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Abstract: Sampling of contaminants in the principal habitat areas of whooping cranes (*Grus americana*) of both the Rocky Mountain and the Aransas/Wood Buffalo National Park whooping crane populations began in the mid-1980's. Contaminants in eggs and tissues of whooping cranes were sampled opportunistically since the 1960's. Chlorinated hydrocarbons existed in low levels in the environment. Some trace elements including aluminum, arsenic, cadmium, chromium, copper, mercury, selenium, and zinc are of sufficient abundance to justify continued monitoring. Declines over time in residues of DDT and mercury in tissues and eggs reflected the prohibition in use of these as pesticides or fungicides. Egg shell thickness did not differ significantly ($P >$ 0.05) from pre-1910 levels. At present, we are unable to confirm any contaminant levels which threaten reproductive performance or bird survival. The major potential contaminant threats to whooping cranes continue to be accidental oil and hazardous substance spills along the Gulf Intracoastal Waterway of Texas.

Key Words: aluminum, arsenic, cadmium, chlorinated hydrocarbons, chromium, contaminants, copper, *Grus americana*, mercury, selenium, whooping crane, zinc

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Analysis of animal tissues is useful for monitoring exposure of a species to chemical and environmental pollutants. Contaminant levels in tissue are influenced by the nature of the contaminant (whether it bioaccumulates or biomagnifies), the age of the individual, the time interval the individual spends in a contaminated environment, and the time elapsed since exposure. Sampling of muscle, kidney, liver, or brain tissue from the carcasses of whooping cranes began in 1964. The first sampling of an egg from Wood Buffalo National Park, Canada, occurred in 1967 with the collection of a dead embryo from a pipped egg (Lamont and Reichel 1970). We review published information on contaminants in the environment of whooping cranes and in their tissues and report results of previously unpublished sampling of the environment and bird tissues.

We thank the many individuals who assisted in sampling tissue, measuring eggs, and collecting whooping crane carcasses, other biota, or sediment. We especially appreciate assistance provided by personnel at Patuxent Wildlife Research Center (PWRC), U.S. Fish and Wildlife Service (Service), Laurel, Maryland, for much of the contaminant analysis work. We are grateful for the editorial assistance of L. S. Shomo, G. H. Olsen, W. H. Mullins, and D. W. Stahlecker.

STUDY AREAS

Whooping cranes occur in 2 wild populations in North America: the Rocky Mountain Population (RMP) and the Aransas/Wood Buffalo National Park Population (AWP). Geographic areas used by these populations are described to better understand the potential for exposure to contaminants.

The RMP resides in the Rocky Mountains of the western United States. This population was created by the cross-fostering experiment started in 1975 (Drewien and Bizeau 1978). The RMP spends April–September (6± months) on their summer grounds. Grays Lake National Wildlife Refuge (NWR), the most important summering area, is an 8,900-ha marsh at an elevation of 1,946 m in southeastern Idaho. The refuge occupies the inner 7,400 ha of the marsh. Private lands bordering the refuge include some agricultural (oats, barley, improved pasture) activities. Other members of the RMP summer in eastern Idaho, western Wyoming, and southwestern Montana where they use various wetland types and agricultural fields (small grains, hay, pasture). Agricultural activities appear to be the principal potential source of contaminant exposure for RMP whooping cranes on their summering areas.

RMP cranes migrate through Utah and Colorado. They spend 4–6 weeks in the San Luis Valley of south-central Colorado in both spring and fall. The Valley has elevations varying from 2,280 to 2,380 m. Annual precipitation is low (18 cm), but streamflow from bordering mountains and groundwater is abundant. The Valley is dominated by agriculture, primarily barley, wheat, potato, and alfalfa production. Cranes roost and loaf in ponds, streams, and associated wet meadows. Barley fields are an important feeding habitat. A key crane use area in the Valley is the Monte Vista NWR, 10 km south of the town of Monte Vista. The associated Alamosa NWR is 10 km southeast of the town of Alamosa. The principal potential sources of contaminants in the Valley are from agricultural activities and runoff from mining activities in the bordering mountains.

