained from GBIF (http://gbif.org) but additional data, including depth records from Ho et al. (2010) were added for members of the genus *Halieutichthys* using the make-your-own function of the web app. The degree of overlap between the oil spill and individual populations was used to better determine the impact of this pollution event on individual species. The degree of overlap was discovered through SpeciesMap (with GBIF records as of October 5, 2011) and was calculated by dividing the number of occurrence records in the region of the spill by the total number of occurrences.

Results

A total of 124 fish species were examined using SpeciesMap to assess their level of overlap with the 2010 Gulf of Mexico oil spill. Table 1 shows the percentage of overlap for all 77 species of fish endemic to the Gulf of Mexico. Table 2 shows the degree of overlap for 47 ecologically and economically important species that are resident, but not endemic to the Gulf. Of all the species that were studied, 64 % were recovered as having distributions that overlapped with the oil spill. Among endemics, 52 % of species were recovered as having populations in the spill zone. The range of overlap of historical populations with the surface spill zone among endemic species ranged from 0.2 to 100 %. Of Gulf of Mexico endemics, 20 species had less than 35 % of their occurrence records in the region of the spill, 14 species had between 36 and 70 % of their records in the spill zone, and six species had over 71 % of their known distribution in the region of the spill. We consider any species that had historical records in the surface spill zone as having been potentially threatened by pollution; the 48 % of species that were not in this region should be evaluated as having the lowest potential threat because they were not in the immediate vicinity of this event. However, it should be noted that subsurface oil may have been even more extensive than the reported surface spill zone.

Table 1 List of endemic fish species from the Gulf of Mexico with scientific and common name. Common names and depth are from FishBase (www.fishbase.org; Froese and Pauly 2000). The "Overlap" column gives the percentage of historical collection's records that are known from the region of the oil spill for each species. The level of overlap was discovered through SpeciesMap (with GBIF records as of October 5, 2011); this percentage is calculated by dividing the number of occurrence records known in the region of the spill with the number of total number of occurrences. Taxa with greater than 35 % of their occurrence records in the region of the spill are in bold and are considered "Species of Greatest Concern." Endemic taxa were listed in McEachran 2009 in and IUCN 2011. Habitat data is also from McEachran 2009

Species: scientific name	Common name	Overlap	Depth (m)	Habitat
Adinia xenica	Diamond Killifish	13.3 %	Near Shore	Bay and near shore, estuarine
Alosa alabamae	Alabama Shad	1.26 %	Near Shore	Bay and near shore, anadromous, neritic
Alosa chrysochloris	Green Herring	1.65 %	Near Shore	Bay and near shore, anadromous, neritic
Anacanthobatis folirostris	**Leaf-nose Leg Skate**	**78.95 %**	**300–512**	**Slope**
Atherinella schultzi	Chimalapa Silverside	0.00 %	Near Surface	Bay and near shore, estuarine
Atractosteus spatula	Alligator Gar	0.00 %	Near Shore	Bay and near shore, neritic, estuarine
Bollmannia communis	**Ragged Goby**	**40.74 %**	**10–70**	**Demersal, soft substrates**
Bollmannia eigenmanni	**Shelf Goby**	**64.29 %**	**Inner Shelf (max 110)**	**Demersal**
Brevoortia gunteri	Finescale Menhaden	2.38 %	0–50	Bay and near shore, neritic, estuarine
Brevoortia patronus	Gulf Menhaden	10.51 %	0–60	Bay and near shore, neritic, estuarine
Calamus arctifrons	Porgy	0.00 %	0–22	Demersal, seagrass
Calamus campechanus	Campeche Porgy	0.00 %	11–18	Demersal
Chasmodes longimaxilla	Longjaw Blenny	0.00 %	Near Shore	Demersal, coral reef
Chriolepsis benthonis	Deepwater Goby	0.00 %	154–350	Demersal
Chriolepsis vespa	Wasp Goby	0.00 %	35–183	Demersal
Citharichthys abbotti	Veracruz Whiff	0.00 %	Near Shore	Demersal, soft substrates
Coryphaenoides mexicanus	**Mexican Grenadier**	**53.85 %**	**730–1,600**	**Benthopelagic, slope, abyssal**
Coryphopterus punctipectophorus	Spotted Goby	0.00 %	18–37	Demersal, coral reef
Ctenogobius claytonii	Mexican Goby	0.00 %	Near Shore	Demersal, bay and near shore, estuarine
Cynoscion arenarius	White Trout	12.39 %	0–110	Demersal, beach and shoreline, soft substrates
Dipturus olseni	Spreadfin Skate	28.57 %	55–384	Demersal, slope
Dipturus oregoni	**Hooktail Skate**	**80.00 %**	**475–1,079**	**Slope**
Eptatretus minor	Hagfish	23.08 %	300–472	Slope, soft substrates, burrower

