Korean J. Ecol., 25(6):389~393, 2002

Comparison of Heavy Metal Concentration and Reproduction of Feral Pigeons (*Columba livia*) between Urban and Industrial Complex Areas from Korea

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ABSTRACT: Pb and Cd concentrations and reproductive progress of feral pigeons were investigated in urban (Seoul) and industrial complex (Ansan) areas from November 2000 to May 2001. Results of the Pb analysis for the feral pigeons from the Ansan industrial complex (egg contents: 1.13 μg/ wet g, bones of adult: 10.5 μg/ wet g) and Seoul (1.64 μg/ wet g, 29.5 μg/ wet g, respectively) indicated that the Pb level of eggs and bones of adults were significantly different between the two colonies ($p<0.05$). Cd concentrations in liver and kidney of adult pigeons were also significantly different between the Ansan (liver: 0.14 μg/ wet g, kidney: 0.43 μg/ wet g) and Seoul (liver: 0.24 μg/ wet g, kidney: 1.05 μg/ wet g) colonies. ($p<0.05$). However, egg size and thickness, incubation period and nestling growth rates did not differ between the study areas. Also, clutch size, number of young hatched per nest and number of young fledglings per nest did not significantly different in the noted areas. Considering the lead and cadmium concentrations of pigeons, these were not as high as those considered as results in toxic effects in other species, and the biological significance from these level differences is uncertain.

Key words: Cd, Feral pigeons, Pb, Toxic effects

INTRODUCTION

Growing concern over the health of the local environment, there has been considerable attention about the biological effects of heavy metal exposure to wildlife and especially to human health (Antonio *et al.* 1988). Concern about the toxicological effects of metals such as Pb and Cd has increased and biological monitoring is thought to be a persuasive way to quantify heavy metal exposures in local environment (Lee 1989, Yasunaga *et al.* 2000, Dip *et al.* 2001).

Birds can be used as a "surrogate" that possibly might indicate potential human hazards or deleterious effects. Because they feed at the upper tropic levels of ecosystems and can provide information on the extent of contamination in the whole food chain (Furness and Greenwood 1993). This concern has made note of the evidence that chronic metal exposure of organisms to potential toxicants for the exposed organisms result in mortality, reproductive failures, behavior, and growth (Scheuhammer 1987), although several studies did not find any clues about that (Grue *et al.* 1986, Custer *et al.* 1986). In an effort to investigate the reproductive effects of heavy metal on breeding birds, several researchers studied the relationships between heavy metal contamination and egg production, hatchability and reproductive success (Grue *et al.* 1986, Custer *et al.* 1986, Elliott *et al.* 1989, Gochfeld and Burger 1988).

Feral pigeons are potentially vulnerable to pollutants because they are sedentary in many populations and forage in limited mobility (Antonio *et al.* 1988). Moreover, the biological and ecological properties of pigeons as bioindicators are quite well known and easily monitored in almost any area, including urban and industrial environment (Kim *et al.* 2001). Thus, feral pigeons could be used as early warning signs of toxicological effects, which could affect the health of humans.

The objective of this study is to compare the heavy metal concentrations and breeding ecology of feral pigeons between urban and industrial colonies, and to determine whether heavy metal accumulation differences in the two colonies affect their reproductive progress.

MATERIALS AND METHODS

Study sites

The urban area is located in Seoul and is surrounded by high

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buildings with a heavy traffic density, more than 100,000 vehicles per day in 2000. The industrial complex area (Ansan) is surrounded by various plants such as base metalworking, assembly plants, electrical machinery, and so on (below 35,000 vehicles/day in 2000).

Feral pigeons were nesting in the artificial nest boxes on the rooftop of City Hall in Seoul, and were nesting at the beam and loft of grain stores in the Ansan industrial areas. In Seoul, they were mainly provided with grains such as maize, wheat, bean and millet by the authorities. Moreover, many individuals in Seoul tend to feed some supplementary foodstuffs in the streets with heavy traffic density. Adult pigeons in the Ansan mainly forage at the gran elevators and silos (grain stores).

Breeding ecology

Eggs and chicks were marked during egg - laying and incubation periods, nestling periods, and monitored every 2 - 3 days from 4 March to 30 May 2001 at the Ansan Industrial Complex (14 nests) and Seoul City (24 nests), simultaneously. Nests containing eggs were considered active. The chicks were banded when first hatched and weighed during every visit to the colony.