Most RMP cranes winter in the middle Rio Grande Valley of New Mexico between Belen State Game Refuge (SGR) and Bosque del Apache NWR from November through February. Belen is 48 km south of Albuquerque and Bosque del Apache NWR is another 96 km south. About 65% of these cranes winter at Bosque del Apache NWR, but other individuals stay at Belen SGR, Casa Colorada SGR, Bernardo SGR, or on private lands. They roost on the Rio Grande or on managed wetlands (1,675 ha) on the 23,070-ha Bosque del Apache NWR and feed in wetlands, pasture, and fields of corn and alfalfa. The principal potential source of contaminants is agricultural activity.

The AWP spends late April to early October (5± months) of the year at Wood Buffalo National Park in Canada. The nesting area is poorly drained and interspersed with numerous ponds, lakes, and marshes within boreal forest habitat (Novakowski 1966) which is isolated and closed to public access. There are no agricultural activities in the vicinity. However, a potential contaminant source for the AWP has been the Pine Point lead/zinc mine located north of Wood Buffalo National Park. The mine operated in the 1970's through 1987; it closed in 1988 when mineral extraction became uneconomical. The operation required a massive dewatering operation (McNaughton 1989), and the area is underlain by karst aquifers which are interconnected regionally. There is no impedance or barrier between the Park and the mine. The volume of water withdrawal was sufficient to raise concerns that surface water levels might be affected within the Park. It does appear that groundwater flow from the mine is towards Great Slave Lake and away from the Park, but this has not been confirmed (McNaughton 1989).

The AWP stages in southern Saskatchewan for up to 6 weeks during fall. The birds roost in lakes, ponds, and marshes and feed on barley and wheat (Kuyt 1992). The principal potential contaminant source in Saskatchewan is from agricultural activities. When whooping cranes continue migration, they enter the United States in eastern Montana and western North Dakota, pass through the western portions of South Dakota, Nebraska, Kansas, and Oklahoma and through central Texas. In the United States they roost in lakes and ponds and feed in wetlands, pastures, and fields of corn, wheat, barley, and sorghum (Howe 1987). Migration through the United States requires as little as 2–4 weeks (Kuyt 1992). Migration stopover areas within the United States do not appear to be used traditionally. We have no information on potential contaminant exposure while whooping cranes use these stopovers, but the probable contaminant sources are agricultural activities.

The AWP spends November to April at Aransas NWR and adjacent areas of the central Texas Gulf Coast. The winter habitat extends 48–56 km along the coast from San Jose Island and Lamar Peninsula on the south to Welder Point and the central portion of Matagorda Island on the north. These cranes winter in estuarine marshes, shallow bays, and tidal flats (Allen 1952, Blankinship 1976) with many winter territories bordering the Gulf Intracoastal Waterway (GIWW). The cranes are exposed to contaminants associated with runoff from agricultural and industrial activities as well as urban development inland and along the coast. The GIWW supports extensive barge traffic carrying a wide range of toxic chemical and petroleum products. Gas and oil production operations offshore and on-shore are another potential source of pollutants. Spring migration follows in reverse the same route as fall migration but is quicker, especially among experienced breeders.