Table 1 continued

Species: scientific name	Common name	Overlap	Depth (m)	Habitat
Eptatretus springeri	**Gulf Hagfish**	**54.17 %**	**410–768**	**Slope, soft substrates, burrower**
Etmopterus schultzi	**Fringefin Lanternshark**	**90.43 %**	**220–915**	**Slope**
Eustomias leptobolus	**Pez Dragon Negro**	**40.00 %**	**0–400**	**Mesopelagic**
Exechodontes daidaleus	Eelpout	0.00 %	219–1,004	Benthic, slope
Floridichthys carpio	Goldspotted Killifish	0.00 %	Near Shore	Bay and near shore, estuarine, seagrass
Fundulus grandis	Gulf Killifish	13.15 %	Near Shore	Bay and near shore, estuarine, seagrass
Fundulus jenkinsi	Saltmarsh Topminnow	4.38 %	Near Shore	Bay and near shore, estuarine
Fundulus pursimilis	Yucatan Killifish	0.00 %	Near Shore	Bay and near shore, estuarine
Fundulus pulvereus	Bayou Killifish	17.82 %	Near Shore	Bay and near shore, estuarine
Gambusia yucatana	Yucatan Gambusia	0.00 %	Near Shore	Bay and near shore, estuarine
Garmanella pulchra	Yucatan Flagfish	0.00 %	Near Shore	Bay and near shore, estuarine
Gobiosoma longipala	Twoscale Goby	0.00 %	Near Shore	Demersal, soft substrates
Gordiichthys ergodes	Irksone Eel	0.00 %	10–189	Demersal, burrower, soft substrates
Gordiichthys leibyi	String Eel	0.00 %	37–72	Demersal, soft substrates, burrower
Gunterichthys longipenis	**Gold Brotula**	**87.50 %**	**<10**	**Demersal, bay and near shore, burrower**
Gymnachirus texae	Fringed Sole	16.24 %	20–187	Demersal, soft substrates
Halichoeres burekae	Mardi Gras Wrasse	0.00 %	0–24	Coral reef
Halieutichthys intermedius	**Louisiana Pancake Batfish**	**67.50 %**	**0–366**	**Benthic, soft substrates**
Heteroconger luteolus	Yellow Garden Eel	0.00 %	33–37	Demersal
Hyperoglyphe bythites	**Black Driftfish**	**81.82 %**	**30–200**	**Benthopelagic**
Hypleurochilus caudovittatus	Zebratail Blenny	No data	Near Shore	Demersal, soft substrates
Hypleurochilus multifilis	Featherduster Blenny	25.00 %	Near Shore	Demersal, coral reef
Ijimaia antillarum	Jellynose	8.33 %	439–549	Benthic, slope
Jordanella floridae	American Flagfish	0.00 %	Near Shore	Bay and near shore, estuarine, seagrass,

