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Contaminants Program

CONTAMINANTS IN REDHEAD DUCKS WINTERING IN BAFFIN BAY AND REDFISH BAY, TEXAS

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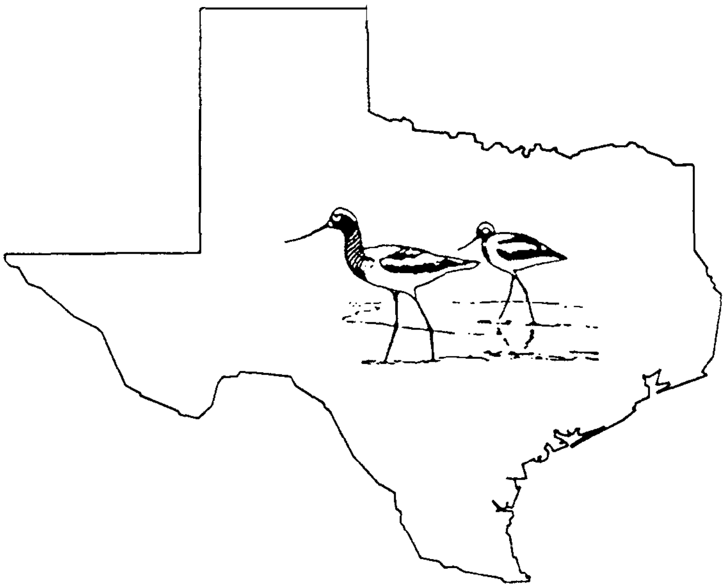

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CONTAMINANTS IN REDHEAD DUCKS
WINTERING IN BAFFIN BAY AND REDFISH BAY, TEXAS

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ABSTRACT

A sample of 39 redhead ducks was collected from Redfish and Baffin Bays on the Texas Coast during the winter of 1988-1989 to obtain baseline information on contaminant concentrations and determine if contaminant levels changed over winter. The sample was distributed approximately evenly between sexes, bays, and two collection periods (early and late winter). Redhead breast muscle was analyzed for organochlorines and livers were analyzed for trace elements. All organochlorines were below detection in breast muscle. Boron, copper, molybdenum and selenium accumulated in redheads utilizing Redfish Bay. Silver accumulated in redheads wintering at both bays. The concentrations of boron, molybdenum, and selenium were generally below levels considered harmful. The concentrations of copper and silver in some redheads were elevated when compared to other studies, however, the biological significance of these concentrations is presently unknown. Lead was found at concentrations known to be acutely toxic in two redheads collected from Redfish Bay and may be the result of ingested lead-shot.

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INTRODUCTION

Baffin and Redfish Bays are relatively shallow and extremely productive bays located on the South Texas coast (Figure 1). Baffin Bay is a secondary bay of the Laguna Madre, the largest hypersaline lagoon in the United States. Redfish Bay is a primary bay located northeast of Corpus Christi Bay. The shallow depths and relatively clear water of these bays provide optimal growing conditions for seagrasses. Both bays support abundant growths of shoalgrass (Halodule wriqhtii), a seagrass which is the single most important food item for wintering redhead ducks (Avthva americana) (McMahan 1970, Cornelius 1975).

Significant numbers of redheads utilize both bays during the winter. The Laguna Madre is the primary wintering area for the continental redhead population (Weller 1964, Bellrose 1976) and Redfish Bay is also an important wintering area (Weller 1964). Fish and Wildlife Service researchers counted approximately 20,000 redheads in Baffin Bay in November 1988. In an aerial census in January 1989, approximately 115,000 redheads were counted in Redfish Bay.

Baffin Bay has virtually no urban or industrial development on its shoreline. However, oil and gas production occurs in the bay, and several creeks flowing into it carry municipal, industrial, and agricultural discharges from inland areas. Redfish Bay, by contrast, has both urban and industrial development near its shoreline. The Gulf Intracoastal Waterway, a major shipping route for a variety of petroleum and chemical products, transects the bay. In addition, the Corpus Christi Ship Channel skirts the southern portion of the bay.

Because of the abundance of wintering redheads along the South Texas coast, and their position as a species of special interest under the North American Waterfowl Management Plan (USFWS 1986), the National Wetlands Research Center (Corpus Christi Field Research Station) has initiated research on the ecology of wintering redheads. One study investigated the body condition of redheads wintering in the Laguna Madre and Redfish Bay. As part of this study, redheads were collected and specific tissues and organs were measured to indicate body condition. This provided the opportunity to choose certain tissues for chemical analysis for selected contaminants. Because approximately equal numbers of redheads were collected during each winter month for the body condition study, it was possible to obtain early and late winter birds. The objectives of this study were to 1) obtain and compare baseline information on contaminant levels in redheads from two Texas bays, and 2) to determine if contaminant level changed over winter.

