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Persistent organic pollutants (POPs) in blood and blubber of common bottlenose dolphins (*Tursiops truncatus*) at three northern Gulf of Mexico sites following the *Deepwater Horizon* oil spill

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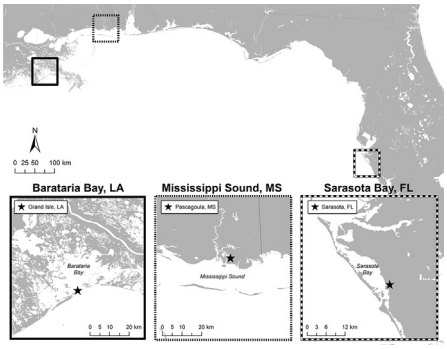
HIGHLIGHTS

- Health concerns were identified in dolphins after the *Deepwater Horizon* oil spill.
- The role of POPs in the adverse health state of oil-impacted dolphins is unknown.
- POPs were measured in dolphins at unoiled and oil-impacted Gulf of Mexico sites.
- Dolphins at oiled sites had POP levels comparable to healthy dolphin populations.
- POPs are unlikely contributing to the adverse health of dolphins at oiled sites.

GRAPHICAL ABSTRACT



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ABSTRACT

Common bottlenose dolphins (*Tursiops truncatus*), including those impacted by the 2010 *Deepwater Horizon* (DWH) oil spill, inhabit the coastal and estuarine waters of the northern Gulf of Mexico (GoM). In response to the spill, dolphin health assessments conducted in Barataria Bay, Louisiana – a site that experienced heavy and prolonged oiling – uncovered a high prevalence of health abnormalities and individuals in poor body condition. Although the health effects observed were suggestive of petroleum toxicity, a lack of pre-spill information regarding dolphin health raises the possibility that other environmental factors may have contributed to the adverse health of dolphins in this oil-impacted area. To assess how exposure to other environmental pollutants may affect the health of northern GoM dolphin populations impacted by the DWH oil spill, a suite of 69 persistent organic pollutants (POPs), including PCBs, PBDEs and organochlorine pesticides, was determined in blood and a subset of blubber samples collected during health assessments of 145 bottlenose dolphins at three GoM sites: two oil impacted sites - Barataria Bay, LA (BB), and Mississippi Sound, MS (MS) and an unimpacted reference site - Sarasota

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Bay, FL (SB). Overall, levels of POPs at all three sites appeared comparable or lower than concentrations previously reported for coastal bottlenose dolphin populations outside of the northern GoM. POP levels measured in BB dolphins were also comparable or lower than those measured at the unimpacted reference site (SB) within the northern GoM. Additionally, the relationship between blubber and blood contaminant levels in a smaller subset of BB and SB suggests that BB animals were not experiencing elevated blood-contaminant concentrations as a result of their poor body condition. Cumulatively, these results suggest that background levels of POPs measured are unlikely to produce the health abnormalities previously reported for BB dolphins.

1. Introduction

Common bottlenose dolphins (*Tursiops truncatus*) inhabit the bays, sounds, estuaries, and coastal waters of the northern Gulf of Mexico (GoM) where they are exposed to a variety of anthropogenic threats, including the residual effects from the 2010 *Deepwater Horizon* (DWH) oil spill (Vollmer and Rosel, 2013). The explosion and subsequent sinking of the DWH drilling rig, located approximately 60 km off the coast of southeastern Louisiana, resulted in the release of an estimated 3.19 million barrels (134 million gallons) of crude oil and 1.84 million gallons of dispersants into the northern GoM over a three-month period (DWH NRDA (Deepwater Horizon Natural Resource Damage Assessment) Trustees, 2016). The spill led to the direct oiling of >1600 km of wetlands, shoreline, and barrier islands from western Louisiana to the Florida Panhandle and unknown impacts to deep sea waters and benthic ecosystems (Kujawinski et al., 2011; McNutt et al., 2012; Michel et al., 2013). Several years later, remnants of the spill and its effects were still evident (Michel et al., 2013; Hsing et al., 2013; Smith et al., 2017).