METHODS

Rocky Mountain Population

Sediment, frogs (*Rana* sp.), juvenile American coots (*Fulica americana*), and aquatic plants (*Potamogeton* spp.) were sampled at Grays Lake NWR in 1986. Unfortunately the samples from Idaho, except for sediment, were accidentally lost sometime after being received at Patuxent Wildlife Research Center. Sediment, juvenile American coots, common carp (*Cyprinus carpio*), and pondweed were collected at the Alamosa/Monte Vista NWR complex in Colorado in August 1986. Results from our sampling at Alamosa/Monte Vista NWR led to a more comprehensive evaluation of trace element contamination during 1989–90 (Archuleta 1992). Water, sediment, mallards (*Anas platyrhynchos*), mallard eggs, and mallard food items were collected for trace element analysis. Sampling of environmental contaminants in the middle Rio Grande Valley, New Mexico, was underway when we initiated our habitat studies, so we chose to await those results rather than duplicate study efforts (Ong et al. 1990). RMP whooping cranes were sampled for chlorinated hydrocarbons (n = 8) and trace elements (mostly lead and iron, n = 4).

Aransas/Wood Buffalo Population

Sediment, blue crabs (*Callinectes sapidus*), crayfish (*Cambarus* spp.), fish, and vegetation were sampled at Burgentine Lake and Saint Charles Bay, Texas, by Maurer et al. (1987). Burgentine Lake is on the northwest corner

Table 1. Selected trace elements (ppm dry weight) in whole animals and plants and surface sediment samples from the Alamosa/Monte Vista NWR's, Colorado, 1986.

Trace element	American coot (n = 5)	Common carp (n = 3)	Aquatic plants (n = 3)	Sediment (n = 3)
Aluminum	233−845	29−271	151−1,180	5,030−10,100
Arsenic	0.3−0.48	0.1−0.88	0.34−1.4	2.1−3.8
Beryllium	<0.01	<0.01	0.02−0.10	0.34−0.91
Cadmium	0.04−0.14	0.04−0.12	0.093−0.26	<0.2−0.77
Chromium	0.2−11	0.50−2.3	<0.2−1.4	6.5−11
Copper	5.97−27.4	4.2−9.69	1.9−3.6	10−21
Iron	870−2,760	364−2,760	229−1,200	9,260−17,900
Lead	<0.4−2.4	<0.4	<0.5−1	8−50
Manganese	11.5−125	28.7−45.9	288−3,970	171−571
Mercury	0.049−0.21	0.4−0.59	0.071−0.076	<0.02−0.03
Nickel	<0.1−5.0	0.4−0.72	0.45−1.8	5.6−8.4
Selenium	0.89−1.3	0.41−1.1	0.2−0.79	<0.1−0.3
Thallium	<0.9−<1.0	<0.8−<0.9	<0.9−<1	<8.0
Zinc	69.9−121	144−190	10.8−19.2	24.6−172

of Aransas NWR and drains into Saint Charles Bay. Samples were analyzed for organochlorines, polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), and selected elements. The Aransas Bay complex (San Antonio and Aransas-Copano Bays) was sampled in 1985−86. Organochlorines, PCB's, trace elements, and hydrocarbon contaminants were examined in biota, and trace elements and oil and grease levels were examined in sediment (Gamble et al. 1989).

Blue-winged teal (*Anas discors*), northern shoveler (*A. clypeata*), and American wigeon (*A. americana*) were collected from the tailings pond at Pine Point Mine. Breast muscle was tested for arsenic, lead, and zinc, and kidney for lead and zinc.

One of the difficulties in sampling contaminants in an endangered species is the limited number of carcasses which become available for analysis. Many of the recovered specimens also were young birds (<12 months) which had little opportunity for exposure to contaminants. Carcasses containing disease organisms could not be analyzed if they presented a health hazard to laboratory personnel (i.e., avian tuberculosis). Carcasses in advanced stages of decay were unsuitable for analysis of chlorinated hydrocarbons and trace elements. Whooping crane tissues were collected (liver, kidney, muscle, or brain) whenever suitable carcasses (n = 13) were recovered. Whooping crane tissues were tested in the 1960's and 1970's primarily for chlorinated hydrocarbons and lead. Heavy metals were added to the analyses in the 1980's when biologists became more aware of the potential for crane exposure.