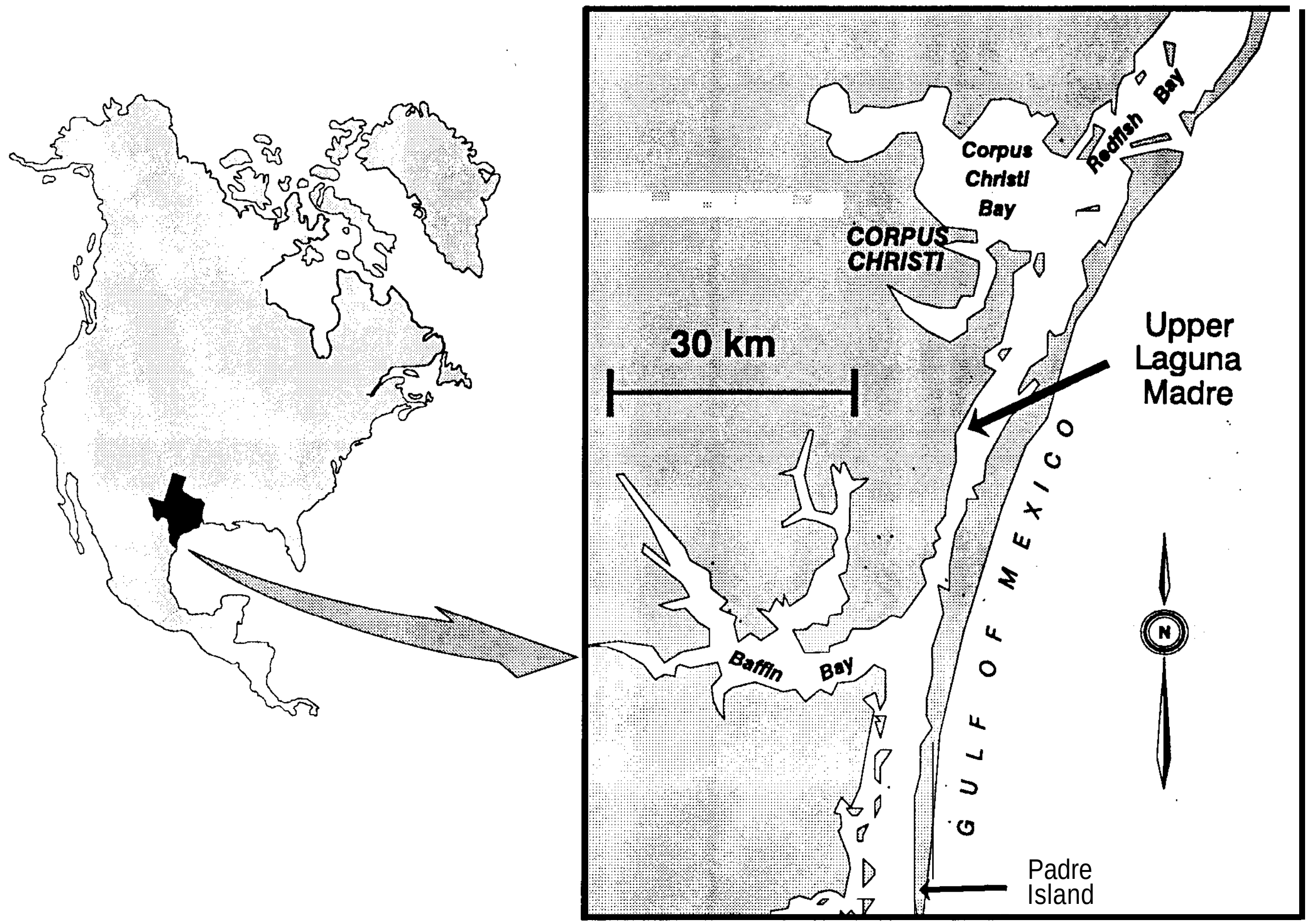

Figure 1. Redfish Bay and Baffin Bay study areas on the South Texas Coast.

METHODS AND MATERIALS

Redheads were collected monthly from November 1988 through March 1989 from Redfish and Baffin Bays for the condition indices study. The birds were collected by shooting using shot guns and steel shot. Immediately after collection, samples were placed on ice and then frozen upon return to the laboratory.

A sample of 39 redheads, approximately evenly distributed between sexes, bays, and two collection periods (early and late) (Table 1), was targeted for the contaminant study. Although adult birds were targeted, three immature birds and one unknown age bird were part of the sample. Birds collected in November 1988 were designated as the early collection. Late collection birds were selected from samples collected in February and March 1989.

Redhead carcasses were thawed in the laboratory just prior to conducting measurements for the condition indices. In addition to these measurements, the liver and one-half of the breast muscle were dissected from the birds selected for the contaminants study. These tissues were placed in acid cleaned glass jars and then frozen until preparation for chemical analysis.

Adipose tissues were originally targeted for analysis of organochlorine contaminants, however, many early winter birds lacked sufficient fat tissues for chemical analysis. Therefore, as an alternative tissue, breast muscle was analyzed for a variety of organochlorine contaminants (Table 2). Organic analysis of breast tissue was conducted at the Texas A & M Research Laboratory, College Station, Texas. Organics were determined by gas chromatography with mass spectrophotometry for confirmations. The detection limits for organic analyses were 0.1 ppm on a wet weight basis. Patuxent Analytical Control Facility assured the quality of the resulting analyses.

Liver samples were analyzed for 23 trace elements (Table 2) at Research Triangle Institute, Research Triangle Park, North Carolina. Inductively coupled plasma emission spectroscopy was used to determine all of the elements except arsenic, selenium, and mercury. Arsenic and selenium were determined by hydride generation with atomic absorption. Cold vapor reduction was used for mercury analysis. Blanks, duplicates, spiked samples, and standards were used for quality control and assurance and was monitored by the Service's Patuxent Analytical Control Facility (Patuxent). Trace element detection limits are presented in Table 3.

