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Case Report—

Mortality Factors, Environmental Contaminants, and Parasites of White-Tailed Sea Eagles from Greenland

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SUMMARY. Twelve white-tailed sea eagles (*Haliaeetus albicilla groenlandicus*) found dead between 1997 and 2000 in Greenland were examined to investigate the health status, including the causes of death and the burden of organochlorine contaminants and potentially toxic heavy metals. The determined causes of death were unspecific trauma ($n = 6$), lead poisoning ($n = 2$) with 36 and 26 ppm lead in the liver tissue, infectious diseases ($n = 1$), injuries sustained during intraspecific conflict ($n = 1$), and gunshot ($n = 1$). One lead poisoned eagle had a single lead shot pellet in its gizzard. No diagnosis could be made in one case because of decomposition of the carcass. Four of the investigated eagles were injured with lead shot or bullet fragments; one of the birds was killed with about 69 lead shots. Levels of organochlorine pesticides, polychlorinated biphenyls, mercury, and cadmium in organs were moderate. The parasite fauna consisted of one coccidian and three helminth species. The acanthocephalas *Profiliocollis botulus* and *Corynosoma suduche* as well as the nematode *Stegophorus stellaepolaris* are all new records for the white-tailed sea eagle.

RESUMEN. *Reporte de Caso*—Factores de mortalidad, contaminantes medioambientales y parásitos de las águilas marinas de cola blanca de Groenlandia.

Se examinaron 12 águilas marinas de cola blanca (*Haliaeetus albicilla groenlandicus*) halladas muertas entre los años 1997 y 2000 en Groenlandia, para investigar el estado de salud, incluyendo la causa de la muerte y la carga de contaminantes organoclorinados y metales pesados potencialmente tóxicos. Las causas determinadas de la muerte fueron trauma inespecífico (6 aves), intoxicación por plomo con niveles entre 26 y 36 ppm en el tejido hepático (2 aves), enfermedades infecciosas (un ave), heridas ocasionadas por peleas con aves de la misma especie (un ave) y muerte por disparo con arma de fuego (un ave). Un águila envenenada por plomo presentaba en la molleja una sola bala de plomo. No se pudo diagnosticar la causa de la muerte en un ave debido a su grado de descomposición. Cuatro de las aves examinadas fueron heridas con balas o fragmentos de balas de plomo, siendo una de ellas asesinada por cerca de 69 balas de plomo. En los órganos se observaron niveles moderados de pesticidas organoclorinados, bifenil policlorinados, mercurio y cadmio. La fauna parasitaria consistió de una especie de coccidia y tres de helmintos. Se registraron por primera vez los acantocéfalos *Profiliocollis botulus* y *Corynosoma suduche* al igual que el nemátodo *Stegophorus stellaepolaris* como parásitos nuevos del águila marina de cola blanca.

Key words: chlorinated hydrocarbons, Greenland, *Haliaeetus*, heavy metals, lead poisoning, mortality factor, parasites, white-tailed sea eagles

Abbreviations: DDE = p,p′-dichlorodiphenyldichloroethylene; DDT = p,p′-dichlorodiphenyltrichloroethane; γ-HCH = γ-hexachlorocyclohexane; HCB = hexachlorobenzene; IUPAC = International Union of Pure and Applied Chemistry; OC = organochlorine; PCB = polychlorinated biphenyl

The white-tailed sea eagle (*Haliaeetus albicilla*) is a large raptor of the Northern Palearctic. The hunting habitats of this top predator of the aquatic food web are closely associated with marine nearshore habitats and fresh water bodies, where it preys upon fish and waterfowl. It is also known as an opportunistic scavenger, especially during the winter season. The white-tailed sea eagle population in Greenland inhabits the southwest seacoast, and its size is estimated at about 161 breeding pairs (21). Because of its bigger size, the greenlandic white-tailed sea eagle should be considered as a distinct subspecies, *Haliaeetus albicilla groenlandicus* (19,36).

The aim of this survey was to investigate the health status and causes of death of white-tailed sea eagles from Greenland and to elucidate their threats.

MATERIALS AND METHODS

Necropsy. All birds investigated in this survey originated from Greenland and were collected between March 1997 and January 2000. The 12 carcasses were stored at −20 C until submission for necropsy at the Institute for Zoo and Wildlife Research, Berlin, Germany. For 11 birds, the origin is known (Fig. 1), whereas one bird was submitted with unknown place of finding. All birds were measured, weighed, and x-rayed prior to dissection. The age categories adult (fifth year and older), subadult (fourth year), immature (older than 1 and younger than 4 yr), juvenile (first year), and nestling (until fledging) were determined by plumage and bill characteristics (12,14,18) and remains of the bursa fabricii (only for juveniles). Sexing was performed by gonad type (ovary or testis). The thickness of subcutaneous, body cavity, and coronary fat tissue was used to evaluate body condition together with the shape of the breast muscle and the weight of the bird. Postmortem examination concentrated on trauma, injuries, organ alterations, diseases, and parasites. Parasitologic techniques were described previously (27). The causes of death were determined by pathologic findings along with the background information provided by the supplier of the carcasses.