We sampled for elements in 39 eggs collected during 1975−89 at Wood Buffalo National Park. These eggs failed to hatch either in the wild or after being taken from the wild for further incubation in captivity. Putrefied eggs were not analyzed since the effect of putrefaction on recovery of organochlorine residues was unknown. Personnel at PWRC measured thickness of the egg shells. All analyses were conducted by Service chemists at PWRC or at laboratories under contract to the Service.

The recent analytical methods for organochlorines, including preparation, Soxhlet extraction, and lipid removal, were described by Cromartie et al. (1975). Samples were analyzed for organochlorine compounds (PCB-1254, arochlor, oxychlordane, heptachlor epoxide, *cis* and *trans* nonachlor, *cis* and *trans* chlordane, p,p'-DDE, p,p'-DDT, p,p'-DDD, alpha and beta BHC, dieldrin, endrin, lindane) and trace elements (aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, tin, vanadium, and zinc).

RESULTS AND DISCUSSION

Rocky Mountain Population

Grays Lake NWR.—Sediment samples (n = 6) taken

Table 2. Trace elements (ppm wet weight) in a 4-month-old male whooping crane from the Rocky Mountain population, 1985. Values shown are in mg element/kg fresh-weight tissue.

Trace element	Muscle	Liver
Aluminum	2.2	3.1
Barium	0.098	0.10
Beryllium	0.098	0.10
Boron	4.9	10.0
Cadmium	0.098	0.10
Chromium	0.33	1.2
Copper	3.9	4.8
Iron	72.0	460.0
Magnesium	230.0	220.0
Manganese	0.98	1.2
Mercury	0.050	0.045
Molybdenum	0.098	0.76
Selenium	0.98	1.1
Vanadium	0.098	0.10
Zinc	39.0	44.0

by Grays Lake NWR staff in 1986 were tested for selenium. The mean was 0.79 ppm dry weight, range 0.49–1.2 ppm (unless otherwise noted, all residue results are presented as wet weights). Selenium tissue concentrations <10 ppm generally are not considered hazardous to bird life. Amounts between 10 and 30 ppm must be assessed by species. Levels >30 ppm present a high risk of embryonic deformity. However, selenium metabolism and degradation are both significantly modified by interaction with heavy metals, agricultural chemicals, microorganisms, and numerous physiochemical factors (Eisler 1985). Until these are understood, it will be difficult to interpret selenium residues in various tissues.

Alamosa/Monte Vista NWR's.—Sampling at Alamosa and Monte Vista NWR's showed organochlorine concentrations in sediments and biota were ≤ 0.02 ppm. Hexachlorobenzene (HCB), x-BHC, r-BHC, ß-BHC, Δ-BHC, oxychlordane, heptachlor epoxide, r-chlordane, t-nonachlor, toxaphene, PCB's (total), o,p'-DDE, x-chlordane, endrin, mirex, o,p'-DDD, o,p'-DDT, p,p'-DDD, p,p'-DDT, and *cis*-nonachlor were not detected in biota or sediment. American coots and common carp (whole body) were the only organisms containing p,p'-DDE, and the levels were near the detection limits of 0.01–0.02 ppm. Dieldrin was detected in only 1 common carp at the level of 0.01 ppm.

Selenium levels (<2 ppm) were low (Table 1; Eisler 1985). Chromium, copper, lead, zinc, arsenic, and mercury were detected but did not appear at levels which would threaten whooping cranes. Some of these trace elements, including mercury and arsenic, are probably a consequence of gold and silver mining activities in the mountains bordering the San Luis Valley. High mercury levels may also have resulted from farming activities for barley and wheat while it was still legal to use mercury as a fungicide.

The sampling of sediment at Alamosa/Monte Vista NWR's in 1989–90 (Archuleta 1992) indicated the geometric means for aluminum, barium, beryllium, boron, iron, lead, manganese, strontium, and zinc exceeded 1 or both of the established sediment guidelines (for Great Lakes Harbors sediments or geometric mean for soils of the western United States) (Beyer 1990, Wells et al. 1988). Sediment concentrations (ppm dry weight) for boron (26.2), lead (18.1), and zinc (93.4) may be significant (Archuleta 1992).

