Science of the Total Environment 562 (2016) 714–723

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Metals and metalloids in nestling tree swallows and their dietary items near oilsands mine operations in Northern Alberta

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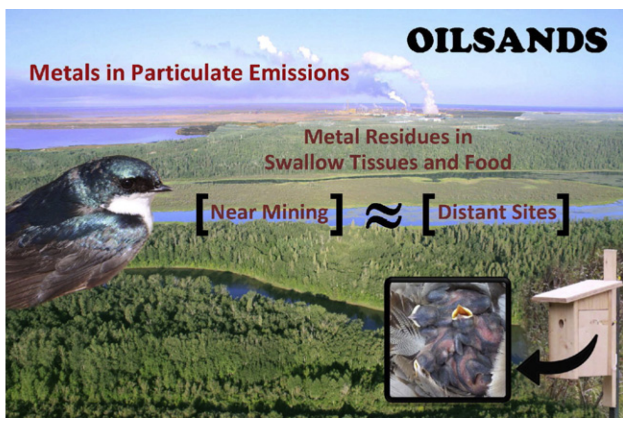
HIGHLIGHTS

- Oilsands mine operations may expose birds to metals and metalloid elements.
- Tree swallows ate up to 50% terrestrial insects, likely limiting exposure to metals.
- Annual variation in tissue element burden highlights need for multi-year data sets.
- Element variability in food is important when interpreting tissue concentrations.
- No evidence that nestling tree swallows accumulated metals approaching toxic levels

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 8 November 2015
Received in revised form 9 April 2016
Accepted 10 April 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Oilsands
Tree swallows
Metals
Tissue residues
Diet
Food web

ABSTRACT

Tree swallows (*Tachycineta bicolor*) nesting near oilsands development in northern Alberta are potentially exposed to elevated levels of metals. The objective of this study was to determine whether levels of metals and metalloid elements in dietary items and tissues of nestling tree swallows inhabiting areas near oilsands mine operations were higher compared to those of reference sites. We hypothesized that if there was increased, industry-related exposure to metals, it would be via the diet. We identified the invertebrate prey in the stomach contents of nestlings. We also collected invertebrates using Malaise traps near nest boxes, and analyzed those taxa found in the nestling diet to understand potential variability in metal exposure. For most elements, we found no significant differences in concentrations in the liver, kidney, or stomach contents between sites near to and far from oilsands operations. Concentrations of five elements were positively correlated among tissues and stomach contents. For invertebrates collected from Malaise traps, location differences occurred in some absolute elemental concentrations, which were most often highest at reference sites away from mining operations. We found no evidence that nestling tree swallows accumulated metals approaching toxic levels. Tree swallows consumed relatively high quantities of terrestrial insects, possibly limiting exposure to water borne, food-web-related contaminants. We suggest that annual variability associated with elemental exposure and dietary levels of elements be considered when interpreting concentrations in bird tissues.

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http://dx.doi.org/10.1016/j.scitotenv.2016.04.069

1. Introduction

The release of heavy metals into the environment is increasingly a concern in the Athabasca oilsands region north of Fort McMurray, Alberta, Canada (Timoney and Lee, 2009; Kelly et al., 2010; Schindler, 2010). Surface mining of the oilsands has been occurring since 1967, and bitumen production from mining is expected to increase from 0.9 million barrels per day (bpd) in 2010 to about 1.6 million bpd by 2020 (ERCB, 2011). A complex mixture of contaminants is derived from bitumen extraction and subsequent upgrading. Nickel and vanadium are found in the raw oilsands material (Research Council of Alberta, 1953; Har, 1981), and are present, along with other metals, in the by-products from bitumen production (Jervis et al., 1982; Holloway et al., 2005; Puttaswamy and Liber, 2012). Nickel, cadmium, lead, zinc, and other metals measured in particulates in snow were higher near oilsands mining operations (Kelly et al., 2010). Higher concentrations of metals have also been measured in lichen (*Hypogymnia physodes*) within 50 km of oilsands operations compared to further distances (Edgerton et al., 2012). Bitumen is converted to synthetic crude oil at upgrading facilities, and atmospheric deposition attributed to emissions from these upgraders is an important pathway of metal input to the environment (Bari et al., 2014), potentially contaminating surface waters (Barton and Wallace, 1979; Kelly et al., 2010; Puttaswamy and Liber, 2012).

Metal contamination in soil and surface water affects the species composition of plant, insect, bird, and small mammal communities (Heliovaara and Vaisanen, 1991; Eeva and Lehikoinen, 1996; Ruohomaki et al., 1996; Kiikkilä, 2003; Koptsik et al., 2003; Mukhacheva et al., 2010). However, there are few peer-reviewed studies that have directly examined the health effects of metals on wildlife in the oilsands region (see Rodríguez-Estival and Smits, 2016). Birds are often used to monitor the environment for metal contamination from industrial activities (Swiergosz et al., 1998; Eens et al., 1999; Bel'skii et al., 2005; Eeva et al., 2009; Berglund et al., 2010), and insectivorous birds in particular are useful for studying effects from metal exposure because the accumulation of metals can occur through the diet (Hunter and Johnson, 1982; Gochfeld and Burger, 1987; Eens et al., 1999).