The data for egg size and thickness were collected in the study areas. Each egg was measured with a "Mitutuyo" digital caliper (accuracy 0.01mm). Clutch size and hatching success were determined for each nest. The incubation period is defined as the day the first egg was laid until the day it hatched. The growth rates were based on body weight, primary wing length, and tarsus length data of nestlings, which survived at the peak weight at 20-24 days old because a decrease in body weight occurs before fledging. For reproductive success, we measured number of young hatched per nest, and number of fledglings per nest during the incubation and nestling periods.

Analysis of samples

Eggs (within 3 days after hatching), chicks (22-24 days), and adults were collected to examine heavy metal levels during November 2000 through May 2001 in Seoul City Hall and in the Ansan industrial complex (under license). Table 1 shows the biological details for each sample. Crop contents were collected at the colonies (20.1-40.4 g/individual). Crop contents taken from chicks and adults were identified and weighted, then the percentages of prey items in crops determined (Table 2). Gizzard contents were also obtained from gizzards at each colony (3.0 - 4.4 g/individual). Quartz is a common form of grit in the gizzard contents (70-95% weight) in this study.

All samples were stored in metal-free polyethylene bags and frozen at -20°C *after collection.* Pigeons were dissected and tissues such as liver, kidney, lung and bone were rapidly excised. Homogenized tissues, crop and gizzard contents were digested

Table 2. Percentages of crop contents of feral pigeons between the Ansan Industrial Complex and Seoul City

Identification	Ansan		Seoul	
	Chick (8)	Adult (10)	Chick (8)	Adult (12)
Maize	95.4	91.7	56.8	57.3
Wheat	0.4	-	24.2	27.9
Bean	2.4	5.9	2.7	7.5
Millet		0.7	-	0.2
Rice			6.4	4.9
Small stone	0.9	0.6	2.1	1.0
Other components	0.9	1.0	6.6	1.3

Values in parenthesis indicate the number of samples. A "-" indicates presence of seeds in small quantities. Other components are composed of domestic scraps, cements, hair, Styrofoam, *etc.*

Table 1. Biological details of feral pigeons collected from the Ansan industrial complex and Seoul

	N		Ansan	Seoul	Sampling date
Egg	28/46[b]	Length (mm)	39.5±2.17	38.8±1.31	March 2001
		Breath (mm)	29.1±0.92	28.4±0.82	
		Thickness (mm)	0.30±0.03	0.30±0.03	
Chick	8/8	Weight (g)[a]	291±19.7	286±21.1	May 2001
		Wing (mm)	159±22.6	160±22.9	
		Tarsus (mm)	30.3±0.90	30.4±1.38	
Adult	10/12	Weight (g)[a*]	300±28.1	345±22.8	November 2000
		Wing (mm)	229±8.01	230±8.01	
		Tarsus (mm)	32.4±1.47	31.6±1.07	
		Liver (g) *	7.73±1.60	9.12±1.22	
		Kidney (g) *	2.12±0.27	1.82±0.23	
		Lung (g)	3.38±0.43	3.12±0.45	
		Testis (mm) *	9.98±2.18[c]	19.5±4.45[d]	

Values indicate mean±SD. [a] Weight removing crop contents. [b] Sample numbers of the Ansan industrial complex and Seoul, respectively. [c] number of samples: 6. [d] number of samples: 7. * Significantly different between the Ansan industrial complex and Seoul at $p<0.05$ using t-tests.

in the presence of a mixture of concentrated nitric, sulfuric and perchloric acid. All samples were diluted by adding deionized water up to 100ml. For the lead and cadmium measurements for the samples, extraction with 4-methyl-2-pentanone was performed after sodium diethyldi-thiocarbamate chelation. These metal concentrations were analyzed in the samples by atomic absorption spectrophoto-meter (Shimadzu AA-6400). Detection limits were 0.5 μg/ml for lead and 0.05 μg/ml for cadmium. Accuracy of elements was measured in batches with reference materials (striped dolphin) (Lee 1989). The accepted recoveries for samples ranged from 85% to 115% and the standard error in triplicate analysis was < 5% for elements. All results are given in μg/g on a wet weight basis.

Statistical analysis

The data are presented as mean ± standard deviation and significant difference between the groups was tested by T-tests. The significant difference was set at $\alpha = 0.05$.