Bosque del Apache NWR.—Except for lead, concentrations of all organochlorines and trace elements in bottom-sediment samples collected from the Rio Grande and the refuge were within or less than (Ong et al. 1990) the geochemical baseline ranges for soils in the western United States (Beyer 1990). All selenium concentrations were less than the baseline range. Most concentrations of pesticides in water and bottom sediments were less than analytical detection limits. Exceptions were a few samples in which concentrations were at or near the detection limits for DDT, DDD, DDE, chlordane, aldrin, PCB's, diazinon, and the herbicide 2,4-D. Trace elements in biological samples (birds, bird eggs, fish, aquatic invertebrates, and aquatic plants) were less than detection limits or were less than samples from other sites considered to be uncontaminated (Ong et al. 1990).

Tissues.—DDE ranged from 0.0099 ppm in several 4- to 5-month-old whooping cranes to 0.43 ppm in muscle of a 7-year-old male. Other chlorinated hydrocarbons were below detection limits. Selenium levels in young birds (about 1 ppm) were below the level of concern. Trace elements present in a 4-month-old male were typical of samples from the RMP. These were below levels of concern (Table 2).

Aransas/Wood Buffalo Population

Wood Buffalo National Park.—In the waterfowl (n = 6) collected at Pine Point Mine near Wood Buffalo National Park, wet-weight lead levels (breast tissue contained 0.44–1.16 ppm; kidney 0.51–8.24 ppm) were not high (Eisler 1988*a*) with the exception of 1 wigeon (4.1 ppm in muscle). Zinc levels (8.6–12.9 ppm in breast and 24.1–30.9 ppm in kidney) are not known to be a threat.

Arsenic levels (<0.4 ppm in breast) were quite low (Eisler 1988*b*) and were in an organically bound form which is rapidly excreted. Zinc and lead-rich Devonian deposits within Wood Buffalo National Park may explain zinc and lead levels found in tissues of AWP whooping cranes.

Burgentine Lake and Saint Charles Bay, Texas.—No organochlorines or PCB's were detected in sediment (Maurer et al. 1987). Only toxaphene, DDT, DDD, and DDE were detected in biota, and overall levels were low and were not in sufficient amounts to cause concern. Overall levels of PAH's and trace elements also were at levels of little concern. However, arsenic levels (1.2 ppm dry weight) approach those reported to cause reduced survival and growth in juvenile bluegill (*Lepomis macrochirus*) (Eisler 1988*a*). Copper (mean = 1.8 ppm) levels were higher than the mean (0.68 ppm) reported in a national monitoring program (Lowe et al. 1985) and similar to those reported in fish from contaminated areas (Maurer et al. 1987). However, copper is an essential element and does not tend to biomagnify (Maurer et al. 1987). High levels have been found in fish without any negative effects. Barium (10 ppm) and nickel (0.9 ppm) seemed elevated, but the significance of these levels is unknown (Maurer et al. 1987).

Aransas Bay Complex, Texas.—Organochlorines were detected at low levels in biota and sediments (Gamble et al. 1989). PCB's were not found above detection limits. DDT metabolites were lower than those detected in past studies and are unlikely to affect reproductive success of the AWP. Most trace elements were detected at low levels, but cadmium and copper were comparatively elevated in American oysters (*Crassostrea virginica*), indicating that other bivalves eaten by the cranes (Allen 1952, Blankinship 1976) may have similar elevated levels. Elevated mercury levels (0.038 ppm) were detected in blue crabs from Lavaca Bay, which is about 16 km northeast of the occupied crane habitat. Lavaca Bay has a history of elevated mercury levels associated with an aluminum processing plant. Levels exceed the FDA action level in fish fillets and the Bay remains closed to fin-fishing and crabbing (Gamble et al. 1989). Oil and grease levels were generally <1,000 ppm, and those samples >1,000 ppm were near oil and gas platforms or submerged pipelines. Most biota were relatively free of petroleum hydrocarbon contamination. All other contaminants were below the levels that affect biotic reproduction (Gamble et al. 1989).

