1-1-2009

ANALYSIS OF MERCURY AND LEAD IN BIRDS OF PREY FROM GOLD-MINING AREAS OF THE PERUVIAN AMAZON

Peggy Shrum
Clemson University, plsbirds817@yahoo.com

ANALYSIS OF MERCURY AND LEAD IN BIRDS OF PREY FROM GOLD-MINING AREAS OF THE PERUVIAN AMAZON

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Wildlife and Fisheries Biology

---

by
Peggy Lynne Shrum
December, 2009

Accepted by:
William W. Bowerman, Chair
Alan R. Johnson
Jeffrey W. Foltz

ABSTRACT

This study was conducted to determine levels of lead and mercury in the raptors of the South-eastern Peruvian Amazon. The study took place within the Los Amigos Conservation Concession in Madre de Dios, Peru. Eighty-six raptors from among sixteen species were captured with Bal-Chatri traps. From each individual, feather samples were obtained for mercury analysis and blood was taken for lead analysis. Each raptor was then released without incident or injury.

Mercury amalgamation for gold extraction is widely used by small-scale, transient mining operations, which are numerous along the rivers and creeks in the tropical forests and other locations in Latin America. These mining operations have a high waste output of mercury into the water and the air. Mercury which is not bound to gold is dumped into the waste water which returns to the river; and mercury which is bound to gold is later burned off to purify the gold. Once elemental mercury is released into the environment, it cannot be cleaned up. It persists for decades, even centuries after the mining has ceased.

Predatory birds are useful for representing the contamination of the ecosystem at levels higher than mammalian bioindicators. The use of feathers to evaluate exposure of birds to heavy metals like mercury is a common method of analysis. During this investigation, a combination of tail and breast feathers were analyzed from each individual sampled.

It was determined that 81 of the raptors sampled had elevated mercury levels, with many at or above the level known to cause reproductive symptoms in other species.

No toxic reference values exist for any of the species sampled. Further study is required to determine if these levels represent a significant threat to raptors.

Blood samples were analyzed for lead concentrations. Lead levels were consistant with or slightly above background levels, with the exception of one individual. This individual appeared healthy and normal upon capture, although his lead levels were consistant with those known to cause symptoms in other species. Probable causes for this individual's elevated blood lead level include having survived being shot with lead shot, ot having consumed a prey item which had been shot with lead shot.

The results of this study will provide insight as to the threat to raptors from mercury and lead from gold mining activity. The results will be reviewed by Peruvian agencies responsible for ecosystem monitoring. This study, among others, may lead to the control of mercury use for gold mining in the Amazon.

ACKOWLEDGEMENTS

I would like to thank my father for giving me an appreciation of nature and ecology from an early age. I thank my mother for encouraging me and for teaching me patience and endurance, and for never allowing me to think for one moment that anything I wanted was beyond my reach. I thank my sisters and my friends for support. I extend special thanks to Juan Rene Escudero Vega for invaluable field assistance, insight, inspiration, and daily motivation. I thank Ursula Valdez for introducing me to this profession and to the Peruvian Amazon with enthusiasm and wisdom. I thank each and every one of my field assistants; your help and companionship has been warmly appreciated. I thank everyone who has helped me at Clemson University: Wayne Chao, William Clark, Lindsey Moore, Lou Jolley, and Billy Bridges. I thank my committee, and I especially thank Dr. William Bowerman for his advice and his guidance, and for his faith in me.

TABLE OF CONTENTS

Table of Contents (Continued)

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

GENERAL INTRODUCTION

The Tropical Forests of South-eastern Peru

The Amazon River Basin in Peru is one of the richest and most bio-diverse tropical humid ecosystems in the world. It is estimated that 1/2 of the world's species reside within tropical rainforests (Wilson 1992). The Amazon rainforest accounts for 60% of the world's remaining tropical rainforests (Laurance and Williamson 2001). These ecosystems are a vital force in shaping the world weather patterns, and are responsible for approximately 15% of global terrestrial photosynthesis (Field et al. 1998).

The Amazon rainforests and the species that inhabit them are being affected by human activities. Logging, agriculture, and mining threaten the future of this ecosystem. The jungles of the Amazon covered about 5.4 million square kilometers as of 2001; and that is an estimated 87% of its original extent (Mahli et al. 2007). The Amazon is currently experiencing the world's highest absolute rate of forest destruction, averaging roughly 3-4 million hectares per year (Laurance and Williamson 2001).

The rapid pace of deforestation has several interrelated causes. Human populations in the Amazon have increased sharply in recent decades as a result of immigration from other areas and high rates of intrinsic growth (Laurance and Williamson 2001). The incidence of cattle ranching, which accounts for 70% of deforestation in Amazonian Brazil (Mahli et al. 2007), industrial logging, and gold mining, all of which practice slash and burn forest-clearing, are growing and penetrating deeper into the heart of the Amazon (Laurance and Williamson 2001). The associated roadways only increase access into the forests for more miners, ranchers, and loggers (Laurance and Williamson 2001).

The overall footprint of human activity is much greater than deforestation alone. Logging exposes the delicate soils to the equatorial sun, which effectively reduces the organic matter and renders the soil infertile. Mining increases sedimentation in the rivers and alters their natural flow patterns. The mining operations contaminate the rivers with mercury. Cattle ranchers bring domestic animals into the forests exposing Amazonian wildlife to new diseases and parasites.

Little hope remains that an intact Amazon rainforest will persist fifty years from today. The forest is being reduced to parcels of protected land; it is therefore essential that we learn as much as possible about the species that live there. We need to understand their ecology and what impacts human activities are having upon them if we are to manage for their survival.

Raptors of Amazonian Peru

More than 40 species of diurnal raptors have been documented in the Peruvian Amazon (Schulenberg et al. 2007). Many of these are endemic or highly specialized. In addition to endemics and residents, many North American raptors migrate through the Amazon rainforest or over-winter there. The diversity is extensive, and includes eagles, hawk-eagles, hawks, falcons, forest-falcons, and kites. Very little is known about the ecology and life history of many of these species. Because of the substantial loss or alteration of habitat and ecosystem contamination, we may not have an opportunity to study these species in a pristine environment.

Gold Mining and Mercury Use

Mercury amalgamation for gold extraction has been widely used in the tropical forests of Peru. Mercury binds readily with gold ore by a process called amalgamation, and the resulting compound is called an amalgam. Amalgamation with mercury is still the preferred method employed by artisanal gold miners today (Veiga et al. 1999). Mercury is an effective, simple, and inexpensive reagent with which to extract gold (Veiga et al. 1999). For that reason, mercury amalgamation is widely used by small-scale, transient mining operations, which are numerous along the rivers and creeks in the tropical forests and other locations in Latin America.

Several methods involving mercury are used in these mining operations. Some methods of using mercury for amalgamation include direct spray application of mercury to the ground, flushing mercury over sediments as they are passed through a concentration box, dumping mercury into a containment pool, or spraying mercury over sediments pumped onto a riffled washboard. In slightly larger dredging operations, amalgamation is done on a board using a blender, and amalgamation tailings are steadily dumped into rivers (Veiga et al. 1999). In each case, the unbound mercury is released into the environment in the wastewater and sediment tailings. Mine tailings frequently contain 200 to 500 parts per million (ppm) of residual mercury (Veiga et al. 1999). Mine tailings can remain a source of mercury long after mining operations have ceased.

Because of the natural processes of riverine ecosystems, mercury is not buried in soil sediment; rather it is continuously transported, re-deposited, and redistributed via the continuous flooding and mixing cycles (Hoffman et al. 1995).

Additionally, the mercury bound to gold in the amalgams is re-released into the environment. To separate the gold from the mercury, the amalgam is heated, vaporizing the mercury. These mercury vapors in the atmosphere can travel great distances before being precipitated or deposited back into the ecosystem.

Mercury as a Contaminant

Once elemental mercury is released into the environment, methylation can occur. Methylation transforms inorganic, elemental mercury into the organic compound methyl-mercury (MeHg) when the oxidized mercuric species (Hg^{2+}) gains a methyl group (CH_3). Methylation is thought to be the result of the action of microorganisms under anaerobic conditions. In the Amazon Basin, the riverine ecosystems provide favorable conditions, such as high temperatures and high concentrations of organic matter, for the methylation of mercury and for exposure of organisms to methyl-mercury (Salomons 1995). Methyl-mercury is readily taken up into the biosphere, where it bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Mercury is a known teratogen (causes malformation or adverse fetal development), a carcinogen (causes cancer), a mutagen (causes permanent change in cellular DNA), and causes embryocidal, cytochemical, and histopathological effects (Eisler 1987). In birds, dietary mercury exposure can be directly lethal, or can have sub-lethal adverse effects on growth and development, reproduction, blood and tissue chemistry, metabolism, and behavior (Eisler 1987).

