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BEHAVIORAL DIFFERENCES BETWEEN URBAN AND RURAL
AMERICAN CROWS (*Corvus brachyrhynchos*)

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Experimental Psychology

by

Carolina Montenegro

July 2017

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

Carolina Montenegro

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

Dr. Kara Gabriel, Committee Chair

Dr. Susan Lonborg

Dr. Tonya Buchanan

Dean of Graduate Studies

ABSTRACT

BEHAVIORAL DIFFERENCES BETWEEN URBAN AND RURAL

AMERICAN CROWS (*Corvus brachyrhynchos*)

by

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The consequences of transforming a natural environment into a human-modified environment (i.e., urbanization) on wildlife has long been a topic of concern, but has been hampered by a lack of empirical evidence focused on animal behavior. The current study was designed to explore behavioral differences between urban and rural American crows (*Corvus brachyrhynchos*) by installing baited perches in urban and rural settings in Kittitas County, Washington. In order to observe differences in urban and rural crow behavior to approach or avoidance-oriented stimuli, perches included custom cameras and audio equipment that alternated between periods of playing crow calls or Red-tailed hawk (*Buteo jamaicensis*) calls. As originally designed, this experiment hypothesized that stress behaviors such as caching, preening, vigilance, and boldness (i.e., approach/avoidance) would differ in response to environmental setting (i.e., urban, rural) and audio stimulus type (i.e., approach call, avoidance call). Unfortunately, total sample size of crows did not provide enough power to investigate dependable behavioral outcomes. When examining overall bird data, birds visited rural areas more often compared to urban areas but spent shorter periods of time on perches in rural environments. Overall, there were no observed behavioral differences in response to

audio stimuli, suggesting that conspecific and heterospecific communication is more complicated than indicated in previous research.

ACKNOWLEDGMENTS

I would like to acknowledge the team of people that made this project possible:
Dr. Kara Gabriel, Dr. Susan Lonborg, Dr. Tonya Buchanan, Dr. Alison Scoville, Mr.
Chris Buchanan, Ms. Katelyn Buchanan, Ms. Sue Hammond and her family, Justin,
Physical Facilities, Graduate Studies and Research, the 2015-2017 Experimental
Psychology cohort, Joel Lambert, Gary Koch, and all the professors and professionals I
consulted regarding this study.

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CHAPTER I

INTRODUCTION

Despite a considerable amount of scientific literature on the topic, the effects of environmental changes on behavior are not fully understood. In our ever-changing world, the anthropogenic pressures of human activity are increasing and have a significant effect on ecosystem function (Liu, Daily, Ehrlich, & Luck, 2003; Seto, Güneralp, & Hutya, 2012; Vitousek, Mooney, Lubchenco, & Melillo, 1997). Through urbanization, humans are not only affecting their own environment but also that of flora and fauna (Hamer & McDonnell, 2009; McKinney, 2002). By investigating differences between species, specifically American crows (*Corvus brachyrhynchos*) that can survive in urban and rural environment, we can better understand what adaptations, personality, or cognitive abilities aid in survival and hopefully better environments for all.

One of the factors that likely impacts the way that crows respond to environment is by vocalizations, typically distinguished as friendly or unfriendly calls, alarms, songs, and many more variations (CrowBusters, 1999; Hauser & Caffrey, 1994; Marzluff et al., 2009). Crows are a more than adequate subject as they live in numerous types of climates and areas, are intelligent, and social (Bird & Emery, 2009; Hunt, 2014; Luniak, 2004; Marzluff, McGowan, Donnelly, & Knight, 2001). Less is known regarding stress in corvids and how stress may translate behaviorally. However, looking at past studies and studies of closely related species, several behaviors such as preening, caching, and vigilance may act as a measure of stress (Boukhriss, Selmi, Béchet, & Nourira, 2006; Bugnyar, Stowe, & Heinrich, 2007; La Saout et al., 2015; Randler, 2005; Salwiczek,

Emery, Schlinger, & Clayton, 2009; Sima, Pika, & Bugnyar, 2015). In addition, changes in animal behavior have been measured to assess individual personality traits and can be applied to adaptations and life in an urbanizing environment (Echeverria & Vassallo, 2008; Scales, Hymans, & Hughes, 2011; Selmann, Jaatinen, Steele, & Öst, 2014).

