Science of the Total Environment 639 (2018) 596–607

Contents lists available at ScienceDirect

Science of the Total Environment

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

Examination of contaminant exposure and reproduction of ospreys (*Pandion haliaetus*) nesting in Delaware Bay and River in 2015

Barnett A. Rattner [a,*], Rebecca S. Lazarus [a], Thomas G. Bean [b], Peter C. McGowan [c], Carl R. Callahan [c], Richard A. Erickson [d], Robert C. Hale [e]

[a] U.S. Geological Survey, Patuxent Wildlife Research Center, Beltsville, MD, USA
[b] Department of Environmental Science and Technology, University of Maryland, College Park, MD, USA
[c] Chesapeake Bay Field Office, U.S. Fish and Wildlife Service, Annapolis, MD, USA
[d] U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, WI, USA
[e] Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, USA

HIGHLIGHTS

- Delaware Estuary is challenged by human population, agriculture, industry and shipping activity
- Study examined spatial trends and food web transfer of contaminants and reproduction in ospreys
- OCP, PCB, and PBDE levels were greater in osprey eggs from Delaware River than its Bay and coast
- Legacy contaminants decreased, no eggshell thinning, productivity adequate to maintain population
- Documents improvement in Delaware Estuary waterbird habitat compared to second half of 20th century

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 30 March 2018
Received in revised form 4 May 2018
Accepted 5 May 2018
Available online xxxx

Editor: Jay Gan

Keywords:
Biomagnification
Delaware estuary
Flame retardants
Persistent pollutants
Ospreys
Reproduction

ABSTRACT

A study of ospreys (*Pandion haliaetus*) nesting in the coastal Inland Bays of Delaware, and the Delaware Bay and Delaware River in 2015 examined spatial and temporal trends in contaminant exposure, food web transfer and reproduction. Concentrations of organochlorine pesticides and metabolites, polychlorinated biphenyls (PCBs), coplanar PCB toxic equivalents, polybrominated diphenyl ethers (PBDEs) and other flame retardants in sample eggs were generally greatest in the Delaware River. Concentrations of legacy contaminants in 2015 Delaware Bay eggs were lower than values observed in the 1970s through early 2000s. Several alternative brominated flame retardants were rarely detected, with only TBPH [bis(2-ethylhexyl)-tetrabromophthalate)] present in 5 of 27 samples at <5 ng/g wet weight. No relation was found between *p,p′*-DDE, total PCBs or total PBDEs in eggs with egg hatching, eggs lost from nests, nestling loss, fledging and nest success. Osprey eggshell thickness recovered to pre-DDT era values, and productivity was adequate to sustain a stable population. Prey fish contaminant concentrations were generally less than those in osprey eggs, with detection frequencies and concentrations greatest in white perch (*Morone americana*) from Delaware River compared to the Bay. Biomagnification factors from fish to eggs for *p,p′*-DDE and total PCBs were generally similar to findings from several Chesapeake Bay tributaries. Overall, findings suggest that there have been improvements in Delaware Estuary waterbird

* Corresponding author at: U.S. Geological Survey-Patuxent Wildlife Research Center, c/o Beltsville Agricultural Research Center-East, Building 308, 10300 Baltimore Avenue, Beltsville, MD 20705, USA.
E-mail address: brattner@usgs.gov (B.A. Rattner).

https://doi.org/10.1016/j.scitotenv.2018.05.068

habitat compared to the second half of the 20th century. This trend is in part associated with mitigation of some anthropogenic contaminant threats.

1. Introduction

The Delaware River and Bay constitute the longest undammed watercourse in the eastern United States (330 miles/531 km of main stem from Hancock, NY to Lewes, DE), and its estuary (Trenton, NJ, River mile 133/River km 214 to Lewes, DE; PDE, 2017) is one of the largest in North America (DRBC, 2017). The Delaware River is fed by 216 tributaries in a 35,065 km^2 drainage basin that includes parts of Pennsylvania, New Jersey, New York and Delaware. Its river basin provides water for millions of households, as well as extensive agricultural and industrial uses (DRBC, 2017). The Delaware Estuary (bay and its tidal reach up the river) has a drainage of 17,681 km^2 that includes parts of Pennsylvania, New Jersey, Delaware and Maryland (PDE, 2008), and provides freshwater for about 6 million people (PDE, 2017). The Delaware River and Bay contain major industrial centers and significant shipping channels and ports for crude oil, paper, steel, meat and produce (DRBC, 2017).

The Delaware Estuary is part of the National Estuary Program Network (USEPA, 2017), with portions designated in the Western Hemisphere Shorebird Reserve Network (WHSRN, 2017), and as a Wetland of International Importance (Ramsar, 2017), an Audubon Important Bird Area (NAS, 2017), and a National Wild and Scenic River (NPS, 2017). It contains notable fauna and flora, and fosters an extensive fishery and game bird population for hunting and other recreational activities. Numerous species of birds depend on this estuary as it is part of the Atlantic flyway, and is a critical staging site for a large population of migrating shorebirds. The Delaware Bay is also home to Pea Patch Island, which provides habitat for the largest mixed heronry in North America north of Florida.