RESULTS

Pb concentration

Mean concentrations of lead in eggshell and egg-contents from Seoul (3.19, 1.64 μg/wet g, respectively) were significantly greater than those from the Ansan industrial complex area (1.41, 1.13 μg/wet g, respectively). The lead values in tissues of nestlings and adult pigeons from Seoul were similar to the Ansan industrial colony, except that bones and kidneys of adult pigeons contained significantly high lead (29.5, 4.13 μg/wet g, respectively) (Table 3).

The proportion of crop contents between chicks and adults in each colony is very similar (Table 2), but relatively high proportions of rice and other components (domestic scraps, cements, hair, Styrofoam, etc.) in Seoul were found in chicks. The lead concentrations of others (small stones and other components) from crop contents in chicks also are significantly higher than adult pigeons in Seoul (Table 3). However, there are no significant differences of other food items between the noted areas, and between lead concentrations of others of crop contents for adults. Concentrations of lead in gizzard contents in Seoul were two or three times the amount of those of lead concentrations in the Ansan industrial complex.

Cd concentration

Mean concentrations of cadmium in eggshell and egg contents were not significantly different between the two colonies (Table 4). The amount of cadmium in bones of nestlings (0.09 μg /wet g), and kidneys and livers of adult pigeons (1.05, 0.24 μg /wet g) were significantly greater than those in the same tissues of pigeons from the Ansan industrial complex.

The concentrations of cadmium in all food items and gizzard contents of pigeons from Seoul were similar to the Ansan industrial complex.

Reproductive progress

Egg size and thickness, incubation period, and mean nestling growth rates did not differ between the study areas (Table 5). Clutch size, number of young hatched per nest, and number of young fledglings per nest, did not significantly different between the study areas (Table 6).

Clutch size in Seoul was similar between the two colonies, 1.9 ± 0.3 in Seoul and 2.0 ± 0.0 in Ansan. The length, breath, and thickness of eggs were not significantly different between the two

Table 3. Comparison of Lead Concentrations (mean±SD, μg/ wet g) in eggs and various tissues of feral pigeons between the Ansan industrial complex and Seoul City

		Ansan			Seoul		
		Egg (n=9)	Chick (n=8)	Adult (n=10)	Egg (n=9)	Chick (n=8)	Adult (n=12)
Egg	shell	1.41±0.40			3.19±0.68*		
	contents	1.13±0.14			1.64±0.18*		
Tissues	Bone		4.09±1.34	10.5±4.69		4.80±2.48	29.5±21.1*
	Kidney		3.15±0.79	2.98±1.38		3.22±1.29	4.13±1.31
	Liver		0.88±0.46	1.80±0.46		0.87±0.09	2.33±0.78
	Lung		1.31±0.44	1.58±0.37		1.29±0.42	1.72±0.66
Crop	Maize		0.45±0.14(3)	0.41±0.19(8)		0.61±0.22(3)	0.56±0.25(12)
	Wheat		0.66±0.17(3)	0.68(1)		0.47±0.18(3)	0.54±0.21(3)
	Bean		0.48±0.12(3)	0.41±0.10(3)		0.61±0.19(3)	0.50±0.13(3)
	Rice					1.31±0.32(2)	0.99±0.19(2)
	Others[a]		1.60±0.83(8)	0.61±0.22(4)		5.19±2.14(8)*	0.88±0.29(4)
Gizzard	Contents		1.62±0.55	1.64±0.24		4.73±1.01*	3.34±0.93*

* Significantly different between the Ansan industrial complex and Seoul at p<0.05 using t-tests. Numbers(n) in parentheses. [a]Others are composed of small stones and other components.

Table 4. Comparison of cadmium (Cd) concentrations (mean±SD, μg/wet g) in eggs and various tissues of feral pigeons between the Ansan industrial complex and Seoul city