In 2011, health assessments of bottlenose dolphins were conducted at two locations within the northern GoM - Barataria Bay, LA (BB), an area that received heavy and prolonged oiling, and an unimpacted (unoiled) reference site, Sarasota Bay, FL (SB) where oil was not observed (Schwacke et al., 2014). Veterinary examinations of BB dolphins uncovered a high prevalence of severe lung disease, as well as evidence of other health abnormalities, such as poor body condition, abnormally low levels of adrenal hormones, and elevated markers of inflammation that were non-existent or less prevalent in dolphins of SB and other western Atlantic locations unaffected by oil (Schwacke et al., 2014). Subsequent health assessments of bottlenose dolphins in Barataria Bay in 2013 and 2014 found that lung disease and impaired stress response persisted for at least 4 years post-spill (Smith et al., 2017). Furthermore, follow-up monitoring showed that BB dolphins also experienced reduced reproductive success and higher mortality rates relative to dolphins in unimpacted locations in the years following the spill (Lane et al., 2015).

The uncommon and severe health effects observed in BB dolphins are strongly suggestive of petroleum toxicity in other species and strongly suggestive of impacts caused by exposure to oil. However, without knowledge of the health of BB dolphins prior to the spill, the possibility that pre-existing and/or co-existing environmental stressors have influenced the severity of the observed health effects must be considered.

As inhabitants of inshore waters, bottlenose dolphins are particularly vulnerable to exposure to anthropogenic contaminants such as persistent organic pollutants (POPs) (Houde et al., 2005). POPs are lipophilic chemicals that bioaccumulate readily in tissues, such as blubber, and blood of bottlenose dolphins (Yordy et al., 2010a; Yordy et al., 2010b), potentially predisposing them to adverse reproductive, immunological and endocrine-related effects (Schwacke et al., 2002; Schwacke et al., 2012). The degree of POP exposure can vary both within sympatric populations (Litz et al., 2007; Wells et al., 2005; Yordy et al., 2010c) and between allopatric populations (Balmer et al., 2011; Balmer et al., 2015; Hansen et al., 2004; Kucklick et al., 2011) as a result of differences in environmental concentrations, life histories, feeding ecologies, and individual movements, making POPs an important factor to consider when assessing environmental impacts on dolphin health.

Blubber serves as the primary repository for POPs in cetaceans, holding >90% of an individual's total body burden of contaminants (Yordy et al., 2010b). A previous study was undertaken to examine POP concentrations in blubber of bottlenose dolphins from several northern GoM sites following the DWH oil spill (Balmer et al., 2015). However, it has been established that for individuals experiencing a decline in body condition – such as those observed following the spill – changes in lipid can result in a redistribution of contaminants, leading to a concomitant increase of blood contaminant levels (Yordy et al., 2010a), and a heightened risk of systemic toxic effects (Kim et al., 2010; Lassiter and Hallam, 1990). Therefore, knowledge of both blubber and blood contaminant levels is important for assessing potential health risks in stressed populations.

To better understand how exposure to environmental pollutants affects the health of northern GoM dolphin populations impacted by the DWH oil spill, POP levels were determined in blood samples collected from capture-release health assessments of bottlenose dolphins during 2011 health assessments in BB and SB (Schwacke et al., 2014) as well as from follow-up health assessments conducted in 2013 and 2014 at each location, and a third site in 2013, Mississippi Sound, MS (MS), which received moderate shoreline oiling relative to BB (Michel et al., 2013). Our objectives were to evaluate differences in background POP exposure levels between the dolphins from the three northern GoM locations and to compare the relationship between contaminant concentrations in a subset of matching blubber and blood samples collected during the 2011 health assessments to determine whether the BB dolphins experienced an increase in bioavailable POP concentrations in blood as a result of their poor body condition.

2. Materials and methods

2.1. Study dates and locations

In 2011, 2013, and 2014, health assessments of bottlenose dolphins (*Tursiops truncatus*) were conducted at three locations within the northern GoM (Smith et al., 2017; Schwacke et al., 2014). The three locations targeted included Barataria Bay, Louisiana (BB), an area that received prolonged and heavy oiling (Michel et al., 2013); Mississippi Sound, Mississippi (MS), which received a lesser degree of oiling (Michel et al., 2013); and Sarasota Bay, Florida (SB), where no oil was observed following the DWH spill (Fig. 1). Sampling was conducted in the summers of 2011 (1 year post-spill; BB and SB only), 2013 (three years post-spill; BB, SB and MS) and 2014 (four years post-spill; BB only). Blood was collected from a total of 145 dolphins over three years, including a limited number of dolphins ($n = 16$) repeatedly sampled in multiple years. Although matching blubber samples were collected from each individual captured, only a subset of those data ($n = 22$), collected from SB and BB in 2011 and previously used by Schwacke et al. (2014) to assess potential health impacts of the DWH spill, is presented here for comparison with concentrations in blood. Details regarding the timing of each health assessment and a breakdown of the age and sex of dolphins sampled at each location are provided in Supporting Information (Table S1).