Birds of Prey as Bio-indicators

Birds of prey are excellent indicators of ecosystem health, as they are top predators occupying multiple trophic levels and various ecological niches. Predatory birds are especially good bio-indicators of bio-accumulative compounds such as methyl-mercury because these compounds bioconcetrate in their prey. Birds also have a relatively high tolerance to mercury contamination in comparison to mammals, allowing them to live with much greater body burdens of mercury. Therefore, predatory birds are useful for representing the contamination of the ecosystem at levels higher than mammalian bioindicators.

The use of feathers to evaluate exposure of birds to heavy metals like mercury is a common method (Westermark et al. 1975, Buhler and Norheim, 1982, Bruane and Gaskin 1987, Bowerman et al. 1994). Adult feathers are molted up to several times per year, and new feather growth quickly follows to replace molted feathers. Mercury is excreted in growing feathers, and once bound to the feather keratin molecule, it is both physically and chemically stable (Appelquist et al. 1984, Thompson et al. 1998). For mercury in birds, about 70% (Honda et al. 1986, Harris et al. 2007) to 93% (Bruane and Gaskin 1987, Harris et al. 2007) of the body burden is in the feathers, and greater than 95% of the mercury bound in feathers is methyl-mercury (Thompson and Furness 1989, Harris et al. 2007). Non-invasive techniques, such as blood and feather sampling are ideal for any species, especially threatened or at risk species. Blood and feather sampling offers valuable information without putting strain on the individual or the species. Feathers are stable over time, and can be readily archived for later analysis.

Objectives

The overall objectives of this study were:

1. To determine if mercury used in gold mining and lead were bioavailable to birds of prey in Madre de Dios, Peru.
2. To compare concentrations of mercury in feathers and lead in blood of birds of prey which occupy different trophic levels.
3. To compare concentrations of mercury in feathers and lead in blood of individuals and species to determine if there is a relationship between capture site habitat characteristics and mercury and lead concentrations.
4. To determine if other variables such as age, sex, weight, or season of capture were related to mercury or lead concentrations.
5. To compare concentrations of mercury and lead found in birds of prey to toxic reference values (TRVs) for birds to determine the risk from mercury or lead.

The results of this study will provide insight as to the threat to raptors from mercury and lead from gold mining activity. The results will be reviewed by Peruvian agencies responsible for ecosystem monitoring. This study, among others, may lead to the control of mercury use for gold mining in the Amazon.

LITERATURE CITED

Appelquist H, Asbirk S, Drabaek I (1984) Mercury monitoring: mercury stability in bird feathers. Marine Pollut Bullet 15: 22-24

Bowerman WW, Evans ED, Giesy JP, Postupalsky S (1994) Using Feathers to Assess Risk of Mercury and Selenium to Bald Eagle Reproduction in the Great Lakes Region. Arch Environ Contam Toxicol 27: 294-298

Buhler U, Norheim G (1982) The mercury content in feathers of the sparrowhawk *Accipiter nisus* in Norway. Fuana Norv Ser C Conclus 5: 43-46

Bruane BM, Gaskin DE (1987) Mercury levels in Bonaparte's gulls *(Larus philadephia*) during autumn molt in the Quoddy Region, New Brunswick, Canada. Arch Environ Contam Toxicol 16: 539-549

Eisler, Ronald. (1987). Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85 (1.10). U.S. Fish and Wildlife Service.

Field CB, Behrenfeld MJ, Randerson JT, Falkowski P. (1998). Science Magazine 281, page 237.

Harris R, Krabbenhoft D, Mason R, Murray M, Reash R, and Saltman T (2007) *Ecosystem Responses to Mercury Contamination*. New York: CRC Press

Hoffman DJ, Rattner BA, Burton GA, Cairns J. (1995) Handbook of Ecotoxicology. CRC Press, Inc. 392-395.

Honda K, Nasu T, Tatsukawa R (1986) Seasonal changes in mercury accumulation in the black-eared kite, (*Milvus migrans lineatus*) Environ Pollut 42: 325-334

Laurance, W. and Williamson, GB. (2001). *Positive Feedabcks among Forest Fragmentation, Drought, and Climate Change in the Amazon.* Conservation Biology Vol 15 (6) pp 1529-1535.

Mahli Y, Roberts JT, Betts, RA, Killeen TJ, Li W, Nobre, CA. (2007). *Climate Change,Deforestation, and the Fate of the Amazon*. Science Vol. 310 (5860) pp 169-172.

Robinson SK. (1994). Habitat selection and Foraging Ecology of Raptors in Amazonian Peru. Biotropa 26(4): 443-458.

Schulenburg TS, Stotz DF, Lane DF. (2007). Birds of Peru. Princeton University Press. Pages 85-116.

Salomons W. (1995). Environmental Impact of Metals Derived from Mining Activities: Processses, Predictions, Prevention. Journal of GeoChemical Exploration 52:5.

Thompson DR, Furness RW (1989) Comparison of the levels of total and organic mercury in seabird feathers. Mar Pollut Bull 20: 557-579

Thompson, DR, Bearhop S, Speakman JR, Furness RW (1998) Feathers as a means of monitoring mercury in seabirds: insights from stable isotope analysis. Environ Pollut 101: 193-200

Veiga, Marcello M.; Hinton, Jennifer; Lilly, Cameron. Mercury in the Amazon: A Comprehensive Review with Special Emphasis on Bioaccumulation Bioindicators. Proceedings Of National Institute for Minamata Disease, Forum 1999. p 19-39. Oct 12-13, 1999.

Westermark T, Odsjo T, Johnels A (1975) Mercury content of bird feathers before and after Swedish ban on alkyl mercury in agriculture. Ambio 4: 87-92

Wilson EO. (1992, 1999). The Diversity of Life. Harvard University Press. Forward Pages ix – xxiv.

CHAPTER 2

ANALYSIS OF MERCURY LEVELS IN BIRDS OF PREY FROM GOLD MINING AREAS OF AMAZONIAN PERU

INTRODUCTION

More than 40 species of diurnal raptors have been documented in the Peruvian Amazon (Schulenberg et al. 2007). Many of these are endemic or highly specialized. In addition to endemics and residents, many North American raptors migrate through the Amazon Rainforest or over-winter there. The diversity is extensive, and includes eagles, hawk-eagles, hawks, falcons, forest-falcons, and kites. Very little is known about the ecology and life history of many of these species. Because of the substantial loss or alteration of habitat and ecosystem contamination in the Amazon Basin, we may no longer be able to study them in a pristine environment.

Mercury (Hg) amalgamation for gold extraction has been widely used in the tropical forests of Peru. Amalgamation with mercury is still the preferred method employed by artisanal gold miners today (Veiga et al. 1999). Mercury binds readily with gold ore by a process called amalgamation, and the resulting compound is called an amalgam. Mercury is an effective, simple, and very inexpensive reagent with which to extract gold (Veiga et al. 1999). For that reason, mercury amalgamation is widely used by small-scale, transient mining operations, which are numerous along the rivers and creeks in the tropical forests and other locations in Latin America.

Several methods involving mercury are used in these mining operations. Some methods of using mercury for amalgamation include: direct spray application of mercury to the ground, flushing mercury over sediments as they are passed through a concentration box, dumping mercury into a containment pool, or spraying mercury over sediments pumped onto a riffled washboard. In slightly larger dredging operations, amalgamation is done on a board using a blender, and amalgamation tailings are steadily dumped into rivers (Veiga et al. 1999). In each case, the unbound mercury is released into the environment in the wastewater and sediment tailings. Mine tailings frequently contain 200 to 500 parts per million (ppm) of residual mercury (Veiga et al. 1999). Mine tailings can remain a source of mercury long after mining operations have ceased. Because of the natural processes of riverine ecosystems, mercury is not buried in soil sediment; rather it is continuously transported, re-deposited, and redistributed via the continuous flooding and mixing cycles (Hoffman et al. 1995).

The mercury bound to gold in the amalgams is also a source to the environment. To separate the gold from the amalgam, the miners heat the amalgam and the mercury vaporizes, leaving a more pure gold to be sold. These mercury vapors in the atmosphere can travel great distances before being precipitated or deposited back into the ecosystem.

Once elemental mercury is released into the environment, methylation can occur. The Amazon basin has many favorable conditions for methylation, such as high temperatures and high concentrations of organic matter. Methyl-mercury is readily taken up into the biosphere, where it bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Mercury is a known teratogen (causes malformation or adverse fetal development), a carcinogen (causes cancer), a mutagen (causes permanent change in cellular DNA), and causes embryocidal, cytochemical, and histopathological effects (Eisler 1987). In birds, dietary mercury exposure can be directly lethal, or can have sub-lethal adverse effects on growth and development, reproduction, blood and tissue chemistry, metabolism, and behavior (Eisler 1987).