Table 1 continued

Species: scientific name	Common name	Overlap	Depth (m)	Habitat
Lepisosteus oculatus	Spotted Gar	0.22 %	Near Shore	Neritic, bay and near shore, estuarine
Leucoraja lentiginosa	**Speckled Skate**	**52.94 %**	**53–588**	**Demersal, slope**
Lupinoblennius nicholsi	Highfin Blenny	0.00 %	Near Shore	Demersal
Lycenchelys bullisi	**Eelpout**	**50.00 %**	**625–1,247**	**Benthic, slope**
Menidia clarkhubbsi	Texas Silverside	0.00 %	Near Shore	Bay and near shore, estuarine
Menidia colei	Golden Silverside	0.00 %	Near Shore	Bay and near shore, estuarine
Menidia conchorum	Key Silverside	0.00 %	Near Shore	Bay and near shore, coral reef
Microdesmus lanceolatus	**Lancetail Wormfish**	**42.86 %**	**0–37**	**Demersal, bay and near shore, burrower**
Monopenchelys acuta	Redface Moray	0.00 %	13–45	Demersal, coral reef
Mustelus sinusmexicanus	**Gulf Smoothhound**	**42.86 %**	**36–229**	**Soft substrates**
Neoopisthopterus cubanus	Cuban Longfin Herring	No data	Near Surface	Neritic, bay and near shore, beach and shoreline, estuarine
Ogcocephalus pantostictus	Spotted Batfish	3.33 %	0–31	Demersal
Ogilbia cayorum	Key Brotula	0.00 %	0–33	Demersal, hard substrate
Oneirodes bradburyae	**Dreamer**	**100 %**	**1,426**	**Bathypelagic**
Ophichthus omorgmus	Dottedline Snake Eel	No data	183–271	Benthic, slope, soft substrates
Ophichthus rex	**King Snake Eel**	**81.82 %**	**22–366**	**Demersal, soft substrates, burrower**
Opsanus pardus	**Leopard Toadfish**	**38.46 %**	**0–80**	**Demersal, hard substrates**
Parmaturus campechiensis	Campeche Catshark	No data	0–1,097	Slope, soft substrates
Prionotus longispinous	**Bigeye Searobin**	**50.00 %**	**9–219**	**Demersal, soft substrates**
Prionotus martis	Barred Searobin	5.13 %	11–110	Demersal
Prionotus paralatus	Mexican Searobin	No data	9–274	Demersal, benthic, slope
Raja texana	Roundel Skate	11.00 %	15–20	Demersal
Saccogaster rhamphidognatha	**Brotula**	**100 %**	**210**	**Benthic, slope, soft substrates**
Sanopus reticulatus	Reticulated Toadfish	No data	Near Shore	Coastal surface and epipelagic, demersal
Sphoeroides parvus	Least Puffer	No data	0–50	Demersal, bay and near shore
Sphoeroides spengleri	Bandtail Puffer	0.39 %	10–40	Demersal, coral reef, seagrass

Table 1 continued

Species: scientific name	Common name	Overlap	Depth (m)	Habitat
Stemonosudis bullisi	Barracudina	No data	814–997	Mesopelagic
Syngnathus affinis	Texas Pipefish	0.00 %	0–24	Benthopelagic, bay and near shore, seagrass
Trichopsetta ventralis	Sash Flounder	31.19 %	30–400	Demersal, benthic, soft substrates
Varicus marilynae	Orangebelly Goby	0.00 %	61–91	Demersal

Endemic species of greatest concern: highest potential impact (>35 % of historical records are from the spill zone): The species with the highest level of distribution overlap were, from highest to lowest: *Saccogaster rhamphidognatha* (100 %), *Oneirodes bradburyae* (100 %), *Etmopterus schultzi* (90 %), *Gunterichthys longipenis* (88 %), *Hyperoglyphe bythites* (82 %), *Ophichthus rex* (82 %), *Dipturus oregoni* (80 %), *Anacanthobatis folirostris* (79 %), *Halieutichthys intermedius* (68 %), *Bollmannia eigenmanni* (64 %), *Coryphaenoides mexicanus* (54 %), *Eptatretus springeri* (54 %), *Leucoraja lentiginosa* (53 %), *Lycenchelys bullisi* (50 %), *Prionotus longispinous* (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 are in this highest potential impact category.

