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Assessment of contaminant levels and trophic relations at a World Heritage Site by measurements in a characteristic shorebird species

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ABSTRACT

The River Elbe is responsible for influxes of contaminants into the Wadden Sea World Heritage Site. We investigated levels of polychlorinated biphenyls (PCBs), oxychlordane (OxC), hexachlorobenzene (HCB), hexachlorocyclohexanes (α-, β-, γ-HCHs), dichlorodiphenyltrichloroethane (DDT) and its metabolites, and polybrominated diphenyl ethers (PBDEs) in blood and feathers from Eurasian oystercatchers (*Haematopus ostralegus*; $n=28$) at the Elbe and compared it with a non-riverine site about 90 km further north. (1) Mean levels of all contaminants in feathers and serum were significantly higher at the river (∑PCBs: 27.6 ng/g feather, 37.0 ng/ml serum; ∑DDTs: 5.3 ng/g feather, 4.4 ng/ml serum) compared with the non-riverine site (∑PCBs: 6.5 ng/g feather, 1.2 ng/ml serum; ∑DDTs: 1.4 ng/g feather, 0.5 ng/ml serum). Mean ∑HCH and HCB levels were <1.8 ng/g in feather and <1.8 ng/ml in serum at both sites. (2) Levels of most detectable compounds in serum and feathers were significantly related, but levels were not consistently higher in either tissue. (3) There was no significant relationship between trophic level in individual oystercatchers (expressed as δ15N) or the degree of terrestrial feeding (expressed as δ13C) and contaminant loads. (4) PBDEs were not detected in significant amounts at either site. The results of this study indicate that the outflow from one of Europe's largest river systems is associated with significant historical contamination, reflected by the accumulation of contaminants in body tissues in a coastal benthivore predator.

1. Introduction

The North Sea is one of the most intensively used marine regions in the world (Halpern et al., 2008). It receives major influxes of nutrients and contaminants from several large river systems, including the Elbe (Bakker et al., 2009). Moreover, the Wadden Sea, located in the south-eastern North Sea, was declared a World Heritage Site in 2009 (CWSS, 2008) and provides food and space for millions of breeding and resting birds. Monitoring of population trends and numbers to assess changes in the quality of this important wetland site have identified alarming negative trends (Laursen et al., 2010; Blew et al., 2013; Koffijberg et al., 2013). Birds are widely used as indicators of health of the marine environment. They are found in the upper levels of the food web and therefore provide useful evidence for the accumulation of persistent contaminants (e.g., Furness, 1993; Thompson and Hamer, 2000; Dittmann et al., 2011), as well as for important changes in trophic relations (e.g., Montevecchi, 1993; Montevecchi and Myers, 1996; Schwemmer et al., 2013).

The contaminant loads of birds inhabiting this internationally important ecosystem have been monitored in terms of persistent organic substances (i.e., polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethanes (DDTs), hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCB), chlordane) and heavy metals (i.e., mercury) since the 1980s, and regularly since the 1990s (Becker and Muñoz Cifuentes, 2004). The results of this monitoring have provided insights into long-term changes in contaminant loads in the eggs of piscivorous (i.e., terns) and benthivorous (i.e., oystercatchers *Haematopus ostralegus*) marine birds.

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High breeding and resting numbers (Laursen et al., 2010; Koffijberg et al., 2013) mean that oystercatchers are one of the most characteristic species in the Wadden Sea. Contaminants in egg shells of oystercatchers have been shown to differ between different sites on the Wadden Sea, with the outflow of the River Elbe as an important hotspot (Becker et al., 1992; Beyerbach et al., 1993; Becker and Muñoz Cifuentes, 2004; Becker and Dittmann, 2009). Although overall levels of all contaminants in most parts of the Wadden Sea (including the Elbe river area) have declined during recent years, levels remain highest in the vicinity of the Elbe outflow (Becker and Dittmann, 2009). Intertidal mudflats and salt marshes in the Elbe estuary provide important feeding and resting areas for various waterbird species, including oystercatchers (Koffijberg et al., 2003).

We investigated the relevance of different types of organic contaminants in the south-eastern Wadden Sea, with a focus on major river influxes. This study had four major objectives:

(1) We compared contaminant levels and compositions of PCBs, HCB, oxychlordane (OxC), α-, β-, γ-HCHs, DDT and its metabolites, and polybrominated diphenyl ethers (PBDEs) between the River Elbe area and Hallig Oland, another important breeding site located about 90 km further north, with no riverine influence. Oystercatchers are very local during the breeding period (Schwemmer and Garthe, 2011), and individual oystercatchers thus reflect contaminant loads from their respective site.

(2) We compared contaminant patterns in blood and feathers from oystercatchers at the two sites to detect differences between different tissues (e.g., Jaspers et al., 2006; Voorspoels et al., 2006; Ahrens et al., 2009). Levels in feathers might integrate contaminant loads over a relatively long period of time and thus be influenced by contaminant levels in areas used outside the breeding period (Jaspers et al., 2007). Blood levels, however, indicate contaminant levels during the breeding period, and thus reflect contaminant loads at distinct breeding sites. We also examined the relationship between contaminant levels in feathers and those in blood, as suggested by Jaspers et al. (2007, 2008) for other bird species.