Objectives

The overall objectives of this study were:

1. To determine if mercury used in gold mining was bioavailable to birds of prey in Madre de Dios, Peru.
2. To compare concentrations of mercury in feathers of birds of prey which occupy different trophic levels.
3. To compare concentrations of mercury in feathers of individuals and species to determine if there is a relationship between capture site habitat characteristics and mercury concentrations.
4. To determine if other variables such as age, sex, weight, or season of capture were related to mercury concentrations.
5. To compare concentrations of mercury found in birds of prey to toxic reference values (TRVs) for birds to determine the risk from mercury.

The results of this study will provide insight as to the threat to raptors from mercury from gold mining activity. The results will be reviewed by Peruvian agencies responsible for ecosystem monitoring. This study, among others, may lead to the control of mercury use for gold mining in the Amazon.

METHODS

Study Area: The study was conducted at the Los Amigos Research Station, in Madre de Dios, Peru (Fig.1). This research station is situated on the grounds of a former gold- mining camp at the confluence of the Los Amigos River and the Madre de Dios River. Gold mining continues along the Madre de Dios, and many active small-scale mining operations are visible from the research station. Pristine forest remains in the areas untouched by mining. Birds were captured in both pristine and disturbed areas. With its known history of use, and its proximity to active mining operations, this station was ideal for sampling birds from a contaminated area.

Capture sites were classified according to characteristics. Capture site characteristics included: riverine, backwater, undisturbed forest, disturbed area, upland forest, and edge.

Trapping Birds of Prey: Birds were captured using variants of Bal Chatri (BC) traps (Fig.2). The BC trap is a painted hardware cloth enclosure containing a lure animal. Monofilament nooses are tied to the top and sides of the enclosure (Bergen and Mueller 1959). The nooses close on the raptor's legs or toes when it attempts to catch the potential prey (Thorstrom 1996). Risk of injuries for raptors and bait animals is minimal if BCs are constantly monitored (Thorstrom 1996). Both live prey and mechanical bait decoys were used as lures inside the BCs.

The live prey items included young chickens (*Gallus gallus*), guinea pigs (C*avea porcellus*), gerbils (*Meriones unguiculatus*), and hamsters (sub-family *Cricetinea*). Each animal was fully vaccinated before arrival at the research station. With the exception of the chickens, only castrated male domestic animals were used, removing any chance of accidental introduction into the jungle. Lure animals were safely closed inside the BC trap, and two individual closure methods were employed to ensure their safety and confinement. The traps were securely anchored at two points so that they could not be moved or carried away when struck by the raptor.

The mechanical prey item decoys used were hunting decoys commercially available for hunters of small game predators. They are designed to mimic movement of small mammals or birds. They operate on one to four AA batteries, and move at pre-set intervals. They were enclosed in the BC traps in the same manner that the live animals are, so they could not be removed when struck by the raptor. Along with the mechanical decoys, a commercially available recording was broadcast from a nearby hidden compact disc player and speaker. The sounds emitted were appropriate to the decoy. For example, a distressed bird call was used alongside a mechanical decoy of a struggling bird inside a BC trap, or a distressed rodent sound was broadcast alongside the BC containing the mechanical rodent decoy.

Feather Collection and Preparation: Feathers were collected from captured birds by clipping a portion of the outermost tail feather, and by plucking 4 breast feathers. Because it has been documented that there are variances in mercury concentrations among different feathers and within each feathers (Dauwe et al. 2003, Altmeyer et al. 1991, Furness et al, 1986, Thomsen 2007) and differences between the feather webbing and rachis (Thomsen 2007), a combination of rachis and webbing from the last 5 cm of an outermost tail feather was used for mercury analysis. Each individual's feather sample was labeled with identification then sealed inside individual envelopes for storage until transported to the laboratory.

Prior to analysis, each feather sample was washed, freeze-dried, and weighed. At the lab, each feather was placed in a labeled Ziploc^{R} bag containing the detergent Acatinox^{R}, and then washed three times with deoxygenated water. The feather was then placed in a freezer for 1 h and then in a freeze-dryer overnight to remove moisture. Approximately 4 mg was weighed for analysis. Once weighed, the samples were ready for mercury analysis.

Mercury Analysis: The feathers were analyzed for total mercury following EPA Method 7473, using a DMA80 Direct Mercury Analyzer (Milestone, Inc, Monroe, CT, USA). This method utilizes thermal decomposition, gold amalgamation, with cold vapor atomic absorption detection. Each batch of five to ten samples included a certified reference material of known Hg concentration (Dorm-2 (dogfish muscle) Dolt-2 (dogfish liver), or Tort-2 (lobster hepatopancreas), along with a blank and a sample replicate.

Statistical Analysis: Statistical analyses were conducted using Statistical Analysis System, SAS 9.1 (SAS Institute, Inc. 2002). Mean Hg concentrations for each individual sample, for each species, and then for the entire sample pool were analyzed. Simple Linear Regression was used to analyze relationships between Hg concentrations and species, weight, age, sex, and season of capture. ANOVA and Multiple Regression were used to analyze relationships between Hg concentrations and capture site characteristics. Species with sample numbers of two or less were excluded from statistical analyses.

RESULTS

Species Captured: A total of 83 birds representing 15 species were captured and sampled. Species captured include 9 Barred Forest-falcons (*Micrastur ruficollis*), 2 Bi-colored Hawks (*Accipiter bicolor*), 1 Black Caracara (*Daptrius ater*), 1 Black-faced Hawk (*Leucopternis melanops*), 1 Broad-winged Hawk (*Buteo platypterus*), 2 Buckley's Forest-falcons (*Micrastur buckleyi*), 4 Collared Forest-falcons (*Micrastur semitorquatus*), 1 Double-toothed Kite (*Harpagus bidentatus*), 9 Lined Forest-falcons (*Micrastur gilvicollis*), 1 Great Black Hawk (*Buteogallus urubitinga*), 1 Ornate Hawk-eagle (*Spizeatus ornatus*), 35 Roadside Hawks (*Buteo magnirostris*), 11 Slate-colored Hawk (*Leucopternis schistacea*), 2 Slatey-backed Forest-falcons (*Micrastur mirandollei*), and 3 White-browed Hawks (*Leucopternis kuhli*) (Table 1).

Mercury Concentrations: The concentrations of Hg in feather samples ranged between non-detectable level (<0.01 mg/kg) and 10.10 mg/kg. Results by species are presented in Table 1. Individual results are presented in Appendix A. No significant relationship was found between mercury concentration and any capture site characteristic, age, sex, or capture season ($p > 0.05$). A significant and negative relationship between weight and mercury concentrations was found ((t=-1.87, df=68, p=0.0652) (Fig. 3). The smallest species captured, the Barred Forest-falcon had the highest mercury concentrations, ranging from 2.86 mg/kg to 10.10 mg/kg with a mean of 7.44 mg/kg. The largest species captured, the Slate-colored Hawk (*Leucopternis schistacea*) had the lowest Hg concentrations, ranging from 1.86 mg/kg to 5.03 mg/kg with a mean of 4.40 mg/kg. Others species were between the ranges of the Barred Forest-falcon and the Slate-colored Hawk, and followed the linear pattern of declining mercury concentrations as weight increased (Fig 3).

DISCUSSION

Captures: Based on personal observation and station records, capture rate represented the relative abundance of the captured species in the area sampled. While other species were present, they were not captured, most likely due to hunting techniques, prey preference, or trap avoidance.

The Roadside Hawk was captured most frequently (n=35). This species very abundant, and because it is an edge specialist and an opportunistic hunter, it was easy to locate and capture. Many were captured within gold mining areas. Roadside Hawks were captured with a variety of prey items including gerbils, hamsters, juvenile chickens, and were seen showing interest in many of the mechanical bait decoys, although none was captured by a decoy.

