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Polycyclic aromatic hydrocarbons in blood related to lower body mass in common loons

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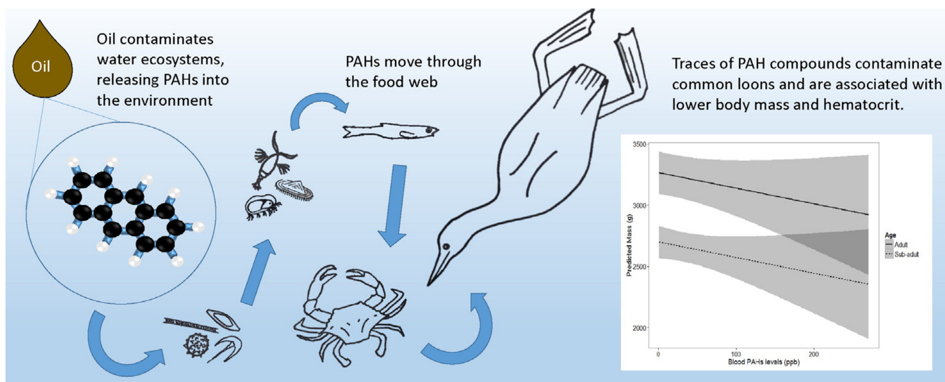
HIGHLIGHTS

- PAHs were found in loon blood in 4/5 years following the Gulf oil spill.
- PAH signatures changed, with light-weights predominating in all years but 2013.
- High PAH levels correlated with low body mass and hematocrit for all birds.
- High PAH levels correlated with high total blood proteins in adult birds.

GRAPHICAL ABSTRACT



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ABSTRACT

We captured 93 wintering adult and subadult Common Loons (*Gavia immer*) in coastal Louisiana from 2011 to 2015 following the Deepwater Horizon oil spill. We tested blood samples for exposure to polycyclic aromatic hydrocarbons (PAHs) and measured physiological variables including hematocrit, hemoglobin and total blood protein. PAH concentrations in loon blood differed from year to year and by age class. High PAH concentrations were significantly related to lower body masses in both adult and subadult birds and higher serum protein levels in adults only. PAH concentrations had marginal relations with both hematocrit and hemoglobin levels. The types of PAHs detected also underwent a major shift over time. The PAHs detected in 2011, 2012, and 2015 were primarily low molecular weight (three carbon rings); however, in 2013, most detected PAHs were high molecular weight (four carbon rings). It is unclear what events led to the increase in PAH concentrations and the shift in type of PAHs over time.

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1. Introduction

1.1. Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are global pollutants derived from fossil fuels and produced during pyrogenic and petrogenic processes. Pyrogenic PAHs are derived from forest fires, engine emissions, and coke production, while petrogenic sources include petroleum combustion and discharge (Albers, 2006; Eisler, 1987). PAHs have been detected in air, soils, drinking water, and groundwater, and although they break down when exposed to UV light or oxygen, they can persist in the sediment for decades (Albers, 2006). Lipid solubility of PAHs is high, but animals vary in their ability to assimilate these compounds. While many invertebrates cannot metabolize PAHs and thus accumulate them in the body, most vertebrates can rapidly metabolize PAHs (<2 weeks) with a well-developed mixed-function oxygenase system in their liver (Albers, 2006; Lawrence and Weber, 1984; Varanasi et al., 1989). Thus, although PAHs move through the food chain, potential for biomagnification of PAHs in vertebrates is thought to be low (Boehm et al., 2004; Broman et al., 1990; Kayal and Connell, 1995; Meador et al., 1995). PAH concentrations in marine organisms after a major oil spill have varied from no detectable increase to initially elevated levels that decrease to baseline within a few months to a few years (Al-Yakoob et al., 1993; Boehm et al., 2004; Xia et al., 2012). Several studies suggest that avian predators may be a good indicator of PAH contamination after a major oil spill due to the ingestion of contaminated prey (Alonso-Alvarez et al., 2007a; Paruk et al., 2014a; Seegar et al., 2015; Zuberogoitia et al., 2006).

PAHs are toxic at low concentrations (e.g., ng/g), and they can be carcinogenic or mutagenic to wildlife and humans (Albers, 2003; Menzie et al., 1992; Wang et al., 2002). Chronic exposure to sublethal PAH concentrations can cause several physiological impairments, leading to a number of health effects. These effects include liver damage (Leighton, 1993; Miller et al., 1978), hemolytic anemia (Leighton, 1993; Nisbet et al., 2013; Troisi et al., 2007; Yamato et al., 1996), impaired osmoregulation (Meador et al., 1995; Miller et al., 1978), weight loss (Burger and Tsipoura, 1998; Leighton, 1986), gastrointestinal damage (Leighton, 1986; Miller et al., 1978;), endocrine disruption (Franci et al., 2014), and immune suppression (Briggs et al., 1996; Nicolas, 1999; Reynaud and Deschaux, 2006; Rocke et al., 1984). Individuals with physiological impairments and poorer body condition may also experience lower reproductive success (Ainley et al., 1981; Day et al., 1997; Golet et al., 2002).