Chemical analysis. Sample preparation and residue analyses of contaminants were performed in the Research Institute of Wildlife Ecology at the University of Veterinary Medicine, Vienna, Austria.

We analyzed 10 livers for levels of organochlorine (OC) pesticides, such as hexachlorobenzene (HCB), γ-hexachlorocyclohexane (lindane) [γ-HCH], and p,p′-dichlorodiphenyltrichloroethane (DDT) and its main metabolite p,p′-dichlorodiphenyldichloroethylene (DDE), and of seven polychlorinated biphenyls (PCBs) according to their International Union of Pure and Applied Chemistry (IUPAC) nomenclature (IUPAC nos. 28, 52, 101, 118, 153, 180). Eleven livers and 12 kidneys were analyzed for their levels of the potentially toxic heavy metals lead, mercury, and cadmium.

Identification and quantification of the OC compounds were performed by capilary gas chromatography with an electron capture detector after Soxhlet extraction by *n*-hexane and a clean-up with deactivated aluminium oxide. The heavy metals in livers and kidneys were analyzed with a Zeeman atomic absorption spectrometer (PE 4100 ZL) equipped with a graphite furnace unit for lead and cadmium and a cold-vapor technique for mercury. A detailed account of the methods was given previously (22,23). Because the data on levels of contaminants were highly skewed to the right and the lack of statistical power in the small sample, we used exclusively nonparametric tests. Significance level was determined as $\alpha \leq 0.05$. All results were calculated as $mg{*}kg^{-1}$ (ppm) on a wet-weight (wet wt) basis.

RESULTS

Necropsy. Slightly more males ($n = 7$) than females ($n = 5$) were found. Six of the 12 birds were juveniles, two were categorized as subadult, and four birds were adult eagles. Body condition assessement indicated that seven birds were at least in good to very good condition, two eagles were in moderate condition, and three birds were in poor to very poor condition. Six birds died because of unspecific traumata, of which humerus fractures were found in four, furcula fractures in two, and broken ribs in one eagle.

In one eagle, a fibrinic pericarditis was detected, suggesting that this bird died because of an infection. Considering the highly decomposed carcass of this specimen, no microbiologic nor histologic examination of tissue samples was performed.

Intraspecific aggression, as territorial fight, was presumed as cause of death in one immature male showing perforations of the skin above the breast, hematoma in the breast muscle, and congestion of the pheripheric vessels resulting in a peracute shock.

More than 69 lead shot pellets were discovered by x-ray in the carcass of a subadult female white-tailed sea eagle, which was killed by lead shot and died due to a combination of a hypovolemic and neurogenic shock. Three other eagles had nonlethal injuries from lead shot or bullet fragments.

Lead concentrations of more than 5 ppm wet wt in hepatic and in renal tissue, indicating lethal lead poisoning (16), were detected in two eagles. One adult female had levels of 36.3 ppm and 10.9 ppm lead in its liver and kidney tissues, respectively, whereas a juvenile female had levels of 26.4 ppm and 14.9 ppm in hepatic and renal tissue, respectively. Both birds had swollen livers, and in the