Forest-falcons (genus *Micrastur*) are a group of raptors which have been poorly understood. Aside from a few recent studies (Thorstrom 2000, Thorstrom et al. 2001, Valdez 2004) much of their natural history remains undocumented. The Barred Forest-falcon (n=12) and the Lined Forest-falcon (n=9) were the most frequently captured of the forest falcons. The Lined Forest-falcon was thought to be conspecific with the Barred Forest-falcon until it was validated as a separate species (Schwartz, 1972). Both the Barred and the Lined Forest-falcons were captured in a variety of habitats including upland, disturbed, undisturbed, and lowland areas. The Lined Forest-falcon was the most frequent species captured by rodent lure animals, although several were caught with chicken lures. The Barred Forest-falcon was captured most frequently with chicken lures, and often the lure animal was considerably larger than the forest-falcon. There are other reports of the Barred Forest-falcon feeding on large prey items (Rohe and Antunes, 2008). Forest-falcons vocalize each morning before dawn, and some evenings. Based on the species commonly heard, the Collared Forest-falcon seemed to be the most abundant of the forest-falcons, however, only 4 were captured, including 1 adult in the rare buffy or tawny morph. All Collared Forest-falcons were captured within upland undisturbed forest on chicken lures. Two Buckley's Forest-falcons were captured, both in lowland forest near water, and both on chicken lures. Buckley's Forest-falcon is a species which was poorly understood and unknown in the area until a nest was discovered and monitored recently (Valdez and Shrum, 2004). Another rare to uncommon Forest-falcon captured (n=2) was the Slatey-backed Forest-falcon, which was undocumented in the area until recently (Valdez 2004). One Slatey-backed Forest-falcon was caught deep in the upland forest interior, and the second was captured in a disturbed lowland floodplain. Both Slatey-backed Forest-falcons were caught on chicken lures.

Eleven Slate-colored Hawks were captured. The Slate-colored Hawk is noted as rare in the most recent literature (Schulenburg et al. 2007), however, this species seemed to be rather abundant in the area sampled. This species is vocal, and was heard frequently. Slate-colored Hawks are endemic to Amazonian backwaters and feed upon reptiles and amphibians. The area sampled had many oxbow lakes which may explain their relative abundance in the area.

Other species captured were excluded from statistical analyses due to a sample number of two or less. Other species personally observed in the area but not captured include: Plumbeous Kite (*Ictinea plumbea*), Swallow-tailed Kite (*Elanoides forficatus*), Snail Kite (*Rostrhamus sociabilis*), Hook-billed Kite (*Chondrohierax* uncinatus), Slender-billed Kite (*Rostrhamus* hamatus), Gray-headed Kite (*Leptodon cayanensis*), Crane Hawk (*Geranospiza caerulescens*), Tiny Hawk (*Accipiter superciliosus*), Black-collared Hawk (*Busarellus* nigricollis), Gray Hawk (*Buteo* nitidus), Zone-tailed Hawk (*Buteo* albonotatus), Osprey (*Pandion haliaetus*), Harpy Eagle (*Harpia harpyja*), Red-throated Caracara (*Ibycter americanus*), Yellow-headed caracara (*Milvago chimachima*), Laughing Falcon (*Herpetotheres cachinnans*), Peregrine Falcon (*Falco peregrinus*), Bat Falcon (*Falco rufigularis*), Black and White Hawk-eagle (*Spizastur melanoleucus*), and Black Hawk-eagle (*Spizeatus tyrannus*).

Mercury Concentrations: A significant and inverse relationship between mercury and weight was found among the five species whose sample size was greater than two. The reasons for this relationship are unclear, but may be related to prey utilization or basal metabolic rate. No other statistically significant relationship was found.

The species with the highest mercury concentrations was the Barred Forest-falcon. The Barred Forest-falcon is a small neo-tropical forest raptor weighing an average of 168 g for males and 233 g for females (Thortsrom 2000). Studies of their diet are few, but suggest that the Barred Forest-falcon feeds on small vertebrates and larger invertebrates (Sick 1993) with reptiles and birds being important components (Thorstrom 2000). Further study of the ecology, habitat use, and trophic level of the raptors sampled, particularly the species with the highest and lowest concentration, is necessary to clarify the relationships between weight, and subsequently species sampled.

The range of mercury concentrations resulting from this study (>0.01 – 10.10 mg/kg) were generally higher than the concentrations found in outer tail feathers of Finnish Sparrowhawks (*Accipiter nisus,* 0.35 – 0.58 mg/kg, Dauwe et al. 2003) and concentrations in feathers from various raptor species in southwest Iran (1.25 – 1.87 mg/kg, Zolfaghari et al. 2007). Peregrine Falcons (*Falco peregrinus*) in Texas (2.50 mg/kg, Mora et al, 2002), Lagger Falcons (*Falco biarmicus jugger*, 3.34 mg/kg) in Pakistan (Movalli 2000), and Bald Eagles *(Haliaeetus leucocephalus*) in Florida (3.28 mg/kg, Wood et al. 1996) showed concentrations similar to those resulting from this study. Concentrations found in White-tailed Eagles *(Haliaeetus albicilla*, 16 – 37 mg/kg Altmeyer et al, 1991), Peregrine Falcons in Sweden (17.6 mg/kg, Lindberg 1984), Osprey (*Pandion* haliaetus, 2-23 mg/kg, Anderson et al. 2008) and Bald Eagles from the Great

Lakes Region (13 – 21 mg/kg, Bowerman et al. 1994) were higher than concentrations determined in this study.

Numerous studies exist on the detrimental effects of mercury upon different avian species, however, no toxic reference values exist for species sampled during this study. A mercury concentration in feathers of 5.0 mg/kg or more has been documented to adversely affect reproduction in birds (Eisler 1987). Many individuals in this study were at or above that concentration. Further study, especially in establishing baseline reproductive parameters and comparing reproduction to mercury concentrations in breeding adults to determine if mercury concentration is affecting reproduction is necessary to determine the risk to these raptors from mercury contamination in the ecosystem.

LITERATURE CITED

Anderson DW, Suchanek TH, Eagles-Smith CA, Cahill TM. (2008). Mercury residues And productivity in Osprey and Grebes from a mine dominated ecosystem. Ecological Applications 18(8) Supp. A227-A238.

Berger, D.D., and Mueller, H.C. (1959). The bal-chatri: a trap for birds of prey. Bird Banding 30: 18-26.

Bowerman WW, Evans ED, Giesy JP, and Postupalsky S. (1994). Using feathers to Assess mercury and selenium risk to bald eagle reproduction in the Great Lakes region. Archives of Environmental Contamination And Toxicology 27:294-298.

Eisler, Ronald. (1987). Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85 (1.10). U.S. Fish and Wildlife Service.

Hoffman DJ, Rattner BA, Burton GA, Cairns J. (1995) Handbook of Ecotoxicology. CRC Press, Inc. 392-395.

Lindberg P. (1984). Mercury in feathers of Swedish gyrfalcons in relation to diet. Bull. Environ. Contam. Toxicology 32:453-459.

Mora M, Skiles R, McKinney B, Paredes M, Buckler D, Papoulias D, and Kleine D. (2002) Environmental contaminants in prey and tissues of the peregrine falcon in the Big Bend Region, Texas, USA. Environmental Pollution 116 169-176.

Movalli PA. (2000). Heavy metal and other residues in feathers of lagger falcons from six districts of Pakistan. Environmental Pollution 109:267-275.

Rohe F and Antunes AP. (2008). Barred Forest-falcon (*Micrastur ruficollis*) predation on relatively large prey. The Wilson Journal of Ornithology. 120 (1) 228-230

Schulenburg TS, Stotz DF, Lane DF. (2007). Birds of Peru. Princeton University Press. Pages 85-116.

Salomons W. (1995). Environmental Impact of Metals Derived from Mining Activities: Processses, Predictions, Prevention. Journal of GeoChemical Exploration 52:5.

Sick, H. (1993). Birds in Brazil: A Natural History. Princeton University Press, Princeton, New Jersey, USA.

Thorstrum, Russell K. (1996). Methods for Capturing Tropical Forest Birds of Prey. Wildlife Society Bulletin 1996, 24(3): 516-520.

Thorstrum, Ruseell K. (2000). The food habits of sympatric forest-falcons during the breeding season in northeastern Guatemala. Journal of Raptor Research 30:44.

Valdez, U. (2009). The distribution and abundance of five species of forest-falcons in Amazonian rainforest in Southeast Peru. In: The secretive forest-falcons of Amazonian Peru: windows into their ecology. PhD Thesis, Dept. of Biology, University of Washington.

Valdez U, and Shrum, P. (2005). Premier record de anidacion y notas sobre la biologia reproductive de Micrastur buckleyi en sureste del Peru. VI Congreso Nacional de Ornitologia, Libro de Resumenes. 160.

Veiga, Marcello M.; Hinton, Jennifer; Lilly, Cameron. (1999). Mercury in the Amazon: A Comprehensive Review with Special Emphasis on Bioaccumulation Bioindicators. Proceedings Of National Institute for Minamata Disease, Forum 1999. p 19-39. Oct 12-13, 1999.

Westermark T, Odsjo T, Johnels AG. (1975). Mercury content of bird feathers before and after Swedish ban on alkilmercury in agriculture. Ambio 4:87-92.

Wood PB, White JH, Steffer A, Wood JM, Facemire CF, and Percival HF. (1996). Concentrations in tissues of Florida Bald Eagles. Journal of Wildlife Management 60:178-185.