Endemic species of concern: (<35 % of historical records are from the spill zone): Species that had recorded populations in the region of the spill but below the 35 % overlap threshold were, from highest to lowest: *Trichopsetta ventralis* (31 %), *Dipturus olseni* (29 %), *Hypleurochilus multifilis* (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 %).

Non-endemic taxa: Among non-endemic taxa examined, 83 % were recovered as having historical populations in the immediate region of the oil spill (Table 2). We defined their levels of overlap as being "low" if only one to five historical collection records are in the spill zone, "moderate" if there are between 5 and 10 records, and "high" if there was greater that 10 records. We found no evidence of overlap for 17 % of species, 34 % had a low level of overlap, 23 % had a moderate level of overlap, and 26 % of species were determined to have a high level of overlap.

Discussion

We created a web app, SpeciesMap (http://speciesmap.org) and used it to evaluate 124 fish species (including 77 endemics) to determine the amount of overlap between their historical ranges and the 2010 Gulf of Mexico oil spill. The goal of this research is to create a priority list of potentially vulnerable taxa that need further research to evaluate their population status in this post-spill period. We find that a large portion of species examined, more than 60 %, had historical populations in the region of the oil spill. We found that more than half of all endemic species had occurrence records in the region of the spill, and

Table 2 Gulf of Mexico resident (but not endemic) fish taxa examined for overlapping populations in the region of the 2010 oil spill. Common names and distributions are from FishBase (www.fishbase.org; Froese and Pauly 2000). The "Overlap levels" column summarizes the degree to which collections records exist in the region of the oil spill for each species. The degree of overlap was discovered through SpeciesMap. Species were determined to have low (fewer than 5 historical records), moderate (5–10 records) or high levels (greater than 10 records). Abbreviations: *CS* Caribbean Sea, *EA* Eastern Atlantic, *EP* Eastern Pacific, *GOM* Gulf of Mexico, *SA* South America, *US* United States, *WA* Western Atlantic

Scientific name	Common name	Overlap levels	Distribution
Anchoa hepsetus	Broad-striped anchovy	Yes < Low	Much of WA
Anchoviella perfasciata	Poey's anchovy	Yes < Low	GOM & CS
Antennarius radiosus	Singlespot frogfish	Yes < High	WA of US, CS and GOM
Ariopsis felis	Hardhead sea catfish	Yes < Low	WA of US, CS and GOM
Astroscopus y-graecum	Southern stargazer	Yes < Low	WA of US and NSA, GOM and CS
Bagre marinus	Gafftopsail sea catfish	Yes < Low	WA of US and NSA, GOM and CS
Centropristis philadelphica	Rock sea bass	Yes < High	WA of US, and GOM
Chaetodipterus faber	Atlantic spadefish	Yes < Low	WA of US and SA, GOM, and CS
Chloroscombrus chrysurus	Atlantic bumper	No	Much of Atlantic
Citharichthys spilopterus	Bay whiff	Yes < Low	Much of WA
Cyclopsetta chittendeni	Mexican flounder	Yes < Moderate	Much of WA
Diplectrum bivittatum	Dwarf sand perch	Yes < High	WA of US and SA, GOM and CS
Etropus crossotus	Fringed flounder	Yes < High	EP, WA including GOM and CS
Galeocerdo cuvier	Tiger shark	No	Circumglobal
Gobiesox strumosus	Skilletfish	No	EP, WA including GOM and CS
Gymnura micura	Smooth butterfly ray	Yes < Moderate	EA and WA including GOM, and CS
Halieutichthys aculeatus	Pancake batfish	Yes < High	WA including GOM, and CS
Larimus fasciatus	Banded drum	Yes < Low	GOM, and WA coast of US
Leiostomus xanthurus	Spot croaker	Yes < High	GOM, CS and WA coast of US
Lutjanus campechanus	Northern red snapper	Yes < Low	GOM, CS and WA coast of US and SA
Menticirrhus americanus	Southern kingcroaker	Yes < Moderate	GOM, CS and much of WA
Micropogonias undulates	Atlantic croaker	Yes < High	GOM, CS and much of WA
Monolene sessilicauda	Deepwater flounder	Yes < High	GOM, CS and much of WA
Mulloidichthys martinicus	Yellow goatfish	Yes < Low	E and WA including CS and GOM
Negaprion brevirostris	Lemon shark	Yes < Moderate	EP, CS and GOM, EA and WA