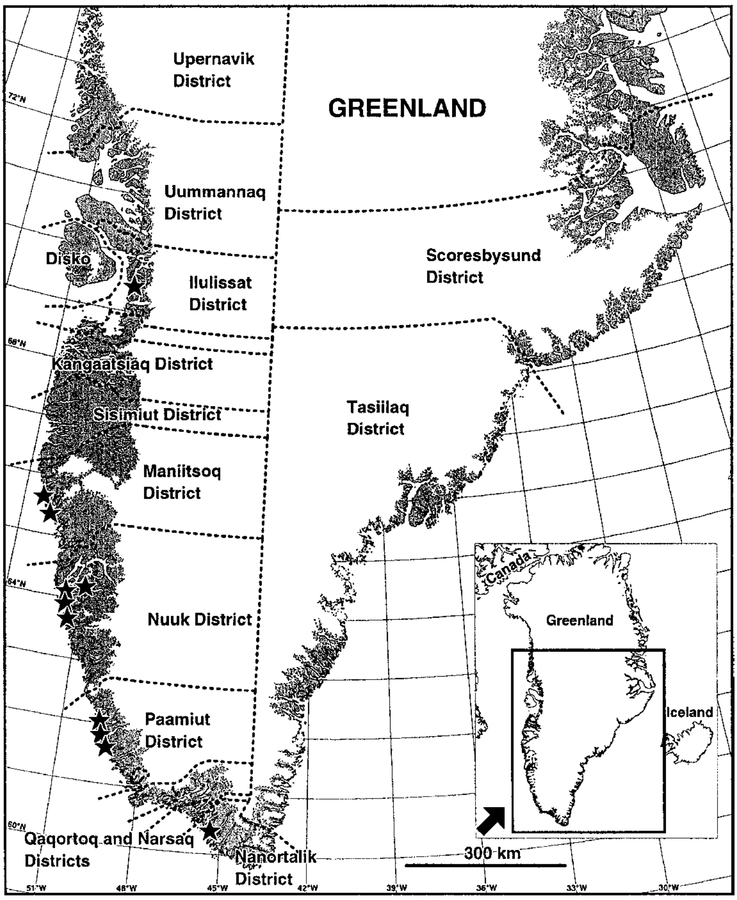

Fig. 1. Locations (indicated by asterisks) of 11 white-tailed sea eagles found dead or moribund in Greenland from 1997 to 2000.

juvenile bird, a lead shot, with a diameter of about 3.2 mm (0.192 g), could be isolated from the gizzard.

In one subadult female, no ultimate death cause could be detected because of its decomposed condition.

Endoparasites were detected in only half of the birds. Oocysts of *Sarcocystis/Frenkelia* sp. were found in the intestine of six eagles, whereas helminths were found in the digestive system of only four birds. Six eagles had no parasites. The nematode *Stegophorus stellaepolaris* was found in the proventriculus of a juvenile eagle, whereas the acanthocephalan *Profiliocollis botulus* was found in two and *Corynosoma suduche* was found in the intestine of one bird (Table 1).

Chemical analysis. All specimens had considerable levels of OCs and heavy metals in their organs; only a few measurements were below the detection limit. We summarized concentrations of DDT and of DDE to $\sum$DDT, and added the seven PCB congeners to $\sum$PCB. Concentrations for γ-HCH, PCB 52, and DDT were frequently below detection limit. The general PCB pattern was PCB 28 < PCB 52 < PCB 101 < PCB 118 < PCB 180 < PCB 138 < PCB 153. Highest hepatic levels were found for $\sum$DDT and the penta-, hexa-, and heptachlorinated biphenyls (IUPAC nos. 118, 138, 153, 180). Highest levels of most OCs were found in an adult male eagle in very poor body condition. For statistical purposes, we set levels below the detection limit to 0.0001 ppm, which was about one-half the limit of detection for most analytes. All results of the toxicologic analysis are given in Table 2. We report the median and the geometric mean; the arithmetic mean and the standard deviation are given for comparisons with data reported elsewhere.

Table 1. Helminths of white-tailed sea eagles from Greenland.

	Species	Number of Parasites (♂, ♀)	Location
Nematoda	*Stegophorus stellaepolaris*	5, 5	Proventriculus
Acanthocephala	*Profiliocollis botulus*	2, 1	Large intestine
	Corynosoma suduche	4, 3	Small intestine

No differences were found among years for different body conditions. Levels of mercury and cadmium in kidney of adult eagles were significantly higher than in the younger ones. All levels of OCs were significantly positively correlated except for levels of γ-HCH and for correlations between the levels of HCB and PCB 52 and between levels of DDT and PCB 52. For each element, we found significant positive correlations between the levels in livers and kidneys and also between the levels of cadmium and mercury of both organs. Correlations were also proved for both kidney levels of mercury and cadmium, with the hepatic levels of $\sum$DDT and the higher chlorinated PCBs (nos. 118, 138, 153, 180), and thus also for $\sum$PCB (Spearman rank correlation).

DISCUSSION

The deaths of most eagles in this study were due to anthropogenic factors, which is consistent with the main causes of death in white-tailed sea eagles from Germany (29) and bald eagles (*Haliaeetus leucocephalus*) from Florida (13). Natural causes of death remain mostly undetected because birds killed by anthropogenic activity or constructions are more likely to be found (24,25). However, the relatively high numbers of birds with shotgun pellets in their body and that died because of lead intoxication give reason for concern.

