Patterns and Trends of Chlorinated Hydrocarbons in Nestling Bald Eagle (Haliaeetus leucocephalus) Plasma in British Columbia and Southern California

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Abstract Patterns and trends of chlorinated hydrocarbons were assessed in bald eagle nestling plasma from sites along the west coast of North America. Eagle plasma was sampled from four areas in southwestern British Columbia (BC), a reference site in northern BC, and from Santa Catalina Island, off the coast of California. Sites were chosen to reflect variation in contaminant exposure due to differing recent and/or historic anthropogenic activities. Santa Catalina Island had significantly greater mean concentrations of p,p -DDE, 41.3 g/kg wet weight (ww), than other sites, and Nanaimo/Crofton, BC had the greatest mean concentration of total PCBs, 28.9 g/kg ww. Contaminant levels measured in 2003 in BC were compared to levels measured in 1993; over that ten year span, concentrations and patterns of chlorinated hydrocarbons have not significantly changed. There were no significant differences in levels of p,p -DDE or hexachlorobenzene between 1993 and 2003, but significant decreases were found for trans-nonachlor and PCBs at BC sites. Levels of total PCBs and trans-nonachlor in the central Fraser Valley and Nanaimo/Crofton area have significantly decreased. Mean concentrations of p,p -DDE measured in bald eagle nestling plasma samples in 2003 exceeded published criteria for effects on bald eagle reproduction at Santa Catalina Island and Barkley Sound, more than 30 years since heavy usage restrictions were imposed.

Introduction

Bald eagles (Haliaeetus leucocephalus) are an important sentinel species for monitoring ecosystem contaminant concentrations and effects of contaminant exposure on wildlife in the North American environment (Bowerman et al. 1998, 2003; Donaldson et al. 1999; Elliott and Harris 2001/2002; Elliott and Norstrom 1998). Since the 1960's, levels of chlorinated hydrocarbons in North America have been monitored in this species (Elliott and Harris 2001/2002). Due to their position at the top of the food chain and their scavenging behavior, bald eagles bioaccumulate a wide array of lipophilic contaminants, including chemicals such as DDT (dichlorodiphenyl-trichlorethane), its metabolite p,p -DDE (1,1-dichloroethylene bis[p-chlorophenyl]), PCBs (polychlorinated biphenyls), PCDDs (polychlorinated dibenzo-p-dioxins), and PBDEs (polybrominanted diphenyl ethers) (Elliott and Harris 2001/2002; McKinney et al. 2006; Roe 2004). Most commercial uses of DDT and PCBs were severely restricted in the United States and Canada during the 1970s due to concerns over environmental persistence, bioaccumulation, and toxicity to humans and wildlife (Elliott and Harris 2001/2002). In bald eagles, these contaminants have been linked to effects such as reduced eggshell quality, decreased breeding success, cytochrome P450 enzyme induction, mortality, and possibly developmental deformities (Bowerman et al. 1994, 1995; Elliott et al. 1996a, 1996c; Elliott and Norstrom 1998

Wiemeyer et al. 1984, 1993). Although the overall contaminant levels in North American bald eagles have decreased since the 1970s, there are geographic regions, including southern California and parts of the Great Lakes region, where contaminant exposure remains high and nest success of bald eagles is lower than expected (Bowerman et al. 2003; Elliott and Harris 2001/2002; Garcelon 1994).

On the southern California Channel Islands, bald eagles were extirpated in the early 1960s, in part due to high DDT and PCB exposure (Garcelon et al. 1989). Although still unable to naturally reproduce as a consequence of continued high DDT and PCB exposure, bald eagles were reintroduced to the island of Santa Catalina more than 20 years ago (Garcelon et al. 1989). Levels of contaminants in bald eagles on Santa Catalina Island have not been reported since 1993.

The number of bald eagles breeding on the south coast of BC has increased steadily since the mid-1980s. Elliott and Harris (2001/2002) showed that the regional rate of increase in the population size of bald eagles from 1966 to 1996 was greater than 1.5% each year in southwestern coastal BC and parts of Vancouver Island. Overall, on the BC coast, bald eagle nest success appears to be influenced mainly by ecological factors such as combined influences of food supply and weather (Elliott and Harris 2001/2002; Elliott et al. 1998, 2005), although there are some localized areas of poor nest success associated with exposure to relatively high concentrations of chlorinated hydrocarbons (Gill and Elliott 2003).

These previous bald eagle contaminant studies in California and BC form the historical baseline for the current study (Elliott et al. 1998b; Elliott and Norstrom 1998; Garcelon et al. 1989; Gill and Elliott 2003). The primary objectives of this study were to (1) evaluate patterns and trends of chlorinated hydrocarbons in nestling bald eagle plasma along the west coast of North America, including four areas in southwestern British Columbia (BC), a reference site in northern BC, Fort St. James (FSJ), and from Santa Catalina Island (SCI), off the coast of California, and (2) compare contaminants levels at sites in BC measured in 1993 and 2003. By continuing to monitor these legacy contaminants, information related to the health of bald eagles, status of the local environments, and fluctuations in contaminant concentrations at monitoring sites can be obtained.