1.2. The Deepwater horizon oil spill

The Deepwater Horizon oil spill (DHOS) was the largest offshore oil spill in U.S. history. Approximately 780 million liters of crude oil (4.9 million barrels) were released into the northern Gulf of Mexico (nGOM) from early April through mid-July 2010 (McNutt et al., 2012), which is about 20 times the volume released from the 1989 Exxon Valdez into Prince William Sound, Alaska (Atlas and Hazen, 2011). Approximately 1700 km of coastline in the nGOM were impacted by oil (Michel et al., 2013), with the Louisiana coastline receiving the majority: 138 km of marsh shoreline were heavily oiled and an additional 364 km were lightly oiled. The oil released in the DHOS contained approximately 3.9% PAHs by weight. Because of their toxicity, PAHs are one of the principal contaminants of concern during an oil spill. After the DHOS, PAHs moved from the planktonic food web to upper-level trophic consumers, suggesting exposure risk to a wide variety of taxa (Mitra et al., 2005). Due to concern over the effects of exposure on vertebrates, several studies have called for continued monitoring of PAHs in the biota exposed to the DHOS (Carmichael et al., 2012; Gohlke et al., 2011; Sammarco et al., 2013).

1.3. Study species

Common Loons (*Gavia immer*) are long-lived (>25 years), piscivorous waterbirds that breed in freshwater lakes of northern North America and overwinter predominantly along seacoasts (Gray et al., 2014; Paruk et al., 2014a). Although wintering loons are primarily found near shore (Daub, 1989; Haney, 1990; Thompson and Price, 2006), many can be found several miles offshore as well (Jodice, 1993). A substantial portion of the interior North American loon population winters in the nGOM (Gray et al., 2014; Kenow et al., 2002; Paruk et al., 2014b), and adults exhibit a high level of winter site-fidelity (Paruk et al., 2015). Loons typically arrive at their wintering area in November, remain there for 4–5 months, and depart in late March to early April, depending on latitude (Paruk et al., 2015; Spitzer, 1995). Typically, beginning in January, loons undergo a simultaneous wing molt and are flightless for a few weeks (Woolfenden, 1967). Adults generally do not fly during mid-winter, even after wing molt is completed, and first or second-year birds rarely fly during this time (Evers et al., 2010; pers. obs.). As such, any PAHs in wintering loons would likely have been obtained locally. Breeding loons have been used as a bioindicator species for other contaminants (e.g. mercury; Evers, 2006), and they may be useful indicators of marine pollution on their wintering grounds as well (Paruk et al., 2014b).

1.4. Objectives and hypotheses

The long-term consequences of oil exposure on migratory birds overwintering in the nGOM have received limited attention despite the enormity of the spill and size of the contaminated area (Franci et al., 2014; Henkel et al., 2012). Acute tests of toxicity in the laboratory are insufficient for ecotoxicological risk assessment, and more field studies are needed in migratory wildlife to fully examine potential sublethal effects of PAHs. Our objective was to evaluate a population of Common Loons for potential exposure to PAHs from the DHOS event. We monitored internal PAH concentrations in loon blood over a period of five years to assess contamination patterns, and we tested for associations between PAH exposure and loon body mass and physiological markers. We hypothesized that birds would show the highest level of contamination in the year following the spill, and that there would be a decreasing trend in blood PAH levels with time. In addition, we hypothesized that PAH exposure may have a deleterious effect on loon physiological markers and body mass.

2. Materials and methods

2.1. Study area

The research area consists of numerous bays and watercourses associated with the much larger Barataria Bay of the Louisiana coast (see Fig. 1). These include: Bay Adams (29.365719°N, −89.620354°W), Bay Batiste (29.458630°N, -89.845540°W), Bastian Bay (29.308186°N, -89.647466°W), Bay Sansbois (29.470335°N, -89.771223°W), Grand Bayou (29.511698°N, −89.765879°W), and Lake Washington (29.385665°N, −89.735918°W). We chose this area because it received moderate to heavy oiling from the DHOS. The watercourses are within 10 km of shore, and are thus considered near-shore environments. The water is typically shallow (1–6 m) and turbid (0.6 m visibility; Paruk et al., 2014a). Other characteristics of the area are described in Paruk et al. (2014a).

2.2. Capture

We captured 93 loons from January–March 2011–2015, using a well-established spotlighting technique in which we boated into bays at night, located rafting or solitary loons, and captured them with a long-handled dip net (Evers, 2001). We did not discriminate between adults and subadults because of the opportunistic nature of this technique. Common Loons were aged by plumage (Evers et al., 2010) as either adult (any loon ≥20 months of age) or subadult (any loon <20 months of age); sexes cannot be determined by plumage. Birds were banded with a U.S. Geological Survey (USGS) aluminum band and a unique combination