To our knowledge, these are the first contamination levels of white-tailed sea eagles of Greenland ever reported. All toxicologic levels indicated moderate exposure of Greenland's white-tailed sea eagles to the potentially toxic heavy metals, OC pesticides, and PCBs except in two birds. Both eagles died obviously due to acute lead poisoning and had lead concentrations of 36.282 ppm and 26.421 ppm in their livers and 10.940 ppm and 14.906 ppm in their kidneys (16). One of these eagles even had one eroded lead shot of about 3.2 mm diameter and weighing 0.192 g in its gizzard.

Lead poisoning in free-ranging birds of prey due to the ingestion of lead pellets has been reported in several communications from Japan, North America, and Europe (20,23,26,32,33,34,39). Raptorial birds are exposed to lead by preying on shot-crippled waterfowl and other game, as well as by scavenging on carcasses or gut piles with embedded lead ammunition. In Japan, for example, regulation of Sika deer (*Cervus nippon*) on Hokkaido, Japan, led to secondary lead poisoning of Steller's sea eagle (*Haliaeetus pelagicus*) and white-tailed sea eagles through ingestion of lead ammunition from carcasses of deer that were left after hunting activities (26,35). This poisoning subsequently resulted in a decrease of wintering Steller's sea eagles and white-tailed sea eagles from 1995 to 1999 (30).

In this study, all four sea eagles with lead shot in their body tissue, including one hunter-killed specimen with 69 embedded lead shots, had organ concentrations of $<$0.350 ppm in liver and kidneys, which are discussed as background level concentrations for birds of prey (16). So no evidence for increased lead concentration due to the embedded lead shot pellets was found. The mercury and cadmium levels were in a range considered harmless for marine piscivorous, or facultative piscivorous, birds, as the sea eagles (17,42,44). Whereas the medians and the geometric means of lead concentrations were in the range we reported from 57 free-ranging white-tailed sea eagles from Germany and Austria, the concentrations of cadmium and mercury in both organs indicated obviously higher metal exposure. The medians for mercury were two and four magnitudes higher in liver and kidneys, respectively, and for cadmium about 20-fold and 15-fold higher in livers and kidneys in Greenland's eagles compared with white-tailed eagles from Germany and Austria (23). The higher levels of mercury and cadmium in kidneys than livers were caused by their long-term accumulation in the kidneys (38). High levels of cadmium and mercury, but not lead, were also reported from Greenland seabirds in accordance to our finding (7).

The median concentrations of OC pesticides and PCBs as well as the pattern of PCBs were similar to, but the maximum values were far below, those we

Table 2. Concentrations of organochlorine pesticides and polychlorinated biphenyls in livers and levels of heavy metals in livers and kidneys of white-tailed sea eagles from Greenland. Values are given in mg*kg^{-1} (ppm) on a wet-weight basis.

Parameter	n	Range	Median	Geometric mean	Mean ± SD	$N \leq$ dl[A]
OCs and PCBs						
HCB	10	0.005–0.188	0.065	0.052	0.072 ± 0.054	0
γ-HCH	10	ND[B]–0.020	0.002	0.002	0.004 ± 0.006	3
DDT	10	ND–0.074	0.002	0.002	0.012 ± 0.023	3
DDE	10	0.011–4.532	1.140	0.496	1.261 ± 1.353	0
∑DDT	10	0.011–4.540	1.150	0.500	1.273 ± 1.357	0
PCB 28	10	0.001–0.041	0.010	0.009	0.015 ± 0.013	0
PCB 52	10	ND–0.167	0.014	0.004	0.050 ± 0.069	4
PCB 101	10	<0.001–0.143	0.063	0.027	0.066 ± 0.054	0
PCB 118	10	ND–0.591	0.237	0.063	0.237 ± 0.195	0
PCB 138	10	0.002–1.769	0.432	0.182	0.506 ± 0.525	0
PCB 153	10	0.005–3.045	0.694	0.314	0.840 ± 0.917	0
PCB 180	10	0.001–1.499	0.286	0.122	0.378 ± 0.456	0
∑PCB	10	0.011-7.212	1.707	0.786	2.091 ± 2.180	0
Heavy metals						
Liver						
Pb	11	0.027–36.281	0.179	0.354	5.835 ± 12.81	0
Hg	11	0.579–5.756	1.409	1.756	2.118 ± 1.509	0
Cd	11	0.084–0.555	0.329	0.317	0.348 ± 0.132	0
Kidney						
Pb	12	0.026–14.906	0.222	0.284	2.321 ± 5.026	0
Hg	12	0.657–3.544	1.648	1.720	1.944 ± 0.975	0
Cd	12	0.447–5.577	2.003	1.754	2.319 ± 0.132	0

[A]dl = detection limit.
[B]ND = not detectable.

reported from livers of 145 white-tailed sea eagles from Germany mainly collected in the 1990s (22). Overall higher OC concentrations from white-tailed sea eagles were also reported in the 1980s from Poland (8,9,10,11) and Finland (41) and from Norway between 1965 and 1983 (15). Liver concentrations of ∑DDT and ∑PCBs of two white-tailed sea eagles from Hokkaido, Japan (20), were in the range of the concentrations we found in this study.