CHAPTER II

LITERATURE REVIEW

Urbanization

Urbanization is defined as the shift of populations from rural to urban areas. Throughout the world, the anthropogenic pressures of human activity are increasing and have a significant effect on ecosystem function (Vitousek et al., 1997). Urban sprawl is continuously progressing and rapidly changing our global environment (Liu et al., 2003; Seto et al., 2012; Vitousek et al., 1997). Growth occurs through the increase of populations in developed and developing areas; these areas are then defined as urban (Liu et al., 2003). The urbanization process involves converting a natural habitat into a human-modified ecosystem and leads to a reduction of biodiversity as well as an increase in invasive plant and animal species (Hamer & McDonnell, 2009; McKinney, 2002). By rapidly changing the delicate balance of ecosystems, humans are not only affecting their own environment but also that of flora and fauna (Hamer & McDonnell, 2009; McKinney, 2002). The urbanization process is not projected to remain steady or to decrease and, therefore, it is imperative to study the effects of urbanization on plants and animals (Hamer & McDonnell, 2009; Liu et al., 2003; McKinney, 2002; Seto et al., 2012; Vitousek et al., 1997).

Rural habitats, which are typically defined as areas largely unsettled by humans but not absent of the presence of humans, become fragmented through the urbanization process (Donovan, Thompson, Faaborg, & Probst, 1995; Fischer & Lindenmayer, 2007; Marzluff, Bowman, & Donnelly, 2001). Habitat fragmentation breaks up large natural

habitats into smaller, isolated habitats that cannot sustain the same diversity as specific animal and plant interactions decrease (Donovan et al., 1995; Fischer & Lindenmayer, 2007; Luginbuhl, Marzluff, Bradley, Raphael, & Varland, 2001). Animal and plant populations inhabiting a fragment usually rely on migrating populations to bring in necessary resources but migrating populations typically choose to migrate to larger continuous areas rather than isolated habitats (Donovan et al., 1995). Animals that remain in rural habitats or move to rural environments are still at risk due to environmental changes that may occur too rapidly for them to adapt (Quintero & Wiens, 2013; Vitousek et al., 1997). In addition, remaining habitats tend to continue to reduce in size and are, therefore, increasingly unable to support the influx of migrating animals (Fischer & Lindenmayer, 2007).

Urbanization and Wildlife

Wildlife either adapts to modified environments or faces local extinction. Some wildlife move into urban environments and species that tend to engage in this behavior include coyotes, deer, raccoons, cougars, rats, bats, and birds (Hamer & McDonnell, 2009; Krausman, Christensen, McDonald, & Leopold, 2014; McKinney, 2002; Murray et al., 2015; Prange, Gehrt, & Wiggers, 2003). An animal that is able to survive in an urban area is considered a synanthrope and the process by which animals adapt to an urban environment is called synurbization (Luniak, 2004). Synurbization presents several stressors for animal populations including habitat loss, habitat fragmentation, and changes in diet and vegetation (Estes & Mannan, 2003; Hamer & McDonnell, 2009; Schlesinger, Manley, & Holyoak, 2008). Furthermore, urban animals are exposed to the

stress of human disturbance that can result in diurnal behavioral and physiological changes in order to avoid humans and in response to artificial light, cars, and toxic gases. Diurnal changes may also involve modifications in learning and feeding styles (Hamer & McDonnell, 2009; Nordt & Klenke, 2013; Russ, Rüger, & Klenke, 2015; Schlesinger et al., 2008; Seferta, Guay, Marzinotto & Lefebvre, 2001). For animals, the benefits of urban environments include warmer winter microclimates, anthropogenic food supplies, artificial lights that aid in detecting predators, and regulations that may protect animals from human harm (Heiss, Clark, & McGowan, 2009; Krausman et al., 2014; Prange et al., 2003).