Zolfaghari G, Esmaili-Sari A, Ghasempouri SM, Kiabi BH. (2007). Environmental Research Vol 104 Issue 2 258-265.

Table 2.1 Concentrations of mercury in feathers of hawks captured in the Amazon Basin of Peru.

Species	(n)	Mercury Concentration (mg/kg or ppm) Mean	Range	Predominant Capture Habitat
Accipiter bicolor	2	4.42	4.31 - 4.52	X
Buteo magnirostris	35	4.73	BDL - 9.04	E
Buteo platypterus	1	9.04	-	X
Buteogallus urubitinga	1	2.76	-	R
Daptrius ater	1	BDL	-	R
Harpagus bidentatus	1	0.48	-	X
Leucopternis kuhli	2	4.84	4.76 - 4.92	X
Leucopternis melanops	1	0.56	-	X
Leucopternis schistacea	11	4.4	1.86 - 5.03	B,L
Micrastur buckleyi	2	4.71	4.33 - 5.08	L
Micrastur gilvicollis	12	3.3	1.51 - 4.99	X
Micrastur mirandollei	2	4.94	4.49 - 5.38	X
Micrastur ruficollis	9	7.44	2.86 - 10.1	X
Micrastur semitorquatus	4	3.91	1.04 - 5.47	X

Key:
BDL = Below Detectable Level
B=Backwater, E=Edge, L=Lowland Forest, R=River, X=Upland Forest

Figure 2.1 Map of South America with Inset of Study Area.

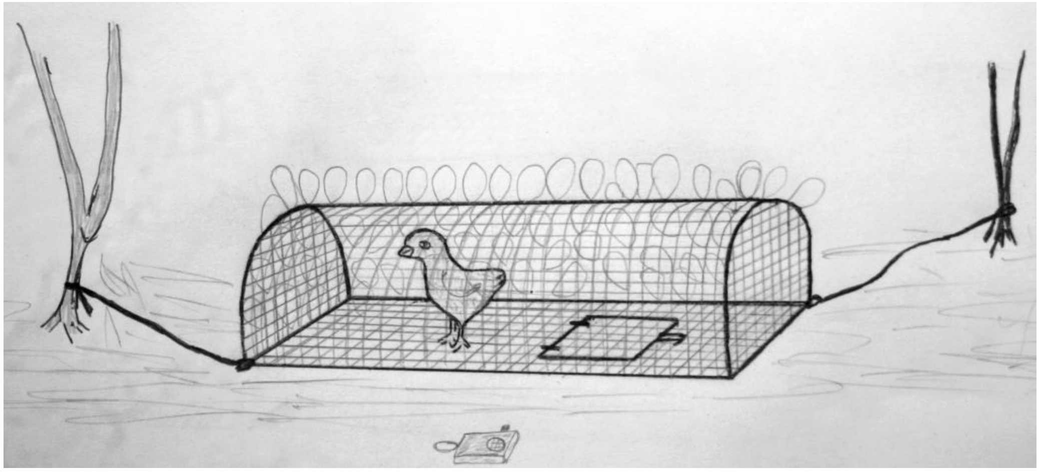

Figure 2.2 Standard Bal-Chatri (BC) Trap used to capture hawks.

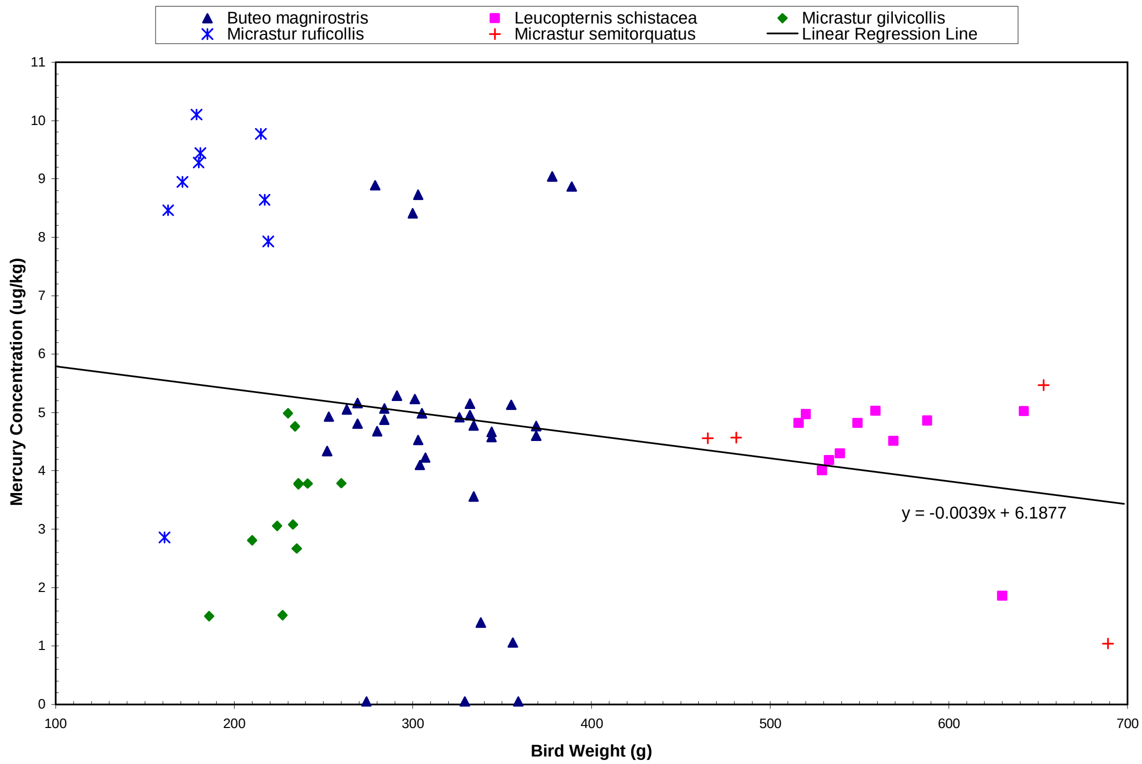

Figure 2.3 Concentrations of mercury in feathers and weight (g) of hawks captured in the Amazon River Basin of Peru.

CHAPTER 3

LEAD IN BLOOD OF RAPTORS FROM SOUTH-EASTERN PERU

INTRODUCTION

More than 40 species of diurnal raptors have been documented in the Peruvian Amazon (Schulenberg et al. 2007). Many of these are endemic or highly specialized. In addition to endemics and residents, many North American raptors migrate through the Amazon Rainforest or over-winter there. The diversity is extensive, and includes eagles, hawk-eagles, hawks, falcons, forest-falcons, and kites. Very little is known about the ecology and life history of many of these species. Because of the substantial loss or alteration of habitat and ecosystem contamination in the Amazon Basin, we may no longer be able to study them in a pristine environment.

Human activities threaten to permanently alter the Amazon and affect the species that live there. Cattle ranching, hunting, logging, and mining alter the delicate ecosystems and introduce contaminants such as lead from the combustion of leaded gasoline or from lead shot, and mercury used in the gold mining process.

The forest is being reduced to parcels of protected land; it is therefore essential that we learn as much as possible about the species that live there. We need to understand their ecology and what impacts human activities are having upon them if we are to manage for their survival.

Lead as a Contaminant

Lead is a non-essential, highly toxic heavy metal which naturally occurs in the earth's crust. All effects of lead exposure to biota are deleterious (Eisler 1989). Lead does not appear to bio-magnify, but does bio-accumulate within individual organisms. Lead is a teratogen (causes birth defects), a carcinogen (causes cancer), a probable mutagen (changes genetic material) and a neurotoxin (damages or alters nervous tissue including the brain, Eisler 1988). Dietary lead exposure can be directly lethal, or can have sub-lethal effects including nervous system damage and impairment, muscular paralysis, damage to red blood cell function, and damage to kidneys and liver (Eisler 1988). In birds, lead toxicosis presents as loss of mobility, sociality, and appetite, weakness, tremors, emaciation, drooped wings, and green liquid feces (Eisler 1988, Hoffman et al. 1995). Neurobehavioral changes, such as the inability to balance, poor depth perception, and other changes are associated with lead at sub-lethal doses (Burger and Gochfield 2000).

Routes of Lead Exposure

Lead does occur naturally in the environment in minute quantities, but most routes of exposure and toxicity are from anthropogenic emissions. Airborne emissions are usually the result of fossil fuel combustion, and are decreasing as stricter controls are enforced (Hoffman et al. 1995). Most other sources occur as a result of mining operations, hunting with lead shot, or industrial use. A significant threat to wildlife, birds of prey in particular, is the ingestion of lead shot contained within prey items. In the

Peruvian Amazon, the most significant sources for lead toxicity are the combustion of fossil fuels to operate mining equipment, the ingestion of lead shot in prey items, or being shot directly with lead shotgun pellets or bullets.