		Ansan			Seoul		
		Egg (n=9)	Chick (n=8)	Adult (n=10)	Egg (n=9)	Chick (n=8)	Adult (n=12)
Egg	shell	0.03±0.01			0.04±0.01		
contents		0.03±0.02			0.03±0.02		
Tissues	Bone		0.02±0.02	0.27±0.08		0.09±0.06*	0.23±0.07
	Kidney		0.05±0.02	0.43±0.28		0.06±0.02	1.05±0.62*
	Liver		0.02±0.01	0.14±0.06		0.03±0.01	0.24±0.08*
	Lung		0.10±0.05	0.21±0.13		0.10±0.03	0.22±0.04
Crop	Maize		0.26±0.09(3)	0.27±0.07(8)		0.22±0.07(3)	0.20±0.04(12)
	Wheat		0.29±0.03(3)	0.33(1)		0.24±0.07(3)	0.25±0.02(3)
	Bean		0.31±0.07(3)	0.30±0.05(3)		0.29±0.05(3)	0.23±0.07(3)
	Rice					0.31±0.02(2)	0.23±0.08(2)
	Others		0.23±0.01(8)	0.29±0.09(4)		0.20±0.01(8)	0.23±0.04(4)
Gizzard	Contents		0.04±0.01	0.05±0.01		0.06±0.02	0.06±0.01

*Significantly different between the Ansan industrial complex and Seoul at p<0.05 using t-tests. Numbers(n) in parentheses.

Table 5. Egg size and thickness, incubation and growth rates in each colony for feral pigeons

Study	Eggs†			Incubation period†	Growth rates†		
area	Length(mm)	Breadth(mm)	Thickness(mm)	(days)	Weight(g/day)	Tarsus(mm/day)	Wing(mm/day)
Ansan	40.5±2.22	29.1±0.90	0.30±0.03	17.4±2.11	16.3±1.25	1.31±0.33	6.94±0.56
Seoul	38.8±1.34	28.4±0.85	0.30±0.03	17.8±1.58	16.2±0.95	1.32±0.26	6.99±0.79

Values indicate mean±SD. Number of nests: 14(Ansan), 24(Seoul), respectively. †Differences between means not statistically significant, P>0.05, t-tests.

Table 6. Reproductive data for feral pigeons nesting in the Ansan industrial complex and Seoul city

Study area	Number	Clutch size	Number of young hatched/nest		Number of fledglings/nest	
	of nests	Mean† ± S.D.	Mean† ± S.D.	% [a]	Mean† ± S.D.	% [b]
Ansan	14	2.0 ± 0.0	1.2 ± 0.4	60.7	0.9 ± 0.2	45.0
Seoul	24	1.9 ± 0.3	1.2 ± 0.3	65.2	0.8 ± 0.1	42.1

Each % was calculated as follows: [a] Hatching (%) = (No. of hatched eggs / No. of eggs) × 100, [b] Fledlging (%) = (No. of fledglings / No. of eggs) × 100. † Differences between means not statistically significant, P>0.05, t-tests.

colonies (p>0.05). Incubation period in Seoul (17.8 days) did not differ from the Ansan (17.4 days). No difference in growth rate based on body weight, primary wing length, and tarsus length was found between the two test groups (p>0.05). In Seoul, 65.2% were hatching, and 42.1% fledging. The proportion of hatching and fledging in the Ansan was 60.7% and 45.0%, respectively. The significant differences between the two colonies for reproductive success were not found (p>0.05).

DISCUSSION

Mean concentrations of lead in bones of adult pigeons from Seoul were about three times greater than those in the same tissues from the Ansan industrial complex. Similarly, the amount of cadmium in kidneys of adult pigeons from Seoul contained significantly more lead (x 2.5, 1.05 μg/wet g) than those in the Ansan industrial complex. Considering the lead and cadmium concentrations of pigeons, these were not as high as those considered as results in toxic effects in other species, and the biological significance from these level differences is uncertain.