Eggs.—Chlorinated hydrocarbons such as DDT are known to interfere with avian physiology by reducing calcium metabolism. As a consequence, the egg shells are thinner and breakage can result. Allen (1952) reported average shell thickness of whooping crane eggs measured in German museums as 0.58 mm (n = 14) but did not indicate the standard deviation. Anderson and Kreitzer (1971) compared thickness of 52 eggs collected before 1910 with 17 eggs collected 1967–69 at Wood Buffalo National Park. The 1967–69 average thickness of 0.612 ± 0.027 mm did not differ significantly (P > 0.05) from the pre-1910 average shell thickness of 0.604 ± 0.007 mm. Measurements of 33 eggs collected 1986–90 indicated an average thickness of 0.600 ± 0.042 mm, which also gave no statistical evidence of shell thinning (P > 0.05) when compared to the 1970's or pre-1910 data.

Table 3. Trace elements (ppm wet weight) in whooping crane egg contents, 1986–89, Wood Buffalo National Park, Northwest Territories, Canada.

Trace element	1986 (n = 8)	1987–88 (n = 13)	1989 (n = 5)[a]
Aluminum	0.94–0.10	0.96–0.99	1.0
Arsenic	0.038–0.044	0.083–0.10	0.096
Cadmium	0.094–0.10	0.096–0.099	0.099
Chromium	0.096–0.37	0.74–0.77	0.14
Copper	0.43–1.0	0.49–2.5	1.2
Barium	0.094–0.10	0.097–0.33	0.12
Beryllium	0.094–0.10	0.096–0.099	0.099
Boron	4.7–5.0	0.96–0.99	0.99
Iron	1.6–21.0	15.0–29.0	24.0
Lead	0.19–0.20	0.19–0.20	0.20
Manganese	0.94–1.0	0.96–0.99	1.0
Mercury	0.10–0.18	0.077–0.20	0.24
Nickel	0.094–0.10	0.17–0.18	0.10
Selenium	0.33–0.72	0.28–0.97	0.25
Strontium	0.096–2.5	0.46–1.6	1.2
Tin	1.8–4.2	0.96–0.99	0.99
Vanadium	0.094–0.16	0.23–0.31	0.10
Zinc	6.4–12.0	8.3–15.0	13.0

[a] Pooled.

Data (n = 9) from 1975 to 1977, compared with those from 1986 to 1989 (n = 26), indicated that DDT and mercury have continued to decline in the environment. In 1975, 5 eggs contained 0.06–0.20 ppm p,p′-DDE. Three eggs contained 0.24–0.73 ppm p,p′-DDE in 1976. Chlorinated hydrocarbons in 1986 (n = 8) ranged from 0.0097 to 0.0099 ppm, from 0.0094 to 0.01 in 1987–88 (n = 13), and (n = 5) 0.0093 pooled value in 1989 (Table 3). Mercury was detected at 0.12–0.36 ppm during the 1975 collection but was 0.077–0.24 ppm in the 1986–89 eggs (Table 3). PCB's showed a slight decrease from 0.25–0.35 ppm in 1976 (n = 3 eggs) to 0.046–0.10 ppm in 1986–89. Selenium did not exceed 0.10 ppm. None of the contaminant

Table 4. Trace elements (ppm wet weight) in muscle and liver of 2 whooping cranes from the Aransas/Wood Buffalo National Park population, 1989.