Objectives

The overall objectives of this study were:

1. To determine if lead is bioavailable to birds of prey in Madre de Dios, Peru.
2. To compare concentrations of lead in blood of birds of prey which occupy different trophic levels.
3. To compare concentrations of and lead in blood of individuals and species to determine if there is a relationship between capture site habitat characteristics and lead concentrations.
4. To determine if other variables such as age, sex, weight, or season of capture were related to lead concentrations.
5. To compare concentrations of lead found in birds of prey to toxic reference values (TRVs) for birds to determine the risk from lead.

The results of this study will provide insight as to the threat to raptors from lead. The results will be reviewed by Peruvian agencies responsible for ecosystem monitoring.

METHODS

Study Area: The study was conducted at the Los Amigos Research Station, in Madre de Dios, Peru (Fig. 1). This research station is situated on the grounds of a former gold- mining camp at the confluence of the Los Amigos River and the Madre de Dios River. Gold mining continues along the Madre de Dios, and many active small-scale mining operations are visible from the research station. Pristine forest remains in the areas untouched by mining. Birds were captured in both pristine and disturbed areas. With its known history of use, and its present proximity to active mining operations, this station was ideal for sampling birds from a potentially contaminated area.

Capture sites were classified according to characteristics. Capture site characteristics included: riverine, backwater, undisturbed forest, disturbed area, upland forest, and edge.

Trapping Birds of Prey: Birds were captured using variants of Bal Chatri (BC) traps (Fig. 2). The BC trap is a painted hardware cloth enclosure with monofilament nooses tied to the top and sides, and contains a lure animal (Bergen and Mueller 1959). The nooses close on the raptor's legs or toes when it attempts to catch the potential prey (Thorstrom 1996). Risk of injuries for raptors and bait animals is minimal if BCs are constantly monitored (Thorstrom 1996). Both live prey and mechanical bait decoys were used as lures inside the BCs.

The live prey items included young chickens (*Gallus gallus*), guinea pigs (C*avea porcellus*), gerbils (*Meriones unguiculatus*), and hamsters (sub-family *Cricetinea*). Each animal was fully vaccinated before arrival at the research station. With the exception of the chickens, only castrated male domestic animals were used, so as to remove any chance of accidental introduction. Bait animals were safely closed inside the BC trap, and two individual closure methods were employed to ensure their safety and confinement. The traps were securely anchored by two separate means so that they could not be moved or carried away when struck.

The mechanical prey item decoys used were hunting decoys commercially available for hunters of small game predators. They are designed to mimic movement of small mammals or birds. They operate on one to four AA batteries, and move at pre-set intervals. They were enclosed in the BC traps in the same manner that the live animals are, so they could not be removed when struck. Along with the mechanical decoys, a commercially available recording was broadcast from a nearby hidden compact disc player and speaker. The sounds emitted were appropriate to the decoy. For example, a distressed bird call was used alongside a mechanical decoy of a struggling bird inside a BC trap, or a distressed rodent sound was broadcast alongside the BC containing the mechanical rodent decoy.

Lead Analysis: Eighty-six blood samples were diluted 1:10 with a 1% Triton X-100 (Fisher Scientific) solution in 0.2% (w/v) nitric acid diluent (analytical grade 70%, Fisher), and vortexed for 30 seconds. Pb analyses were performed using a Thermo® M-Series Graphite Furnace-Atomic Absorption Spectrophotometer with a transversely heated graphite atomizer, and an FS95 autosampler (Thermo® Electron Corp. Waltham, MA, USA). All data were captured by Thermo® SOLAAR (version 10.10) instrument control software. Spectral absorbance for Pb was corrected for background interference using a Zeeman background correction system. Eight-point matrix-matched (Pb-free pig blood spiked with a progression of Pb concentrations) calibration curves were developed before each run using Pb standards. Matrix stabilization was acquired by adding 5 μg Pb and 3 μg MgH_2NO_3 to each sample. All analytical data were expressed as ng Pb/mL blood (w.w.). The accuracy of digestion and analytical methods was determined by the use of a certified bovine blood standard reference material (SRM; 955b; National Institute of Standards and Technology, Gaithersburg, MD, USA), and Pb-spiked pig blood. Blanks and standard reference materials and/or spikes were run at least every 12 samples, and the spectrophotometer was recalibrated after every 20 samples. Pb recovery from SRMs was 98% ± 2% (n = 12) and from spikes was 100% ± 2% (n = 6). The method detection limit for blood Pb was 0.001 ppm (parts per million) based on the analysis of eight Pb-spiked blood samples analyzed in duplicate.

Statistical Analysis: Statistical analyses were conducted using Statistical Analysis System, SAS 9.1 (SAS Institute, Inc. 2002). Pb concentrations for each individual sample, for each species, and then for the entire sample pool were analyzed. Simple Linear Regression was used to analyze relationships between Pb concentrations and capture site habitat characteristics, species, weight, age, sex, and season of capture. ANOVA and Multiple Regression were used to analyze relationships between Pb concentrations and capture site characteristics. Species with sample numbers of two or less were excluded from statistical analyses.

RESULTS

A total of 86 raptors were captured and blood samples were collected for Pb analysis. The results of blood sample analyses for Pb concentrations ranged from below levels detectable (bld, < 0.001 ppm) to 1.272 ppm. Table 2 contains the results by species. The majority of the birds sampled had levels less than 0.200 ppm (n = 76). Nine individuals had levels ranging from 0.201 to 0.610 ppm. One individual, *Buteo magnirostris* # 23 (sample BuMa 23) had a level of 1.272 ppm.

Statistical analysis showed no significant relationship ($p > 0.05$) between lead concentration and habitat characteristics, age, sex, weight, species, or season of capture. Pb concentrations were compared with mercury concentrations for each individual sample, and no relationship was found.

DISCUSSION

Blood lead concentration analysis is a useful, non-invasive method for monitoring lead exposure in wild populations without sacrificing the individual (Mautino and Bell 1987). Avian toxic reference values for lead in blood range from 0.2 ppm to > 1.0 ppm (Beyer et al. 1985). Lead concentrations in blood less than 0.1 ppm are considered normal in uncontaminated areas (Feierabend and Myers 1984). Blood concentrations of lead ranging between 0.2 and 1.5 ppm result in sub-clinical effects, levels above 1.0 ppm cause toxicological effects, and results greater than 7.5 ppm are consistent with death (Franson 1996, Beyer et al 1985). Nine individuals had levels in the range causing sub-clinical toxicological effects. All nine birds appeared healthy upon capture, and were within normal weight parameters for their sex and species.

The individual with the highest blood Pb concentration, BuMa 23, also appeared healthy upon capture, and was in good body condition and normal weight range. BuMa 23 was captured within an active mine site, and close to the miners' homes and land in which the miners frequently hunt. Possible explanations for this individual's lead level include: survival of shooting with lead shot, ingestion of a prey item which had been shot with lead shot or had ingested lead shot, or possibly exposure to contamination due to the combustion of leaded gasoline.

Lead blood concentrations detected in this study are consistent with or lower than findings from evaluation of raptor blood samples from other parts of the world. Migratory Cooper's Hawks (*Accipiter cooperii*) of various ages and migratory stages in the Rocky Mountains of the United States were found to have similar blood lead levels to the raptors in this study; and 3% of the Cooper's Hawk's sampled equaled or exceeded background levels (McBride et al. 2004). Ferrunginous Hawks (*Buteo regalis*) and Golden Eagle (*Aquila chrysaetos)* blood lead levels at Thunder Basin National Grassland in Wyoming, USA were below sub-clinical levels (Stephens et al. 2000). Blood levels consistent with lead toxicosis were found in Bald Eagles (*Haliaeetus leucocephalus)* from two regions of the North American Great Plains (Miller et al. 1998) and falcons (Genus *falco*) in Saudi Arabia.

LITERATURE CITED

Berger, D.D., and Mueller, H.C. (1959). The bal-chatri: a trap for birds of prey. Bird Banding 30: 18-26.

Burger, J. and Gochfield, M. 2000. Effects of Lead on Birds (Laridae): A Review of Laboratory and Filed Studies. Journal of Toxicology and Environmenatl Health, Part B. 3:59-78.

Eisler, R. Lead Hazards to Fish, Wildlife, and Invertabrates: A Synoptic Review. Washington D.C.: U.S. Fish and Wildlife Service.

Hoffman DJ, Rattner BA, Burton GA, Cairns J. (1995) Handbook of Ecotoxicology. CRC Press, Inc. 392-395.