(3) Trophic position of consumers such as birds and the origin of prey can be investigated by analysis of stable isotopes (Inger and Bearhop, 2008). We therefore measured carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in red blood cells, serum and feathers to assess potential differences in feeding behaviours between individuals breeding at the two sites. $\delta^{13}C$ in body tissues of consumers provides information on prey origins (i.e., low $\delta^{13}C$ values indicate terrestrial origin, whereas high values indicate marine origin); $\delta^{15}N$ levels provide information on the trophic level of the prey (i.e., high $\delta^{15}N$ indicates prey from higher trophic levels; Fry, 2006; Inger and Bearhop, 2008; Ceia et al., 2014). We therefore aimed to relate levels of different types of pollutants to the feeding habits of the birds (Jaspers et al., 2007). We hypothesised that higher contaminant loads would be accompanied by higher $\delta^{15}N$ levels as a consequence of birds foraging at higher trophic levels, and by higher $\delta^{13}C$ levels as a result of foraging in more contaminated marine environments (when foraging terrestrially, oystercatchers commonly use pastures which in our study area are not treated with agricultural contaminants).

(4) Finally, we investigated the importance of PBDE contamination in birds in the Wadden Sea, particularly at the River Elbe site. PBDEs have been less-well investigated than many other substances, but have been suggested to influence hormone levels in different organisms (WWF, 2000; Jaspers et al., 2006; Voorspoels et al., 2006).

2. Methods

2.1. Study area

Incubating adult oystercatchers ($n=28$) were caught in the saltmarsh of Kaiser Wilhelm Koog (53° 57′ 55 N, 8° 54′ 14E; $n=11$) and on pastures on Hallig Oland (54° 41′ 52N, 8° 42′ 18E; $n=17$) in summer 2008 using walk-in nest traps (Fig. 1). The first site was located in the immediate vicinity of the River Elbe outflow, which is a significant source of contaminants (Bakker et al., 2009), while the latter site was located on an island in the north-eastern Wadden Sea, with no major river inflows. Both study areas are about 90 km apart. As oystercatchers show very local foraging flights (maximum up to 4 km distance) during the breeding period (Schwemmer and Garthe 2011) we can exclude that oystercatchers switched between the two study sites.

2.2. Sampling

Caught birds were ringed and about 1 ml of blood was taken from the brachial vein and preserved in serum tubes. Bird-catching and blood-sampling procedures complied with EC Directive 86/609/EEC for animal experiments and current German laws. Permits were obtained from the Ministerium für Landwirtschaft Umwelt und ländliche Räume (file numbers V 312-72241.121-37 (69-6/07) and V 312-72241.121-37 (27-3/08)). Samples were

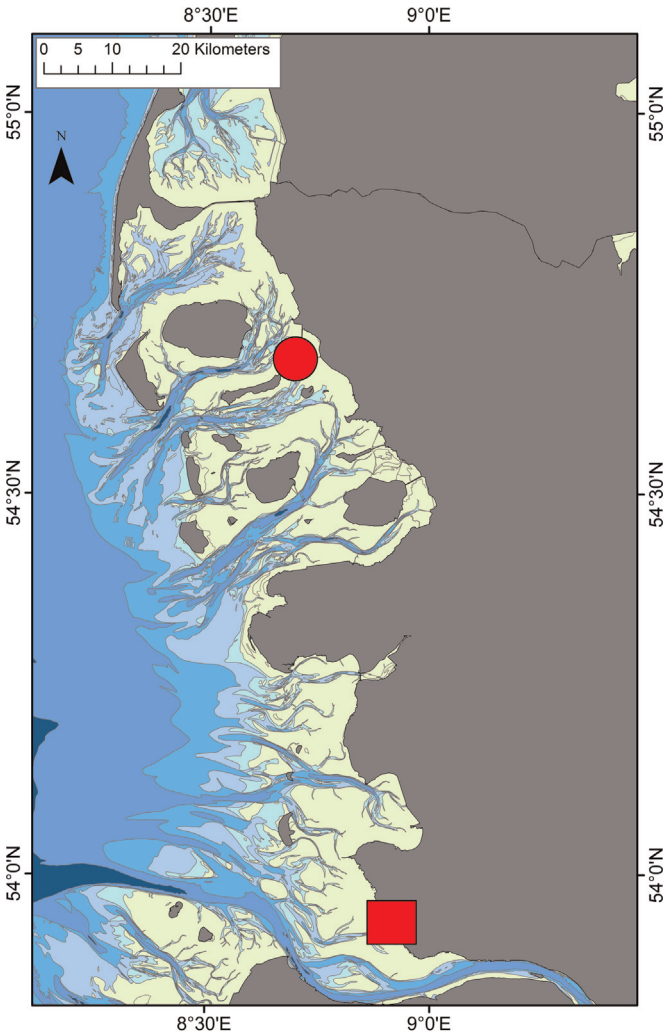

Fig. 1. German North Sea coast indicating sampling locations on the River Elbe (square) and Hallig Oland (circle).