Data Analvsis

Descriptive statistics and further statistical comparisons were not conducted for organochlorine data, because all organochlorine analyses were below levels of detection. Median, minimum, and maximum values were determined for selected trace elements in early and late winter birds from both Baffin Bay and Redfish Bay. Because the data for trace elements were not normally distributed, the nonparametric Mann-Whitney test (Zar 1984) was used to determine if contaminant concentrations in males and females were significantly different. Unless noted

Table 1. Number of female and male redheads sampled from Redfish Bay and Baffin Bay, early and late winter, 1988-1989.

	Early Winter		Late Winter	
	Females	Males	Females	Males
Redfish Bay	5	5	5	4
	Sub Total= 10		Sub Total= 9	
	Early Winter		Late Winter	
	Females	Males	Females	Males
Baffin Bay	5	5	5	5
	Sub Total= 10		Sub Total= 10	

Table 2. Organochlorine and trace element analytes for redhead tissues collected from Redfish and Baffin Bays, Texas, 1988-1989.

ORGANOCHLORINES	TRACE ELEMENTS
Oxychlordane	Aluminum
c - Chlordane	Antimony
t - Chlordane	Arsenic
c - nonachlor	Barium
t - nonachlor	Beryllium
Heptachlor	Boron
Heptachlor Epoxide	Cadmium
Methoxychlor	Chromium
o,p' - DDE	Copper
o,p' - DDD	Iron
o,p' - DDT	Lead
p,p' - DDE	Magnesium
p,p' - DDD	Manganese
p,p' - DDT	Mercury
Endrin	Molybdenum
Dieldrin	Nickel
Aldrin	Selenium
alpha-BHC	Silver
beta-BHC	Strontium
gama-BHC	Thallium
delta-BHC	Tin
Hexachlorobenzene	Vanadium
Endosulfan I	Zinc
Endosulfan II	
Endosulfan Sulfate	
Mirex	
DCPA	
Dicofol	
Arochlor 1248	
Arochlor 1254	
Arochlor 1260	
Arochlor 1262	
Toxaphene	

Table 3. Detection limits of analytical methods used in the analysis of redhead tissues collected from Redfish and Baffin Bays, Texas, 1988-1989.

TRACE ELEMENTS	DETECTION LIMITS (ppm dry weight)
Aluminum	2.0
Antimony	5.0
Arsenic	0.3
Barium	0.2
Beryllium	0.05
Boron	0.5
Cadmium	0.1
Chromium	0.5
Copper	0.5
Iron	5.0
Lead	1.0
Magnesium	5.0
Manganese	0.3
Mercury	0.02
Molybdenum	0.8
Nickel	0.8
Selenium	0.3
Silver	2.0
Strontium	0.3
Tin	5.0
Vanadium	0.3
Zinc	1.0

otherwise, all statistical tests were conducted with p=.05.

Since no significant differences between sexes were found in concentrations of trace elements in livers, data from males and females were pooled to make the following comparisons between samples of redheads: 1) early Baffin Bay versus late Baffin Bay, 2) early Redfish Bay versus late Redfish Bay, 3) early Baffin Bay versus early Redfish Bay, and 4) late Baffin Bay versus late Redfish Bay. The first two comparisons were utilized to examine the potential for the accumulation of selected trace elements during the wintering period. The last two comparisons examine the differences between birds using the two bays. The nonparametric Mann-Whitney was used for these comparisons. For the determination of medians and for most statistical comparisons, a value one-half the detection limit was used when the analytical result was below-detection-limit. Statistical comparisons were not conducted when fewer than 50 percent of the temporal samples were below detection.

Comparisons are based on the assumption that redheads wintering in Redfish and Baffin Bays are distinct subpopulations which do not intermingle throughout the winter. This assumption is supported by Moore (1991), who examined site fidelity of wintering redheads by capturing and marking birds on freshwater ponds near the Upper Laguna Madre, Baffin Bay, and the Lower Laguna Madre. Typically, greater than 90 percent of resightings were within 25 km of the capture location, although some birds were sighted as far as 60 km from the capture site. Moore (1991) concluded that redheads exhibited site fidelity during the winter and from year to year.

RESULTS AND DISCUSSION

All organochlorines and PCBs were below detection limits in breast muscle tissues. Breast muscle, however, is not the best tissue for assessing levels of lipophilic contaminants such as organochlorine pesticides and PCBs. Fat tissue is preferable and was originally targeted, but was unavailable in most early redhead samples, therefore breast muscle was substituted. Although some lipid tissue was likely associated with the breast muscle samples, the percentage of lipid was not quantified. The fact that organochlorines and PCBs were below detection in all samples suggests that these contaminants are at low levels in these bays, although this is not conclusive.

Twenty-one of the 23 analyt trace elements were found above detection limits in redhead duck livers. Antimony and tin were below detection limits in all livers. The following results and discussion are presented for 9 trace elements selected for their significance as potential environmental contaminants and on the availability of comparative results from the literature. Median, minimum, and maximum values for these selected trace elements in redhead livers are presented in Table 4.