The geometric means of OC levels in livers of 93 glaucous gulls (*Larus hyperboreus*) from Greenland sampled in 1994 (6) were comparable with our data. However, the white-tailed sea eagles showed levels of ∑DDT that were about 50% higher than, and levels of ∑PCB that were twice as high as, those reported from the glaucous gulls, which was mostly attributed to the hexa- and heptachlorinated PCBs (IUPAC nos. 138, 153, 180). Furthermore, the pattern of PCBs in livers of glaucous gulls was almost equal to our data. Glaucous gulls from the east coast had greater levels of higher chlorinated PCBs and ∑DDT than birds on Greenland's west coast (6).

Twenty-six bald eagles collected from 1993 to 1998 from the nonmigratory population of the Aleutian Islands, Alaska, had geometric means for cadmium in livers and kidneys twice as high as our data on a calculated dry weight basis with the factor 3.5 for liver tissue and 4 for kidney tissue as in the following comparisons (1,23,37,40). Whereas mercury levels in livers were similar to our data, the levels in kidneys were also about 100% higher. No residues for lead were reported. Geometric mean for HCB was similar, but we computed twofold and threefold higher values for ∑PCBs and DDE. Maximal levels were twofold higher for HCB and DDE in livers of Greenland sea eagles, contrarily the maximal value for ∑PCBs reported from the Aleutian Islands' bald eagles exceeded the value we report in the present study. PCBs were not given congener specific.

The endoparasite spectrum found in the Greenlandic white-tailed sea eagle is characterized by a small diversity, reflecting the prey items of a top predator within the arctic food chain. All endoparasites diagnosed use intermediate or paratenic hosts that are prey items of the eagles. *Profilicollis botulus* is an acanthocephalan parasite known from common eiders (*Somateria molissima*) and king eiders (*Somateria spectabilis*), which are common species within the distribution area of the sea eagle in Greenland. Eiders feed mainly on crabs (i.e., *Hyas araneus*), which are intermediate hosts for *P. botulus*, where the cystacanth develops (4). No paratenic host for *P. botulus* is known (31). *Corynosoma suduche* has been recorded only from the intestine of harlequin ducks (*Histrionicus histrionicus*), a circumpolar sea duck species (5). The life cycle of this acanthocephalan is not completely known, but aquatic arthropods serve as intermediate and marine fish as paratenic hosts. The only nematode (*S. stellaepolaris*) detected is described from divers (Gaviiformes), fulmars, skuas, storm-petrels (Procellariiformes), gulls, and auks (Charadriiformes) (3). The life cycle of *S. stellaepolaris* is unknown, but acuarioids that parasitize aquatic hosts develop to their third stage in the hemocoel of crustaceans. The white-tailed sea eagle, as piscivorous as well as avivorous predator, may get infected with acanthocephalan or nematode parasites by feeding on paratenic hosts (mainly fish) that consume crustacean intermediate hosts or by ingestion of infective larvae from recently infected water birds (2). The only protozoan parasite belonging to the genus *Sarcocystis/Frenkelia* was diagnosed in five eagles. This obligate heteroxenous coccidian uses mammals, birds, or reptiles as intermediate host to undergo an asexual multiplication resulting in muscle or brain cysts. These intermediate hosts need to be ingested by the definitive host for the parasite to complete its life cycle. Within the eagle, the parasite undergoes a gamogony before the typical oocysts are spread with the feces. In heavy infections, an enteritis may be a clinical symptom (28). Only one of six eagles infected with *Sarcocystis/Frenkelia* carried a heavy burden, but no sign of an enteritis was noticed because of the decomposed condition of the carcass. According to our data, the endoparasitic fauna of Greenlandic white-tailed sea eagles seems to be very specific and differs from that of sea eagles from continental Europe (29) and bald eagles from North America (43). Although totally protected in Greenland, occasionally some white-tailed sea eagles are shot, as this study shows. However, this study also indicates a much more alarming effect of the intense hunting in Greenland; namely, poisoning by ingestion of lead shots from crippled or killed but not retrieved birds. Further studies should be initiated to elucidate the impact of and subsequently mitigate this human induced mortality factor.

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