Trace element	1.5-year-old male		4-year-old female	
	Muscle	Liver	Muscle	Liver
Aluminum	<5.0	ND[a]	2.7	5.2
Antimony	<1.0	<2.0	ND	ND
Arsenic	<0.10	<0.10	0.2	0.35
Barium	<0.50	<1.00	ND	ND
Beryllium	<0.05	0.12	<0.04	<0.04
Boron	<0.05	<1.00	ND	ND
Cadmium	<0.05	0.10	<0.08	0.1
Chromium	0.48	0.30	<0.5	0.7
Copper	7.76	24.30	23.1	27.2
Iron	53.30	432.0	234.0	5,150.0
Lead	0.41	0.60	<0.9	<1.0
Magnesium	301.0	198.0	1.8	ND
Manganese	0.46	2.58	1.8	6.7
Mercury	0.050	0.30	0.32	1.6
Molybdenum	0.59	2.26	ND	ND
Nickel	<0.40	<0.80	<1.0	<1.0
Selenium	0.35	1.10	4.7	11.0
Strontium	<0.10	<0.20	ND	ND
Thallium	<2.00	<4.00	ND	ND
Tin	<0.50	<1.00	ND	ND
Vanadium	<0.50	<1.00	ND	ND
Zinc	17.80	75.10	63.8	234.0

[a] ND = Not detectable.

levels in eggs in the late 1980's are considered harmful to whooping cranes.

Tissues.—Lamont and Reichel (1970) and Robinson et al. (1965) reported levels of organochlorine pesticide residues of p,p′-DDT, p,p′-DDD, p,p′-DDE, and dieldrin in whooping crane tissue as <0.01–0.20 ppm. Four 1-year-old and 18-month-old whooping cranes recovered in 1989 contained these and other organochlorines at levels of <0.05–0.099 ppm in their tissues. These levels are not cause for concern.

Our tissue samples from 4 birds, including 2 birds of ages 1.5 and 4 years (Table 4), contained residues which may be harmful. Selenium levels were 4.7–11 ppm in a 4-year-old breeding female; the upper level is within the range that potentially causes reproductive impairment but must be assessed individually by species (Eisler 1985). Mercury levels of up to 3.3 ppm (in kidney) also may be excessive.

Interpretation of the results of contaminant studies is difficult. Toxic or harmful levels for materials such as zinc, aluminum, iron, and copper are unknown for bird life. Also, trace elements can have antagonistic, additive, or synergistic effects with each other and with organic compounds. Species-specific information about dangerous levels of trace elements is lacking for whooping cranes.

CONCLUSIONS AND RECOMMENDATIONS

The principal threat of environmental pollutants to whooping cranes continues to be the possibility of a contaminant spill along the Gulf Intracoastal Waterway in Texas. It is one of the busiest waterways in the world, and much of the commercial barge tonnage is petro-chemical products. The U.S. Coast Guard is working with other agencies and private groups in preparing for spill containment and cleanup. Another concern is maintenance dredging of the waterway, which is necessary at about 3-year intervals. Dredging can expose contaminants bound in sediments, which then may become chemically available to further cycling in the aquatic environment.

The U.S. Fish and Wildlife Service is presently updating its contingency plan for response to any contaminant spill in the winter habitat of whooping cranes. Dredging activities are conducted by the U.S. Army Corps of Engineers (Corps). The Corps must consult with the Service before initiating dredging and depositing spoil. Such consultations, as required under the Endangered Species Act, are designed to reduce or eliminate any detrimental effects on whooping cranes and their habitat. A significant aspect of these consultations will continue to be careful disposal of dredge materials to avoid reentry of contaminants into the whooping cranes' food chain. Analyses of eggs and tissues should be continued in the future to detect any changes in environmental contaminants within whooping crane habitat. Periodic monitoring of winter habitat should include analyses of water, sediments, and crane food chain biota for trace elements, organochlorines, and perhaps PAH's as part of the new national biomonitoring program being established for refuges.

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