Significant differences ($p<.05$) for at least one trace element were found between early and late Redfish Bay samples, early and late Baffin Bay samples, early Baffin Bay and early Redfish Bay samples, and late Baffin Bay and late Redfish Bay samples. These differences support the assumption that redheads wintering in Redfish and Baffin Bays are distinct subpopulations.

Arsenic

Thirty-one percent ($n=12$) of all liver samples were below the detection limit for arsenic. All of these samples were from birds collected in Redfish Bay. All of the samples from birds collected from Baffin Bay were above detection limits. The range of the eight samples above detection from early and late Redfish Bay collections (Table 4) was very similar. The highest concentrations from the early and late Redfish Bay collection were 0.42 ppm and 0.68 ppm, respectively. The maximum values for early and late Baffin Bay collections (0.97 and 1.04 ppm, respectively) were nearly double those from Redfish Bay. There was no significant difference between the early and late Baffin Bay collections.

It is interesting to note the relative differences between the levels of arsenic in the livers of birds from Baffin versus Redfish Bay. Maher (1985) noted that marine biota can accumulate arsenic from seawater, resulting in higher arsenic concentrations than freshwater organisms. It is likely that the water and shoalgrass of Redfish Bay, which is influenced far more by freshwater inflows than the hypersaline Baffin Bay, have lower concentrations of arsenic.

Despite these apparent differences, the levels of arsenic do not appear to be biologically significant. White et al. (1980) determined that arsenic concentrations in the livers of several different species of shorebirds collected in the vicinity of Corpus Christi, Texas, ranged up to 5.4 ppm dry weight (converted from wet weight). They considered these levels to be low and not

-able 4. Median, minimum, and maximum values for selected trace elements in redhead duck livers collected early and late from Redfish and Baffin Bays, Texas (all values presented as ppm on a dry weight basis).

	Early Redfish	Late Redfish	Early Baffin	Late Baffin
As	---[1] 0.31-0.42[2] 3[3]	--- 0.34-0.68 4	0.75 0.56-0.97 10	0.78 0.47-1.04 10
B	4.84 1.30-12.80 10	7.25 4.12-11.00 9	5.78 4.24-8.36 10	4.62 1.59-7.45 10
Cd	1.56 0.33-3.47 10	1.96 1.01-3.28 9	1.92 0.95-4.32 10	1.52 1.21-3.84 10
cu	72 12-344 10	158 40-820 9	240 35-1120 10	366 136-1290 10
Pb	--- 1.08-2.16 3	--- 1.02-46.3 4	--- 2.01-5.37 2	--- 1.79-1.79 1
Hg	0.042 0.040-0.195 6	0.074 0.024-0.155 9	0.099 0.035-0.843 10	0.240 0.12-.439 10
Mo	1.59 1.03-2.81 10	4.25 2.38-6.49 9	1.92 1.22-2.91 10	2.55 1.10-3.71 10
Se	2.46 1.08-5.85 10	3.67 2.91-5.12 9	4.12 3.37-10.20 10	5.35 3.99-6.56 10
Ag	All Below Detection	4.5 2.6-19.1 8	3.1 2.0-11 .o 9	24.2 5.5-56.4 10

1 The median value (--- indicates that medians were not determined because 50 percent or more of the samples were below detection).

2 The minimum (above the detection limit) and maximum value.

3 The number of samples that exceeded the detection limit for each trace element.

likely to cause harm. Goede (1985) considered that levels exceeding 7 ppm dry weight (converted from fresh weight) in avian liver tissue were elevated.

Boron

Boron was found above detection in all liver samples. The median concentrations for early Redfish Bay, early Baffin Bay, and late Baffin Bay samples (4.84, 5.78, and 4.62 ppm, respectively) were similar. The median for late Redfish Bay samples was 7.25 ppm. The highest boron concentration was 12.80 ppm in an early Redfish Bay liver sample. This concentration was an outlier, being more than twice that of any of the other early samples from Redfish Bay. The next three highest concentrations (11.00, 10.90, and 8.41 ppm) were detected in late Redfish Bay samples.

No significant difference was found between the boron levels of early Redfish Bay and early Baffin Bay samples. However, late Redfish Bay samples were found to be significantly higher than late Baffin Bay samples. In conjunction with this result, boron would have been expected to have accumulated during the winter in redheads from Redfish Bay . While boron concentrations from early and late Redfish Bay samples did not differ at $p<.05$, there was a significant difference at $p<.10$. Although, not conclusive, the data does tend to indicate that after wintering for several months, only the birds at Redfish Bay accumulated boron.

Smith and Anders (1989) fed adult female mallard ducks diets containing 0, 30, 300, and 1000 ppm boron (on a fresh weight basis). None of the doses affected adult survival or egg fertility. The geometric mean concentration of boron in livers for the 300 ppm and 1000 ppm groups were 15 ppm and 33 ppm (on a dry weight basis), respectively. Boron concentrations ranged from 7 to 24 ppm boron for the 300 ppm group and 6 to 74 ppm boron for the 1000 ppm group. The hatching success of fertile eggs laid by the adults fed 1000 ppm boron was significantly reduced. In addition, the hatchlings from the 1000 ppm and 300 ppm diet groups had significantly lower body weights compared with controls. The mean boron concentrations in duckling livers from the 1000 ppm and 300 ppm diet group were 17 ppm and 51 ppm, respectively.