Feierabend, J.S. and Myers, O. 1984. A notional summary of lead poisoning in Bald Eagles and waterfowl. National Wildlife Federation, Washington, D.C.

Franson, JC. 1996. Interpretation of tissue lead residues in birds other than waterfowl. Pages 341-356 in WN Beyer, GH Heainz, and AW Redmon-Norwood (eds) Environmental Contaminants in Wildlife. Lewis Publishers, Boca Raton, Florida.

Miller, MJR, Restani, M, Harmata AR, Bortolotti GR, and Wayland, ME. 1998. A Comparison of Blood Lead Levels in Bald Eagles from Two Regions on the Great Plains of North America. Journal Of Wildlife Diseases 34(4). 704-714.

Mautino, M and Bell JU. 1987. Experimental Lead Toxicity in the Ring-necked Duck.

Environmental Research 41: 538-545.

McBride TJ, Smith JP, Gross HP, and Hooper, MJ. 2004. Blood-Lead and ALAD Activity Levels of Cooper's Hawks Migrating through the Southern Rocky Mountains. Journal of Raptor Research 38 (2): 118-124.

Schulenburg TS, Stotz DF, Lane DF. (2007). Birds of Peru. Princeton University Press. Pages 85-116.

Thorstrum, Russell K. (1996). Methods for Capturing Tropical Forest Birds of Prey. Wildlife Society Bulletin 1996, 24(3): 516-520.

Table 3.1 Concentrations of Lead in Blood Samples of hawks captured in the Amazon River Basin of Peru.

	Number Captured	Lead Concentration (mg/kg or ppm)	
Species	**(n)**	**Mean**	**Range**
Accipiter bicolor	2	BDL	BDL
Buteo magnirostris	35	0.105	BDL - 1.272
Buteo platypterus	1	BDL	BDL
Buteogallus urubitinga	1	BDL	BDL
Daptrius ater	1	BDL	BDL
Harpagus bidentatus	1	BDL	BDL
Leucopternis kuhli	2	BDL	BDL
Leucopternis melanops	1	0.056	0.056
Leucopternis schistacea	11	0.081	BDL - 0.411
Micrastur buckleyi	2	BDL	BDL
Micrastur gilvicollis	12	0.14	BDL - 0.494
Micrastur mirandollei	2	BDL	BDL
Micrastur ruficollis	9	0.080	BDL - 0.605
Micrastur semitorquatus	4	BDL	BDL

Key:
BDL = Below Detectable Level

CHAPTER 4

A VARIATION OF THE BAL-CHATRI TRAP FOR OPEN AREAS

During the course of an investigation of mercury levels in raptors of southeastern Madre de Dios, Peru, a new adaptation of the Bal Chatri (BC) trap was developed and employed. The new method was developed for birds which were observed walking around or attempting to turn over the standard BC without actually touching the noosed area of the trap. The new adaptation was successful for all seven raptors which were located and targeted for the use of this new adaptation.

The Bal-Chatri (BC) trap is a painted hardware cloth enclosure containing a lure animal and monofilament nooses tied to the top and sides (Bergen and Mueller 1959) (Fig.4). The device is an adaptation of ancient technique developed by East Indian falconers (Bergen and Mueller 1959). The standard Bal-Chatri is quonset-shaped (Berger and Hamerstrom 1962), although several variations have been used (Thorstrom

1996). The Bal-Chatri can be secured either with weights, or by tying it to a fixed object such as a tree, so that it cannot be removed when it is struck by the raptor. For the purpose of this study, raptors were captured using previously described design variations as well as one new design.

Previously described methods used to capture raptors include the standard Bal-Chatri, and an envelope Bal-Chatri (Thorstrom 1996). The envelope design is pouch-shaped with nooses on the top. It is best suited for capturing raptors which have been flushed while feeding on a prey item (Thorstrom 1996). The raptor will often leave the prey item when startled, and the prey item is then placed in the pouch and quickly returned to the location where the raptor was feeding and secured. The raptor will often return for the prey item, and can be captured while attempting to continue feeding (Thorstrom 1996). This design was effective for all three birds which we encountered feeding and flushed. Captures using the envelope Bal-Chatri included one juvenile Collared Forest-Falcon (*Micrastur semitorquatus*), and two adult Roadside Hawks (*Buteo magnirostris*).

The new method can be described as a Platform Bal-Chatri (Fig. 5), and was developed for the capture of Great Black Hawks (*Buteogallus urubitinga).* This species is commonly seen hunting by walking on sandy riverbanks. While attempting to capture this species with a standard Bal-Chatri containing a dead fish (unknown species) or a young chicken (*Gallus gallus*), it was observed that several individuals were attracted to the trap, but only walked around it, or occasionally turned it over by scratching beside it in the sandy bank. To capture this species, a standard Bal-Chatri was placed on a platform measuring approximately 3 feet by 3 feet and covered with 30 pound test monofilament line tied in nooses. It was then baited with a lure animal such as a dead fish or a young chicken, weighted on all four corners with iron disc weights to prevent it from being turned over, and placed on the beach. This trap was effective on all four Great Black Hawks we attempted to capture, as well as attracting and capturing two Black Caracara (*Daptrius ater*) which had been observed standing or circling beside but not striking the standard Bal-Chatri, and one Roadside-Hawk (*Buteo magnirostris*) which was observed several times standing next to but not striking the standard BC.

The new Platform BC is suitable for catching birds which may be drawn to other types of BC traps but hesitant to strike them; and seems to be particularly effective in open areas such as fields or river banks. The size of the trap and the difficulty in transporting it may limit its use in forested or remote areas.

LITERATURE CITED

Berger, D.D., and Mueller, H.C. 1959. The bal-chatri: a trap for birds of prey. Bird Banding 30: 18-26.

Thorstrum, Russell K. 1996. Methods for Capturing Tropical Forest Birds of Prey. Wildlife Society Bulletin 1996, 24(3): 516-520.

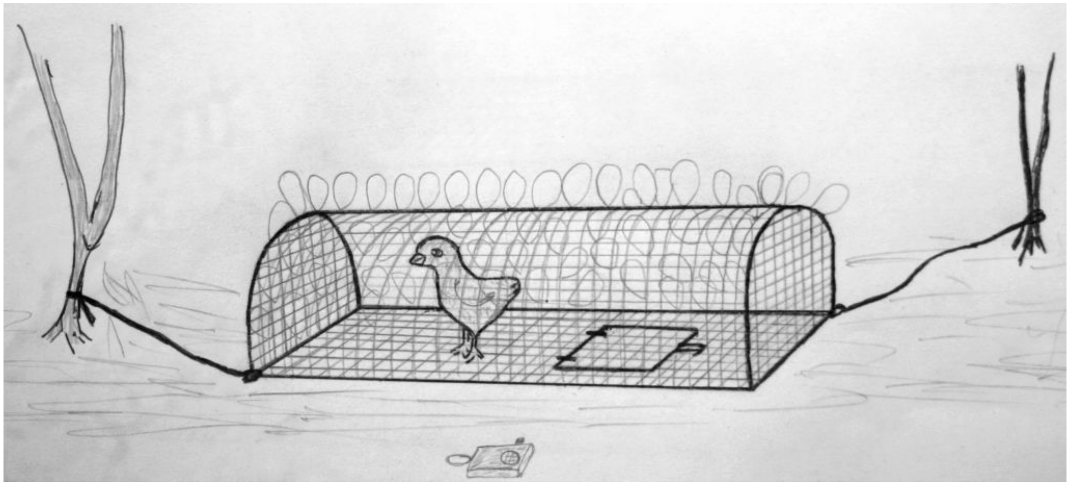

Figure 4.1 Standard Bal-Chatri trap.