Table 2 continued

Scientific name	Common name	Overlap levels	Distribution
Neomerinthe hemingwayi	Hemingway's scorpionfish	Yes < Moderate	WA of US, GOM and CS
Ogcocephalus declivirostris	Slantbrow batfish	Yes < High	GOM, CS and much of WA
Ophidion welshi	Crested cusk-eel	Yes < Low	GOM, CS and much WA
Paralichthys albigutta	Gulf flounder	Yes < Low	GOM, CS and WA coast of US
Peprilus burti	Gulf butterfish	Yes < Moderate	GOM, CS and WA coast of US
Porichthys plectrodon	Atlantic midshipman	Yes < High	GOM, CS and WA coast of US and SA
Prionotus carolinus	Northern searobin	No	GOM and WA
Prionotus rubio	Blackwing searobin	Yes < High	GOM and CS
Prionotus tribulus	Bighead searobin	Yes < Moderate	GOM and WA coast of US
Selene setapinnis	Atlantic moonfish	No	EA and WA
Selene vomer	Lookdown	Yes < Low	WA, including GOM, and CS
Setarches guentheri	Channeled rockfish	Yes < Moderate	Circumglobal
Stephanolepis hispidus	Planehead filefish	No	EA and WA
Syacium gunteri	Shoal flounder	Yes < Moderate	WA coast of US and GOM and CS
Symphurus parvus	Pygmy tonguefish	Yes < Low	WA coast of US and GOM and CS
Symphurus plagiusa	Blackcheek tonguefish	Yes < Low	WA coast of US and SA, GOM and CS
Syngnathus louisianae	Chain pipefish	Yes < Low	WA coast of US, GOM and CS
Synodus foetens	Inshore lizardfish	Yes < Moderate	WA including GOM and CS
Trichiurus lepturus	Largehead hairtail	No	Circumglobal
Urophycis floridana	Southern codling	Yes < Moderate	WA coast of US, including GOM
Urophycis regia	Spotted codling	Yes < High	WA coast of US, including GOM
Xyrichtys novacula	Pearly razorfish	No	EA and WA including CS and GOM

that one quarter of all endemics had more than 35 % of their known distribution records in the region of the spill (this 25 % of endemic species are in our "Species of Greatest Concern" category).

Nine of the 19 endemic species in the Species of Greatest Concern category can be found in deep waters ($\geq$400 m depth), 15 of the 19 are found in waters deeper than 100 m. This deep realm of the Gulf of Mexico is where additional information about the extent of oil and dispersants is most needed. Currently, only data showing the extent of the spill at the surface is available. The location of oil and dispersants below the surface remains largely unknown or is not publically reported. Shallow-dwelling forms, and taxa that have surface dwelling pelagic larvae were largely focused on during the spill period but little is known about the population status of deep-sea endemics. This lack of information is unfortunate given the fact that the source of the spill was in the deep-sea.