Tree swallows (*Tachycineta bicolor*) have been used as an indicator of environmental exposure to contaminants in the oilsands region (Smits and Fernie, 2013; Cruz-Martinez et al., 2015), and contaminants have been shown to accumulate in nestlings (Custer, 2011). Tree swallows are an ideal model organism because they readily use nest boxes, allowing for appropriate sample sizes and standardization of methods (Jones, 2003). Tree swallows are semi-colonial, and birds will nest in close proximity to each other, allowing relatively high densities of birds within a small area (McCarty, 2001/2002). Broods of birds nesting in a common area are assumed to be exposed to the same contaminants, reducing the variability in dietary metal concentrations and making it possible to study the potential effects from metal exposure.

The objective of our study was to determine if the levels of metals and other metalloid elements in nestling tree swallows inhabiting areas near oilsands mine operations were higher compared to reference sites. We used nestling tree swallows because adults spend only a short period in the study area and may be exposed to metals during migration or on wintering grounds, and accumulation in adults may be affected by age and health. We hypothesized that if there was increased exposure to metals, it would be via the diet because contaminant exposure through foraging has been most frequently documented (McCarty, 2001/2002), compared to exposure from inhalation or drinking water. We measured the element burden in bird tissues and in the food items provided to the nestlings by adults, as determined from stomach contents. We predicted that higher levels of metals would occur in the tissues of nestlings near oilsands mining operations compared to birds in reference sites (distant from mining operations) that would reflect the natural environmental conditions. If the nestlings were being exposed to metal contaminants through food, then we expected that metal levels in tissues would be correlated to the metal levels in the diet. Adult females excrete metals into eggshells (Burger, 1994; Dauwe et al., 1999), with some transfer of metals to the eggs. However, a minimal portion of the body load is excreted into the eggs (Dauwe et al., 2005), and is diluted through the rapid gain of mass during post-hatching development of the nestlings from <2 g as eggs which includes shell mass (Whittingham et al., 2007), to 22 g (unpublished data) as fledglings.

Tree swallows forage primarily on invertebrates with aquatic larval stages (Mengelkoch et al., 2004). They consume brachyceran, nematoceran and cyclorrhaphan Diptera, as well as Trichoptera, Ephemeroptera, Odonata, and Hemiptera (McCarty and Winkler, 1999; Smits et al., 2000). Tree swallows generally forage within a few hundred metres of their nest through the breeding season (Quinney and Ankney, 1985; McCarty and Winkler, 1999; McCarty, 2002; Mengelkoch et al., 2004), and therefore, any measured metal accumulations in nestlings can be attributed to local exposure from foods brought to them by adults (Echols et al., 2004). We collected invertebrate samples near nest locations to measure metal concentrations in dietary items to understand the potential metal exposure from the tree swallow diet.

2. Methods

2.1. Study sites

Our study was conducted in 2012 and 2013 with populations of tree swallows using nest boxes near Fort McMurray (Zone 12 V, 0476688 Easting, 6287042 Northing, Datum NAD83), Alberta, Canada. We sampled nestlings at six sites; Sites 1, 2, and 3 were within 5 km of active oilsands mining operations and were exposed to aerial emissions and potentially to contaminants in water (Fig. 1). The reference sites (Sites 4, 5, and 6) were located 60 to 65 km south of the active mining area. The prevailing winds in the region are generally west to east (Vickers et al., 2001). Therefore, we considered reference sites to be unexposed to contaminants from upgrader emissions and mining activities. Each site had 20 to 30 nest boxes, and was near an open water body, wetland or pond. Near operations, Site 1 was beside a pond built in 1993 to support tailings research, and contained fine tailings that have settled to the bottom with a cap of natural surface water. The area around the pond has naturally revegetated. Site 2 was a reclaimed area and on the edge of a wetland that formed following reclamation in 2003. Site 3 was also reclaimed from an overburden dump in 1983, and now supports a mature upland forest and wetland habitat. Reference Site 4 was on the edge of an old borrow pit that provided gravel fill for road construction, and has naturally revegetated and filled with water. Site 5 was adjacent to a beaver pond and a natural drainage system. Site 6 was on a grass-sedge wetland on the edge of Maqua Lake.

2.2. Tissue sampling

We monitored tree swallow nest-boxes regularly from the initiation of nest building beginning about 20 May in both 2012 and 2013. We inspected nest boxes daily or every second day during egg laying to determine the date of clutch completion. Nest boxes were left undisturbed during incubation until hatching, and then checked daily until all nestlings had hatched. We considered day zero to be when half or more of the eggs had hatched. At the age of 14 days, one to three nestlings were randomly collected from each nest box for tissue sampling. The laying order was not known, and bias from laying order was avoided by selecting nestlings at random. Three nestlings were collected from larger brood sizes (six or more nestlings) to improve sample sizes. Nestlings were anesthetized with isoflurane, and then euthanized by cervical dislocation. Once nestlings were euthanized, the liver and kidney were removed and immediately frozen in liquid nitrogen. The stomach was removed and kept on ice until being transferred to a freezer at the end of each day. The protocols used in this study were approved by the Animal Care Committee at the University of Calgary (LESACC protocol number BI11R-27), in compliance with standards set by the Canadian