Mean concentrations of lead in bones from Seoul were far lower than those recorded in other cities such as London (108 - 669 mg/kg w.w) (Hutton and Goodman 1980), Paris (174-500 mg/kg w.w) (Jenkins 1975), and Philadelphia (90-480 mg/kg w.w) (Tansy and Roth 1970). Hutton (1980) proposed that renal and hematological toxicity related too more contaminated environments for the urban pigeons. That is, the kidney to body weight ratio in pigeons living in more contaminated urban area was higher than controls, suggesting the presence of renal edema in the central London population. In some cases, 100ppm given to breeding ring doves resulted in adverse effects with respect to testis weights, sperm counts, and number of fledglings, but there were no impairment in egg production, and reproductive success (Kendall and Scanlon 1981). A number of studies have been proposed that reproductive effects including infertility, fecundity, embryo morbidity, hatching success, contaminant burdens, nestling survival, fledging success, developmental defects, post-embryonic growth and development, and behavior related to contaminants for ecosystems monitoring (Blakely 1985, Peakall 1985). However, it should be noted that several studies have not found reproductive effects to be linked by contaminants. In this study, the concentration differences between the study areas may not have played a role in reproductive effects including egg size and thickness, incubation period, nestling growth rate, clutch size, number of young hatched, and number of young fledglings. Still, it was suspected that the concentrations of lead in eggs and adult pigeons in Seoul were significantly greater than those of the Ansan industrial complex. This includes that increased lead concentrations of egg contents in Seoul could be related in the light of predisposing factor that may be influenced by the lead levels of adult pigeons directly. Of course, these differences in lead concentrations could be normally associated with the toxic effects of lead in terms of transportation into avian embryos during oogenesis (Gullvag *et al.* 1975, Kendall and Scanlon 1981) because the developmental stage is extremely sensitive to lead exposure (Hirano and Kochen 1973, Birge *et al.* 1974). There are, however, difficulties in determining threshold concentrations for toxic or reproductive effects of pigeons as many factors, such as exposure regime (acute or chronic), subcellular distribution, influence toxicity, and species-specific. It may also be considered the low-level effects of lead accumulation since the reproductive effects of low-level Pb exposure in feral pigeons have not been well studied.

Many of the effects - retardation of growth, decrease in body weight, nephropathy, Cd-induced anemia, bone-marrow hyperplasia, cardiac hypertrophy, testicular hyperplasia, malabsorption of lipids and other nutrients - could be induced by the effects of Cd (Scheuhammer 1987). However, investigations have not always shown cadmium to influence the body weight of animals and especially reproductive effects for cadmium residues are well not known for birds. Regardless of the consumption of dietary Cd, very small contents of Cd are transferred to eggs of birds (Sell 1975, White and Finley 1978). Low levels of Cd in eggs of birds could thus not be influenced on growth and reproductive effects.

Present study shows that the Cd concentrations in kidneys of adult pigeons were significantly different between the two colonies, but the levels of egg contents and prey items were very similar in each colony. The cadmium levels in kidney are 1.05 μg/g wet weight in Seoul City, and 0.43 μg/g w.w in the Ansan industrial complex. These levels of feral pigeons were lower when compared to London population (1.5 - 50.7 μg/g d.w) (Hutton and Goodman 1980). As for cadmium, high levels were found in tissues, especially the kidneys, and very low levels were noted in eggs; these results are in general agreement with those for several pelagic species. Our study also indicates that the trends of Cd accumulation show the chronic influences, liver: kidney concentration ratios <1, and low level exposure situations noted by Scheuhammer (1987). Body weight and growth rate of nestlings from the Ansan industrial complex was also similar to those of Seoul. Although the body weight of adult pigeons from Seoul was higher than that of the Ansan industrial complex (Table 1), this may be related not by heavy metal concentrations, but by artificial supplies of foodstuff in Seoul.

In general, diet, age, body size, inter-clutch interval, plumage correlates, testis size and the refractory period can be explained by variables influencing reproductive success (Johnston and Janiga 1995). And also, ontogenetic variation, locality variation, aseasonal breeding, and environmental conditions can be related to different reproductive effects (Johnston and Janiga 1995). Recently, residues concerning anthropogenic pollutants such as endocrine disrupters (especially organochlorines, chlorinated hydrocarbons, organophosphates, PCB, DDT, pesticides, etc), oil, and some chemicals have increased. Many studies have reported the results of effects of these pollutants on animals (Gilbertson *et al.* 1991, Tillitt *et al.* 1992, Mora *et al.* 1993). Yet, it is still difficult to elucidate the cause and effect for the impact on such pollutants because some results in real conditions can be correlated with many physiological condition and environmental factors together. The present study did not find the differences of reproductive success, although we investigated the variation of metal levels in feral pigeons between the noted colonies. However, this is crucial because the capability of urban-dwelling pigeons to accumulate elevated lead concentrations draws caution to the potential hazards for humans: health: Pb and Cd concentrations of Seoul City (where approximately one fourth of the human population of Korea is located), and are higher than those of the Ansan industrial complex. It should be needed to investigate estimation, including those associated with subcellular, pathophysological effects, and hormones to be more sensitive of low-level metal accumulation.

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(*Received October 14, 2002, Accepted November 15, 2002*)