Several species in our "Species of Greatest Concern" category need special attention. *Coryphaenoides mexicanus,* the Mexican Grenadier, occur in the immediate region and depth of the wellhead that was the source of the spill (around 1,500 m depth). The Leaf-nose Leg Skate, *Ancanthobatis folirostris*, has rarely been collected in the past 50 years (based on GBIF records), which may reflect pre-spill population declines that would make it even more vulnerable during the spill. The Gold Brotula, *Gunterichthys longipenis*, is fossorial and rare in collections, it is found close to the shoreline buried in shallow waters. This species may be heavily impacted by dredging but it may also have been impacted by post-spill clean up that moved sediment at the shoreline. Each species examined here presents its own set of challenges, but the lack of data on most of these species needs to be addressed.

It is clear that more data are needed for pre- and post-spill populations on all of these vulnerable endemic taxa. It will be important for biologists and resource managers to consider prioritizing efforts on the 19 taxa that are designated as "Species of Greatest Concern" and to evaluate whether there have been deviations in population number or distribution caused by the spill in these species. Some of these taxa, such as *Oneirodes bradburyae* and *Saccogaster rhamphidognatha* are extremely poorly known (both are only known from the holotype, and only known from the deep-sea region of the spill). The paucity of data about these species likely reflects poor collection's data but also potentially low population numbers. Rarity of individuals of these species in GBIF and other databases should not dull concern over how they were affected by the oil spill. To the contrary, they may be the species that have the highest extinction risk.

Species for which we did not discover distributional overlap with the oil spill should not necessarily be considered unaffected. It is possible that although these species never had documented collections in the region (i.e., they were never captured and catalogued) that they still may have populations that were exposed to oil. For instance, the tiger shark, *Galeocerdo cuvier*, is a circumglobal species that is rarely ever collected for museum holdings. It will be important, but difficult, to evaluate how Gulf migrants such as the tiger shark were impacted during the spill. Likewise, species with low or moderate distribution overlaps may have been rare before the spill and post-spill data should be gathered to see if these populations are now extirpated.

The 2010 Gulf of Mexico oil spill was unique: subsurface oil could have affected midwater pelagic, deep sea, and benthic habitats in ways we have never seen (Campagna et al. 2011; Safina 2011). Without historical baseline data on the distribution of species, future faunal surveys will be unable to truly gauge the impact of this deep-water pollution event. As the largest oil spill in the deep sea and the first to use subsurface dispersants, the majority of the impact of the spill may have taken place below the surface (Gaskill 2010; Jernelöv 2010). Unfortunately, direct observation of the impact of the spill at depth will be extremely difficult. The SpeciesMap project makes this task easier by providing content and a user-friendly web application and data visualization tool that can be used for a wide variety of projects. For example, we foresee that this project will be able to support discovery of information about: (1) the spill's affects on migrating and spawning organisms that travel through the Gulf (in order to focus protection on vulnerable eggs and larvae); (2) which species of migrating mesopelagic organisms were most severely impacted by concentrated plumes of sub-surface oil and dispersant; (e.g., such as those that feed on the vulnerable layers of plankton); (3) interactions between important fisheries and non-commercial and commercial fishes in sites of subsurface oil plumes (e.g., deep-ocean coral species in Louisiana and Florida that were in the path of the plumes); (4) which life history stages of different fishes may have been affected by oil/dispersant plumes; (5) which species are most effected by expanding dead-zones created by microbes consuming oil/dispersant and oxygen; (6) where the effects of bioaccumulation are most prevalent, and; (7) how communities of organisms have changed in terms of their distribution and make-up since the inception of the oil spill.

In conclusion, we hope that our studies of potentially impacted species will encourage post-spill collecting in the Gulf. Determination of the conservation priority for the taxa exposed to the spill will depend on a more thorough assessment of the importance of these Gulf populations for each individual species. Increased knowledge of the extent of sub-surface oil will also be necessary to determine the impact on species at depth. Despite the current lack of a full understanding of the oil spill this study is an important first step in targeting species potentially impacted by this immense and enduring pollution event.

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