The highest boron concentrations in redhead livers are in the range of the lowest concentrations found in adult female mallards that hatched low body weight ducklings (Smith and Anders 1989). Median levels in redheads, however, were generally below the levels in female mallards that were found to have affects on their hatchlings. Therefore, although the data indicate that boron may be accumulating in redheads wintering in Redfish Bay, the concentrations are not likely to harm adults and are typically below levels associated with impacts on embryos and hatchlings.

Cadmium

Cadmium was found above the detection limit in all samples. The highest median (1.96 ppm) was from the late Redfish Bay collection. The highest individual sample concentration was 4.32 ppm cadmium in a sample from the early Baffin Bay collection. In general, the median, minimum, and maximum values were similar for all temporal and bay collections. No significant differences were found in the comparisons.

Cadmium is generally considered a nonessential trace element (Eisler 1985). It is potentially toxic to most fish and wildlife at sufficient concentrations. Di Giulio and Scanlon (1984) measured cadmium concentrations in the livers of 15 species of waterfowl wintering in the Chesapeake Bay region. Median cadmium concentrations ranged from 0.39 ppm (dry weight) for wood ducks (Aix sponsa) to 5.14 ppm for oldsquaws (Clanqula hvemalis). They found that seaducks, such as the oldsquaw, had the highest levels of cadmium, followed by brackish-water omnivores, then freshwater herbivores. The highest concentration of cadmium they found was in the liver of a canvasback (Avthva valisineria) (23.51 ppm). This concentration was several times higher than the highest concentration from this study. Di Giulio and Scanlon (1984) considered liver concentrations exceeding 7 ppm in waterfowl as potentially harmful. All cadmium concentrations in redhead livers from the present study were below this level.

Copper

Copper concentrations exceeded the detection limit in all redhead livers. The median copper concentrations for early and late Baffin Bay (240 and 366 ppm, respectively) were higher than the median levels for early and late Redfish Bay (72 and 158 ppm, respectively). The highest copper concentration detected was 1290 ppm from a redhead duck collected in Baffin Bay. Eight of the 10 highest concentrations detected were from samples collected in Baffin Bay.

Copper concentrations appear to be higher in Baffin Bay samples than Redfish Bay samples for both the early and late collections. Copper concentrations in early Baffin Bay and early Redfish Bay samples were not significantly different at $p<.05$, however, the two collections were significantly different at $p<.10$. The comparison of late collection samples from the two bays indicated that late Baffin Bay samples were significantly greater than late Redfish Bay samples ($p<.05$). The comparisons of early and late samples within each bay revealed a significant difference only from Redfish Bay, where late sample concentrations were greater than those of early samples.

These comparisons suggest that redheads at Baffin Bay had higher copper concentrations upon arrival and maintained these higher concentrations through the wintering period. This occurred despite the apparent accumulation of copper in birds wintering at Redfish Bay.

A number of studies have examined copper levels in bird livers, however, few studies have documented effects associated with these copper levels. Ohlendorf and Fleming (1988) examined trace element concentrations, including copper, in tissues of greater scaup (Avthva marila) and surf scoters (Melannitta perspicillata) from San Francisco Bay. The mean copper concentrations for greater scaup and surf scoters were 96.8 and 49.8 ppm (dry weight), respectively. Ohlendorf and Fleming (1988) indicated that the significance of these levels was unknown. Di Giulio and Scanlon (1984) reported copper levels in the livers of 15 species of waterfowl. They found that the median levels ranged from 15.3 ppm (dry weight) in wood ducks (Aix sponsa) to 182.1 ppm in ring-necked ducks (Aythva collaris). The highest concentration (990.9 ppm) detected in their study was also found in ring-necked ducks. Only the concentrations found in ring-necked ducks reported by Di Giulio and Scanlon (1984) are on the same order of magnitude as the highest levels found in redheads. Di Giulio and Scanlon (1984) were unable to determine the significance of the copper levels they found.

Adverse effects have been attributed to copper in controlled dietary studies with chickens and turkeys (NAS 1980). Reduction of growth is a common sublethal effect seen in both chickens and turkeys. The recommended maximum dietary concentration for these two species is 300 ppm (NAS 1980). Previous work by the senior author indicates that copper levels in shoalgrass from Redfish and Baffin Bays (ranging from 1.2 to 14.7 ppm dry weight) are much lower than this recommended dietary concentration (USFWS, unpublished data). Based solely on copper concentration in shoalgrass, redheads do not appear to be at risk from their dietary intake.

Although copper concentrations appear to be elevated in some redheads collected from both bays, the biological significance of these concentrations is unknown. The source of the copper to these redheads is also unknown. Further basic research is needed to determine the significance of these copper concentrations to redhead ducks and to determine the source and cause of these elevated copper levels.

Lead

Lead was found above the detection limit in only 10 samples (26 percent of samples). For all but two of these samples, lead was detected at relatively low levels. The two birds with the highest concentrations were from the late Redfish Bay collection. The concentration of lead in these two samples was 46.30 and 39.80 ppm. The remaining samples ranged from 1.02 to 5.37 ppm.