Pollution of this unique watershed has been documented for over two centuries, and the contribution of organic contaminants (e.g., DDT and other halogenated pesticides, PCBs, flame retardants) and trace metals (e.g., lead, mercury) to poor water quality became apparent during the second half of the 20th century (DRBC, 2017). Most notably, the section of the Delaware River between Trenton, NJ (River mile 133/River km 214) and New Castle County, DE (River mile 63/River km 101) includes centers of high human population density and large industrial centers (refining petroleum, manufacturing and processing of plastics, industrial and commercial chemicals including pharmaceuticals) (DRBC, 2017). There are 128 National Pollution Discharge Elimination System permits for Delaware River and Bay (Kent Barr, DRBC, personal communication 2017), and many National Priority List Superfund Sites at various stages of remediation within the Delaware River, Bay and its drainage (USEPA, 2017).

During much of the 20th century, pollutant loading and retention resulted in elevated concentrations of PCBs, total petroleum hydrocarbons and mercury in sediment throughout much of the Delaware Bay and Delaware River (e.g., Kim et al., 2017). While water quality has shown remarkable improvement (DRBC, 2017), fish consumption advisories continue for several species (e.g., American eel *Anguilla rostrata*, white perch *Morone americana*, channel catfish *Ictalurus punctatus*, striped bass *Morone saxitilis* and white sucker *Catastomus commersonii*) for the tidal Delaware River south to the Chesapeake and Delaware (C&D) Canal, principally due to high concentrations of PCBs and dioxins, but also dieldrin, chlorinated pesticides and mercury (DDNREC, 2016; NJDEP, 2017). During the second half of the 20th century, several species of predatory birds suffered declines in productivity (e.g., peregrine falcon *Falco peregrinus*, bald eagle *Haliaeetus leucocephalus*, osprey *Pandion haliaetus*, great blue heron *Ardea herodias*) related to eggshell thinning and other toxic effects associated with exposure to DDT metabolites, and to a lesser degree PCBs (Henny et al., 1977; Wiemeyer et al., 1988; Steidl et al., 1991a, 1991b, 1991c; Parsons and McColpin, 1995; Clark et al., 1998; Rattner et al., 2000; Clark et al., 2001, 2009).

In 2002, a large scale avian ecotoxicology study in the Delaware Bay and Delaware River examined concentrations and spatial trends of pesticides, PCBs, PBDEs, perfluorinated compounds and metals in ospreys (Toschik et al., 2005), a widely used sentinel of environmental pollution (Grove et al., 2009). Toschik and coworkers found that osprey eggs collected from nests located between the C&D Canal and Bensalem, Pennsylvania (30 km north of Philadelphia) contained greater concentrations of the most toxic PCB congeners, organochlorine pesticides and PBDEs compared to coastal Delaware, lower Delaware Bay and Stroudsburg, Pennsylvania (90 km north of Trenton). Concentrations of lead in feathers of 45-day old nestlings were also greatest between the C&D Canal and Trenton (Rattner et al., 2008). Productivity in this vicinity (1.0 fledgling/active nest) was judged to be marginally adequate to maintain a stable population, and egg loss from nests was related to concentrations of several halogenated contaminants in eggs (Toschik et al., 2005). While osprey nest occupancy is related to factors such as water depth and clarity, abundance of food resources, land use and nest availability, contaminants were suggested to be a major stressor on osprey productivity in Delaware River (Toschik et al., 2005, 2006).

Since 2002, there have been limited ecotoxicological investigations of wildlife in the Delaware Bay and Delaware River. In 2003, a die-off of Canada geese (*Branta canadensis*) at a petroleum fly ash pond and subsequent toxicology study demonstrated that pentavalent vanadium at the site constituted a direct lethal hazard to wildlife (Rattner et al., 2006). In 2004, the *Athos I* leaked nearly 265,000 gal of crude oil into the Delaware River and tributaries killing 206 waterfowl (DARRP, 2013). Other work examined the utility of seaside and saltmarsh sparrows (*Ammodramus maritimus*, *A. caudacutus*) as sentinels for mercury, with concentrations in some blood samples approaching potentially toxic levels (Warner et al., 2010). A search of the Contaminant Exposure and Effects –Terrestrial Vertebrate Database (Rattner et al., 2005) revealed 196 records (mainly waterfowl) for the Delaware Bay after 2002. This search was dominated by isolated incident reports from Tri-State Bird Rescue and Research Inc. (Newark, DE) describing lead and waste oil exposure and poisoning incidents in raptors and waterfowl.

Over a decade has elapsed since the last large-scale ecotoxicology study of wildlife in the Delaware Bay and Delaware River. In 2015, samples were collected to examine concentrations of both legacy and more contemporary pollutants in ospreys with the objective of evaluating spatial and temporal trends, and potential adverse effects. As part of this effort, we recently reported the detection of 8 of 20 active pharmaceutical ingredients (APIs) in plasma of fish commonly consumed by ospreys, yet only 2 of 20 of these APIs exceeded method detection limits in plasma of osprey nestlings (Bean et al., 2018). Notably, concentrations of acetaminophen (detected in 22 of 29 samples) and diclofenac (detected in 2 of 29 samples) in nestling plasma were at least 2 orders of magnitude below the human therapeutic concentration and at the lower bound of safety factors (0.01 and 0.001 of effect concentrations) (Bean et al., 2018). Herein we describe concentrations of halogenated