Methods

Sample Collection

Nestling bald eagle blood samples were collected from five sites in British Columbia, Canada and one site in California, USA, which were chosen to reflect variation in contaminant exposure due to differing current and/or historic anthropogenic activities (Fig. 1). Samples were collected in 2003 from southwestern BC and California sites, and in 2001 from the northern BC site. In BC, samples were obtained from Delta-Richmond (lower Fraser Valley, n

Contaminant Analysis

Determination of organochlorines (OCs) and polychlorinated biphenyls (PCBs) were performed by staff at the Canadian Wildlife Service National Wildlife Research Center (NWRC; Ottawa, ON, Canada). The suite of organochlorines analyzed included: chlorobenzenes (tetra, penta, and hexa), hexachlorocyclohexanes, chlordane-related compounds (oxychlordane, trans-chlordane, cis-chlordane, trans-nonachlor, cis-nonachlor, and heptachlor epoxide), p,p -DDT and metabolites (p,p -DDE and p,p -DDD), mirex, photomirex, and dieldrin. Sixty-seven major PCB congeners were analyzed and summed to present the level of total PCBs. The PCB congeners analyzed for include the following: PCB 16/32, PCB 17, PCB 18, PCB 22, PCB 28, PCB 31, PCB 33/20, PCB 42, PCB 44, PCB 47/48, PCB 49, PCB 52, PCB 56/60, PCB 64, PCB 66, PCB 70/76, PCB 74, PCB 85, PCB 87, PCB 92, PCB 95, PCB 97, PCB 99, PCB 101/90, PCB 105, PCB 110, PCB 118, PCB 128, PCB 130, PCB 137, PCB 138, PCB 141, PCB 146, PCB 149, PCB 151, PCB 153, PCB 156, PCB 157, PCB 158, PCB 170/190, PCB 171, PCB 172, PCB 174, PCB 176, PCB 177, PCB 178, PCB 179, PCB 180, PCB 183, PCB 187, PCB 194, PCB 195, PCB 196/203, PCB 200, PCB 201, PCB 202, PCB 206, PCB 207, PCB 208. Of these PCB congeners, PCB 99, PCB 188, PCB 138, PCB 153, and PCB 180 had the highest mean concentrations.

The analysis of contaminants followed standard procedures and is described in full in the CWS Laboratory Service Methods Manual (Environment Canada 2003). Briefly, the plasma samples were denatured with formic acid (1:1 v/v) after the addition of internal standards.

sites were compared individually. Levels of trans-nonachlor significantly decreased over the 10 years, pooling data from the four BC sites (Fig. 3B; Z 2.20, p 0.03, df 1), but levels of HCB did not (Fig. 3C; Z 0.33, p 0.74, df 1). Concentrations of total PCBs significantly declined between 1993 and 2003 in BC (Z = 2.17, p 0.03, df 1; Fig. 3D, pooling all four sites). The largest decrease in total PCBs was noted in the central Fraser Valley (Z 2.2874, p 0.0452, df 1).

Discussion

In North America, many studies have monitored contaminant levels in plasma of bald eagle nestlings (Dominguez et al. 2003; Elliott and Norstrom 1998; Roe 2004). Concentrations of p,p -DDE and total PCBs in bald eagle plasma are shown to be variable among the sites compared fourfold. Using the regression of Strause et al. (2007), the mean predicted egg concentration of p,p away from any major urban and industrial development. There is some industrial forest industry activity in Port Alberni at the head of the inlet, but only relatively minimal increases in polychlorinated dioxin (PCDD) and furan (PCDF) contamination was found previously in bald eagle plasma and egg samples in Barkley Sound (Elliott and Norstrom 1998; Elliott et al. 1996b).

The Nanaimo/Crofton area showed high levels of PCBs, which is consistent with previous studies (Elliott and Harris 2001/2002; Elliott et al. 1998b). The southeastern portion of Vancouver Island, including the coastal area between Nanaimo and Crofton has had a considerable forest industry presence including lumber sorting yards, sawmills, and two large pulp and paper mill complexes. Discharge from those industries have been linked to releases of PCDDs and PCDFs into the local marine environment and bioaccumulation associated effects in fish-eating birds (Elliott et al. 1996b, 1998a). However, there has not been evidence of any substantial PCB inputs to the Nanaimo/Crofton area. Earlier surveys of chlorinated hydrocarbon contaminants in eggs and plasma samples of bald eagles did find that PCB concentrations were higher in samples from the Nanaimo/Crofton area, but also from the opposing mainland coast at Powell River (Elliott and Norstrom 1998; Elliott et al. 1996c). This may reflect some localized contamination inputs, however we believe that diet and food chain variation also plays an important role in determining the spatial contaminant patterns that we have measured here and in previous studies. It has previously been shown that patterns of PCB congeners in eggs of bald eagles varied among sites on the BC coast, which was attributed in part to dietary variation (Elliott et al. 1996c). In a related study, Weech et al. (2006) found a significant relationship between stable nitrogen isotope ratio (d^{15}N) and mercury in plasma of adult bald eagles from BC. Further work on the role of diet and trophic levels as an influence on contaminant concentrations in eagles is planned. This information will assist in explaining difference in contaminant concentrations and in determining the sources of contamination.

Temporal changes showed that the level of total PCBs and trans-nonachlor decreased in BC between 1993 and 2003 (data were pooled from the four BC sites), but the levels of p,p -DDE and hexachlorobenzene did not. The greatest decrease in total PCBs and trans-nonachlor was in