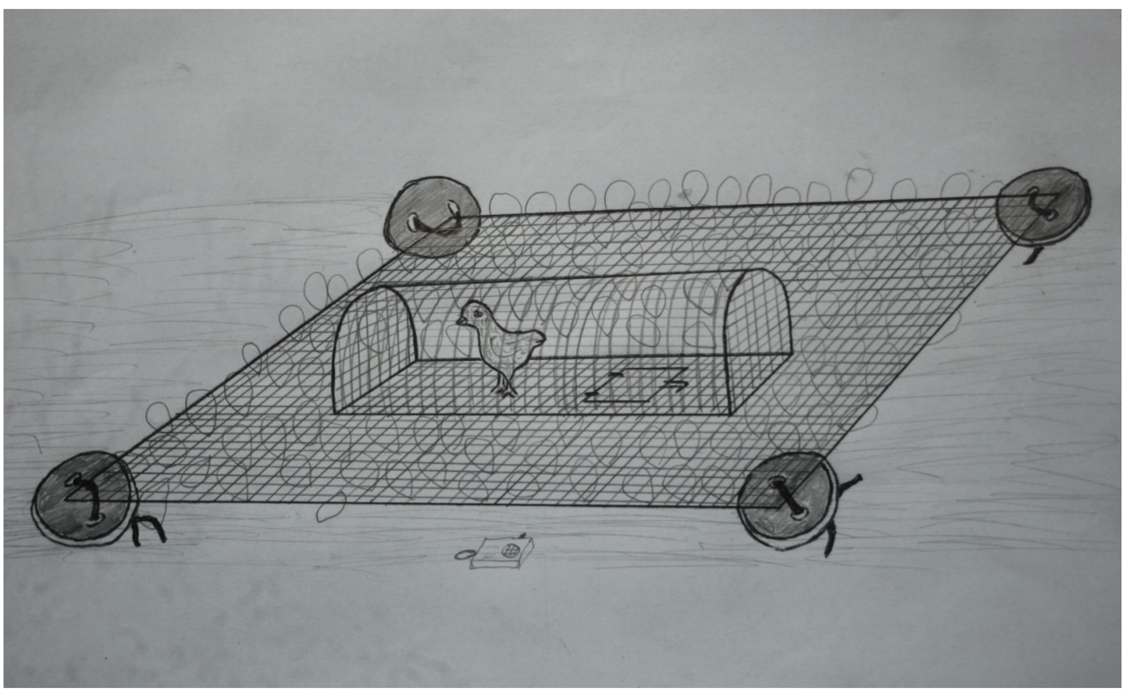

Figure 4.2 Platform Bal-Chatri

CHAPTER 5

CAPTURE OF DOUBLE-TOOTHED KITE (*HARPAGUS BIDENTATUS)* IN A BAL-CHATRI TRAP

The Double-toothed Kite (*Harpagus bidentatus)* is a small (~ 200 g) accipiter-like raptor occupying the humid tropical and subtropical forests of Central and South America. This kite is named for the two tomial "teeth" formed by notches in the upper mandible. Their diet consists of lizards and insects snatched from the air or from limbs and foliage, and they are known to follow monkey troops and possibly army ants (Ferguson-Lees and Christie, 2001) to forage on the prey disturbed by the movement. They may even encourage movement of monkey troops by swooping down and touching them with their talons (Ferguson-Lees and Christie, 2001). During the course of an investigation of mercury levels in raptors of southeastern Peru, one Double-toothed Kite was captured in a Bal-Chatri trap on the forest floor, with a black rat (*Rattus rattus*) as a lure.

On 01 December 2006 at 10 30, a Double-toothed Kite was captured in Bal-Chatri trap on the forest floor near The Los Amigos Biological Station in Madre de Dios, Peru (380500E 8610297N). The lure animal inside the trap was a medium-sized (~ 350 g) black rat. The kite was an adult weighing 197 grams. The sex of the individual is unknown, as its weight of 197 g falls within the known weight range for males (175-198 g) and females (190-229 g) (Brown and Amadon, 1968). The whole body measurement was 32.1 centimeters (cm) and the wing chord measured 21.8cm. The individual was in good body condition.

The capture area was upland mature forest with slopes, and a small creek was located ~ 300 metes from the capture site. The bal-chatri trap was placed on the ground near a fallen tree which had created a significant clearing in the canopy. A call box, which emitted the sound of a distressed rat, was placed beside the trap. The weather was sunny with no wind. No monkey troops were noted nearby, but the bird could have been in the trap for as long as twenty minutes.

Based on existing information for this species, this was an unexpected capture, as these kites generally are not known to feed on the forest floor, nor to take mammals consistent with the size rodent in the trap. Double-toothed kites were observed during nesting and 550 prey items were identified: 60.6% insects, 38% lizards, and 1.4% rats, snakes, birds, and bats (Shulze et al, 2000). To increase efficiency; larger prey items relative to the kites' size may be taken during nesting (Shulze et al, 2000). The individual captured may have been nesting, based on the time frame and known nesting periods of Double-toothed Kites (early to mid rainy season) (Shulze, et al 2000), however, no brood patch was noted. The capture of this bird in a Bal-Chatri may represent an option for trapping and further study of this species which may otherwise have been overlooked due to known prey preferences or previously known hunting techniques.

CHAPTER 6

DESCRIPTION OF TWO BLACK-FACED HAWKS (*Leucopternis melanops)*
CAPTURED IN MADRE DE DIOS, PERU

The genus Leucopternis includes 10 species of South American forest raptors. Seven species of Leucopternis occur in Peru, although their distribution remains poorly understood (Bierregard 1995, Martuscelli 1996). *L. melanops* and its sister species, *L. kuhli*, are both small (~ 40 cm) forest hawks distinguishable by only subtle differences in plumage and call. They were once thought to be conspecifics and more recently have been thought to replace one another north (*L. melanops*) and south (*L. kuhli)* of the Amazon River (Meyer de Schaunesee 1966, Brown and Amadon 1968, Haffer 1987, Sick 1997).

Recent investigations reveal that these two species may be sympatric; and that *L. melanops* irregularly occurs south of the Amazon River (Raposo Do Amaral et al., 2007). Recently, two *L. melanops* were captured and photographed (Barlow et al, 2002) in the lower Tapajos River area, which is south of the Amazon River in Brasil; and these captures were only 6 km from capture sites of *L. kuhli*, documenting the sympatry of these species (Raposo Do Amaral et al, 2007).

During the course of an investigation of mercury levels in raptors of Madre de Dios, Peru, two *L. melanops* and six *L. kuhli* were captured. All captures occurred within 14 km of each other, in similar upland mature forest, further suggesting the sympatry of these two species.

The first *L. melanops* was captured on 04 June 2007 at 930 ~6 km from the Los Amigos Research Station (380500E 8610297N) in a Bal-Chatri trap containing a juvenile chicken (*Gallus gallus*) as a lure. The individual weighed 366 grams, and had a whole-body measurement of 36.2cm.

The second *L. melanops* was captured in a Bal-Chatri trap on 15 July 2008 at 12 42 ~ 2 km from the Los Amigos Research Station.

Confusing similarities in plumages of juvenile *L. kuhli* and juvenile and adult *L melanops*, and the unlikelihood of sympatry of such similar species makes identification difficult and controversial. Captured individuals were identified according to most recent descriptions of diagnostic characteristics. *L. kuhli* adult plumage consistently has a dark, almost solid black head with a white supercilium, no white blotches on the back, and one white tail band (Raposo Do Amaral et al., 2007). Juvenile *L. kuhli*, which are most easily confused with both adult and juvenile *L. melanops*, have a white head with black streaking and a prominent black mask, white mottling on the back, and two white tail bands (Raposos Do Amaral et al., 2007). *L. melanops* adult plumage is similar to that of juvenile *L. kuhli* in that the head is white with black streaks and a prominent black mask, and there is white mottling on the back. The only characteristic that definitively distinguishes the juvenile *L. kuhli* from the adult *L. melanops* is the single white tail band of the adult *L. melanops*, versus the two banded tail of juvenile *L. kuhli (*Raposo Do Amaral et al., 2007). The captured individuals in Madre de Dios (Fig. 6*)* had a white head with black streaking, a prominent black mask, white mottling on the back, and only one tail band; and were therefore identified as adult *L. melanops.* Identification was confirmed at the American Museum of Natural History by (insert name), Fabio Raposo Do Amaral, and William S. Clark. Collaborative DNA analysis of captured individuals will be done when funding permits.

LITERATURE CITED

Barlow J, Haugasen T, and Peres CA. (2002) Sympatry of the Black-faced Hawk and White-browed Hawk in the lower Rio Tapajos, Para, Brasil. Cotinga 18: 77-79

.Bierregard RO. (1995). The biology and conservation status of Central and South American Falconiformes: a survey of current knowledge. Bird Conservation International 5: 325-340.

Fergusson-Lees J, and Christie DA. (2001) Raptors of the World. Houghston Miffin Press. New York, NY. USA.

Haffer J. (1997) Neotropical biogeography of birds. Biogeography and quaternary history in the tropical Americas. Ed:Whitmore and Prance. Claredon Press. New York, NY. USA.

Martuscelli P. (1996). Hunting behavior of the mantled Hawk and the White-necked hawk in Southeastern Brasil. Bull. Brit. Ornithologists Club 116: 114-116

Meyer de Schaunsee R. (1966) The species of birds of South America and their distribution. Livingston Publishing Company. PA. USA

Raposo Do Amaral FS, Silviera LF, and Whitney BM. (2007). New localities for the Black-faced Hawk south of the Amazon River and the description of the immature plumage of the White-browed Hawk. The Wilson Journal of Ornithology 119 (3): 450-454.

Figure 6.1 Leucopternis melanops