Lead is considered both a nonessential and nonbeneficial element. Lead is toxic in most of its chemical forms and can bioaccumulate, causing sublethal effects to hematopoietic, vascular, nervous, renal, and reproductive systems (Eisler 1988). Scheuhammer (1987) concluded in his review of chronic toxicity of lead in birds that concentrations ranging from 0.5 to 5.0 ppm (dry weight) were "normal background levels". Levels greater than 35.7 ppm (dry weight basis, converted from weight wet) in bald eagle liver tissue were considered indicative of acute exposure (Pattee et al. 1981). Friend (1987) indicated that liver lead concentrations of 20 to 30 ppm (dry weight basis) were suggestive of lead poisoning.

The lead concentrations from the two highest samples indicate that these two redhead ducks had been exposed to toxic levels of lead. The most common cause of lead poisoning in waterfowl is the ingestion of spent lead shot while feeding (Friend 1987). The lead shot is ground down in the gizzard and then absorbed by the gut (White and Stendel 1977). Wintering redhead ducks feed predominantly on shoalgrass in shallow bays by pulling the grass rhizomes from the sediment (McMahan 1970). This feeding mode puts the redhead duck at risk for picking up lead shot or lead fishing weights that may be in shallow sediments. Because the two birds were part of the late collection and the time between exposure and death is between 2 and 3 weeks (Friend 1987), it is assumed that the lead exposure occurred in Redfish Bay.

The gizzard contents of 95 redheads collected during the winters of 1987-1988 and 1988-1989 from three Texas bays (Redfish Bay, Laguna Madre/Baffin Bay, and Espirito Santo Bay) were examined for lead shot by Texas Parks and Wildlife Department personnel (David Lobpries, pers. comm.). Thirteen birds (13.7 percent) contained lead shot in their gizzards. Of the 95 gizzard contents examined, 30 were from birds collected from Redfish Bay and 10 of these contained lead shot. Therefore, most birds that had lead shot in their gizzards were collected from Redfish Bay, and 33 percent of the redheads examined from Redfish Bay had lead shot in their gizzards.

The results of the present study, in addition to the findings of the Texas Parks and Wildlife Department, indicate that redheads have a greater chance of exposure to lead shot in Redfish Bay than in the Laguna Madre (including Baffin Bay). The results also suggest that a substantial proportion of redheads using Redfish Bay may ingest lead shot. This is likely due to the greater waterfowl hunting pressure at Redfish Bay.

The extent to which this remains a problem is unknown. A complete ban on the use of lead shot by waterfowl hunters for the two counties that encompass Redfish Bay went into affect during the winter of 1991-1992 (USFWS 1986), two years after the samples for this study were collected. Further study would be needed to determine if this ban has reduced the exposure of redheads to lead shot in Redfish Bay.

Mercury

Mercury was found above the detection limit in all but four samples. The median concentrations for early and late Redfish Bay were 0.042 and 0.074 ppm, respectively. The medians for early and late Baffin Bay were higher at 0.099 and 0.240 ppm, respectively. The sample with the highest mercury concentration (0.843 ppm) was part of the early collection from Baffin Bay. Mercury concentrations in samples from early Baffin Bay were significantly greater than those from early Redfish Bay samples, and late samples from Baffin Bay were also significantly higher late Redfish Bay samples. No significant differences were found for early versus late samples from either bay, indicating that redhead ducks were not accumulating mercury during the winter at these two bays. Sublethal effects have been observed for birds with liver concentrations as low as 1.7 to 5.0 ppm (dry weight) (Fimreite 1971) and liver levels of approximately 66 ppm (dry weight) have been associated with acute mercury toxicosis (Fimreite and Karstad 1971). All samples from the present study were below these effect levels.

Molybdenum

Molybdenum was found above the detection limits in all samples. The median concentrations for early Redfish, late Redfish, early Baffin, and late Baffin bays were 1.59, 4.25, 1.92, and 2.55 ppm, respectively. Molybdenum levels in all samples ranged from 1.03 to 6.49 ppm. The five highest molybdenum concentrations were detected in samples from the late Redfish Bay collection. There was no significant difference between early Redfish Bay and early Baffin Bay samples. However, concentrations of molybdenum in late Redfish Bay samples were significantly greater than early Redfish Bay and late Baffin Bay samples. These results indicate that molybdenum concentrations remained relatively constant in birds wintering in Baffin Bay but accumulated in birds wintering in Redfish Bay.

Molybdenum is an essential trace nutrient for most plant and animals. Information on the significance of molybdenum levels in avian wildlife tissues is lacking. Studies on domestic poultry indicate that diets containing 1.0 ppm molybdenum are required for normal growth. Adverse effects may be seen when diets contain 200 to 300 ppm molybdenum (Eisler 1989). The levels of molybdenum detected in shoalgrass ranged from 0.76 to 3.25 ppm in samples from Baffin and Redfish Bay (USFWS, unpublished data). Based on these levels in the redheads primary food it is assumed that liver concentrations are indicative of background levels of molybdenum.

Selenium

All liver samples contained detectable levels of selenium. Median levels in early and late Redfish Bay samples (2.46 and 3.67 ppm) were generally lower than the median levels for early and late Baffin Bay (4.12 and 5.35 ppm). The highest concentration (10.20 ppm) was detected in an early Baffin Bay sample. The next five highest concentrations were detected in late Baffin Bay samples. Selenium concentrations in livers of redheads from early Baffin Bay were significantly higher than in those from early Redfish Bay. Likewise, late Baffin Bay samples were significantly higher than in those from late Redfish Bay. The selenium concentrations in samples from early Redfish Bay were significantly less than those from late Redfish Bay, but early Baffin Bay selenium concentrations were not significantly different than those from late Baffin Bay.

The data indicate that when redhead ducks arrived on the Texas Coast, the birds utilizing Baffin Bay had significantly higher selenium levels than the birds utilizing Redfish Bay. This difference continued through the winter, with the Baffin Bay birds maintaining higher selenium levels, despite the indication that some selenium accumulation was occuring in redheads wintering in Redfish Bay. Although the selenium levels of the late Baffin Bay collection were slightly higher than the early Baffin Bay collection, the difference was not significant, indicating that selenium was not bioaccumulating in birds that wintered in the Baffin Bay area.

Ohlendorf et al. (1986) examined selenium levels in birds nesting at Kesterson National Wildlife Refuge, California, a site contaminated with selenium, and compared it to Volta Wildlife Area, California, an uncontaminated site. The selenium concentration in the livers of American coots and mallards from Volta ranged from 3.9 to 5.6 ppm (dry weight), while selenium in the livers of these two species collected at Kesterson ranged from 19 to 63 ppm. In general, birds from uncontaminated areas have liver selenium levels below 12 to 16 ppm (dry weight) (Ohlendorf et al. 1986). Based on these findings, the selenium levels found in redheads are below levels of concern. In addition, the levels of selenium found in shoalgrass from Baffin and Redfish Bays (all samples were below the detection limit of 0.6 ppm dry weight) (USFWS, unpublished data) are well below levels found to cause adverse effects in dietary studies (10 to 25 ppm) (Heinz et al. 1987, Hoffman and Heinz 1988).

Silver

Silver was detected in only 27 samples (67 percent). None of the early Redfish Bay samples contained silver concentrations above the detection limit, while only one of nine samples from the late Redfish Bay collection were below the detection limit. Silver was below the detection limit in only one sample collected from Baffin Bay (from the early collection). The median levels for silver for early and late Baffin Bay were 3.1 and 24.2 ppm, respectively. The highest concentration of silver was 56.4 ppm in a late Baffin Bay sample. The next seven highest concentrations were also in samples from the late Baffin Bay collection. Silver concentrations were significantly higher in late Baffin Bay samples compared to early Baffin Bay. Also, late Baffin Bay samples were significantly higher than late Redfish Bay samples. These results indicate that silver accumulated in redhead ducks wintering in both Redfish and Baffin bays. Accumulation of silver was greatest for birds wintering in Baffin Bay.

Ohlendorf and Fleming (1988) found silver concentrations of 1.05 and 0.90 ppm (dry weight) in the livers of greater scaup and surf scoters from San Francisco Bay. Although this comparison indicates that the concentrations found in this study are elevated, there is a paucity of information on the significance of silver concentrations in tissues of avian wildlife. The maximum dietary tolerance level for poultry is 100 ppm (NAS 1980). The concentration of silver in shoalgrass from Baffin and Redfish Bays was found to be below a detection limit of 3.0 ppm (USFWS, unpublished data). Further study is required to shed light on the significance of these silver concentrations in redheads.

SUMMARY AND RECOMMENDATIONS

All organochlorines and PCBs were below detection limits in breast muscle. Although breast muscle is not the best tissue for detecting lipophilic contaminants, the fact that all samples were below detection limits indicates that these contaminants were at low levels.

Five trace elements accumulated in redheads wintering either at Redfish or Baffin Bays. Boron, copper, molybdenum, and selenium accumulated in redheads utilizing Redfish Bay. Silver accumulated in redheads wintering at both bays. It is presently unknown whether these trace elements were accumulating as a result of naturally elevated concentrations in bay waters, sediment, and diet, or whether anthropogenic sources played a role. Despite the fact that copper and selenium accumulated in redheads wintering at Redfish Bay, concentrations of these two trace elements were significantly higher in redheads wintering at Baffin Bay. Baffin Bay redheads arrived with higher levels of copper and selenium and maintained these higher levels through the winter. The concentrations of boron, molybdenum, and selenium were generally below levels considered harmful.

The concentrations of copper and silver in some redhead samples appears to be elevated when compared to other studies. The highest copper concentrations in redheads from this study exceeded all the copper concentrations reported for 15 different species collected from Chesapeake Bay (Di Giulio and Scanlon 1984). The median silver concentrations for the late collections from both bays was several times higher than the average concentration reported for two species of diving ducks collected in San Francisco Bay (Ohelendorf and Flemming 1988). There is a paucity of information, however, on the biological effects of these two trace metals relative to concentrations in the liver. Therefore, although apparently elevated, the biological significance of these levels of copper and silver is unknown.

Of the contaminants examined in this study, only lead was found at concentrations known to be acutely toxic. Lead was detected at elevated concentrations in two redheads. The concentrations detected in these two birds is indicative of exposure via ingestion of spent lead shot or lead fishing weights. Because both birds were from the late Redfish Bay collection, it is assumed that the exposure occurred in Redfish Bay. Data collected by Texas Parks and Wildlife personnel (David Lobpries, pers. comm.) also suggest that lead shot may be a problem for redheads wintering in Redfish Bay. They examined the gizzard contents of 30 redheads collected from Redfish Bay during the winters of 1987-1988 and 1988-1989, and found that 33 percent of the gizzards contained lead shot. The use of lead shot for waterfowl hunting in Redfish Bay was recently banned and should result in a lower rate of lead shot ingestion by redheads. Further investigation to verify that the ban has resulted in lower rates of lead shot ingestion is recommended.

Basic dose-response research with waterfowl for both copper and silver is recommended. Without such research it will not be possible to determine the significance of these trace metals. Additionally, trace element data (in sediment, fish, and crabs) for samples collected by the Corpus Christi Ecological Services Field Office from Corpus Christi Bay, Redfish Bay, the Upper Laguna

Madre, and Baffin Bay should be examined for differences between the bays for copper and silver.

Finally, future monitoring of trace elements, especially lead, copper, and silver, in redheads and their food items should be considered. The redhead should be considered as one of the Service trust species to be monitored by the Biomonitoring of Environmental Status and Trends (BEST) Program.

LITERATURE CITED

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books. Harrisburg, PA. 543 pp.

Cornelius, S.E. 1975. Food choice of wintering redhead ducks (Avthva americana) in Lower Laguna Madre, Texas. M.S. Thesis. Texas A&M Univ. College Station, TX. 121 pp.

Di Giulio, R.T. and P.F. Scanlon. 1984. Heavy metals in tissues of waterfowl from the Chesapeake Bay, USA. Environ. Pollut. 35: 29-48.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85 (1.5). 46 pp.

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85 (1.14). 133 pp.

Eisler, R. 1989. Molybdenum hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85 (1.19). 61 pp.

Fimreite, N. 1971. Effects of dietary methylmercury on ring-necked pheasants. Can. Wildl. Serv. Occ. Pap. No 9. 39 pp.

Fimreite, N. and L. Karstad. 1971. Effects of dietary methyl mercury on red-tailed hawks. J.Wildl. Manage. 35: 293-300.

Friend, M. 1987. Lead poisoning pages 175-189 In Field guide to wildlife diseases. Milton Friend (ed.). U.S. Fish Wildl. Serv. Res. Pub. 167. 225 pp.

Goede, A.A. 1985. Mercury, selenium, arsenic, and zinc in waders from the Dutch Wadden Sea. Environ. Pollut. 37A: 287-309.

Heinz, G.H., D.J. Hoffman, A.J. Krynitsky, and D.M.G. Weller. 1987. Reproduction in mallards fed selenium. Environ. Tox. Chem. 6: 423-433.

Hoffman, D.J. and Heinz, G.H. 1988. Embryotoxic and teratogenic effects of selenium in the diet of mallards. J.Tox. Environ. Health. 24: 477-490.

Maher, W.A. 1985. The presence of arsenobetaine in marine animals. Comp. Biochem. Physiol. 80C: 199-201.

McMahan, C.A. 1970. Food habits of ducks wintering on Laguna Madre, Texas. J.Wildl. Manage. 34: 946-949.

Moore, J.L. 1991. Habitat related activities and body mass of wintering redhead ducks on coastal ponds in South Texas. Masters Thesis. Texas A & M University. 97 pp.

National Academy of Science. 1980. Mineral tolerance of domestic animals. National Academy Press. Washington, D.C. 577 pp.

Ohlendorf, H.M. and W.J. Fleming. 1988. Birds and environmental contaminants in San Francisco and Chesapeake bays. Marine Pollut. Bull. 19: 487-495.

Ohlendorf, H.M., D.J. Hoffman, M.K. Saiki, and T.W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. Sci. Total Environ. 52: 49-63.

Pattee, O.H., S.N. Wiemeyer, and B. Mulhern. 1981. Experimental lead-shot poisoning in bald eagles. J.Wildl. Manage. 45: 806-810.

Scheuhammer, A.M. 1987. The chronic toxicity of aluminum, cadmium, mercury, and lead in birds: review. Environ. Pollut. 46: 263-295.

Smith, G.J. and V.P. Anders. 1989. Toxic effects of boron on mallard reproduction. Environ. Toxicol. Chem. 8: 943-950.

U.S. Fish and Wildlife Service. 1986. North American Waterfowl Management Plan. Prepared in Cooperation with the Canadian Wildlife Service. 31 pp.

U.S. Fish and Wildlife Service. 1986. Final supplement environmental impact statement on the use of lead shot for hunting migratory birds. Office of Migratory Bird Management. Washington, D.C.

Weller, M.W. 1964. Distribution and migration of the redhead. J.Wildl. Manage. 28: 64-103.

White, D.H., K.A. King, and R.M. Prouty. 1980. Significance of organochlorine and heavy metal residues in wintering shorebirds at Corpus Christi, Texas, 1976-77. Pestic. Monitor. J. 14: 58-63.

White, D.H. and R.C. Stendell. 1977. Waterfowl exposure to lead and steel shot on selected hunting areas. J.Wildl. Manage. 41: 469-475.

Zar, J.H. 1984. Biostatistical analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 718 pp.