Stress

While urbanization offers some protection to wildlife, the number of stressors is thought to outweigh the benefits. A stressor is what helps an organism react to a threat. The physiological response to encountering a stressor results in activation of the hypothalamic-pituitary-adrenal (HPA) axis. The hypothalamus signals for the release of corticotrophin-releasing hormone to the pituitary gland, which then signals for the release of adrenocorticotrophic hormone, which travels to the adrenal gland and triggers the release of glucocorticoids into the blood. Once in the blood, stress hormones such as the glucocorticoid, cortisol, travel around the body affecting organs that contain glucocorticoid receptors and an organism can then respond to the stressor after which the HPA cycle continues (Anestis, 2010; Melmed, Polonsky, Larsen, & Kronenberg, 2015; Norris & Carr, 2013).

Once cortisol reacts with the appropriate receptor, the effects of stress are displayed through an organism's behavior and physiology. For example, cortisol affects blood sugar levels, regulates metabolism, reduces or increases inflammation depending upon the specific immune pathway, and has been shown to affect cognitive abilities such as memory (Melmed et al., 2015; Pravosudov, Mendoza, & Clayton, 2003; Sapolsky, 2002; Sapolsky, Romero, & Munck, 2000). Depending on glucocorticoid concentration and the length of the stressful situation, these effects can be beneficial or detrimental to an organism's health and well-being. In a stressful situation, animals feel a sense of urgency and enter an "emergency life history stage" through the HPA cycle (Wingfield et al., 1998). In contrast to the beneficial effects of acute activation of the HPA cycle, chronic stimulation of the stress response can cause insulin-resistant diabetes, gastrointestinal ulcerations, hypertension, impotence, osteoporosis, depression, immunological disorders, and a host of other deleterious effects (Melmed et al., 2015; Sapolsky, 2002). Additionally, high levels of stress can cause cells that would not normally have glucocorticoid receptors to accept cortisol, possibly exacerbating cortisol's harmful effects (Melmed et al., 2015; Norris & Carr, 2013; Sapolsky et al., 2000).

Reproductive health is also impacted by stress (Melmed et al., 2015). Cortisol is derived from progesterone, a hormone that is the source of testosterone and estrogen, which are both essential to reproduction. Testosterone is necessary for producing eggs and sperm, and estrogen for egg production. When under chronic stress, fertility is no longer as important as survival especially for animals in captive-type settings such as zoos and wildlife refuges (Melmed et al., 2015). Recent studies and meta-analyses have

only defined productivity and survivability in different bird species in urban environments, producing mixed results (Chamberlain et al., 2009; Marzluff, Bowman et al., 2001). It is possible that when an animal facing urbanization experiences chronic stress, the animals' productivity decreases (Chamberlain et al., 2009). However, it may also be plausible that an urban animals' productivity decreases as an adaptation to the stressful environment (Chamberlain et al., 2009).

Measuring stress and defining chronic stress are difficult processes due to differences between species and between individuals within a species. Between and within species, factors such as personality, developmental differences, physiological differences, age, sex, environment, and social interactions all influence the stress response (Melmed et al., 2015; Sapolsky, 2002; Seferta, et al., 2001; Stracey & Robinson, 2012; Walker, Boersma, & Wingfield, 2005).

Corvids (*Corvus*) Overview

American crows are of the *Corvus* genus, corvidae family, and passerine species, also known as perching birds (Cornell Lab of Ornithology, 2015). American crows are characterized by their large size (0.5 meters long, 1.0-meter wingspan), long legs, thick neck, squared tails, and black bodies. They are commonly found throughout North America. Crows often inhabit fields, woodlands, forests, as well as cities and towns (Cornell Lab of Ornithology, 2015). They are especially social animals, curious, great learners, and problem solvers (Bird & Emery, 2009; Cornell Lab of Ornithology, 2015; Hunt, 2014). Crows can also be aggressive towards other animals and people. However, aggressive behavior is usually in response to a threat (Cornell Lab of Ornithology, 2015;

Marzluff, Walls, Cornell, Withey, & Craig, 2009). Mobbing behavior involves multiple crows grouping together to attack a threat (Audubon Society of Portland; Lorenz, 1967, Marzluff, 2009). In a field study, American crows exhibited alarm calls and would mob any person wearing a mask that was previously worn during the trapping and banding of American crows in the area (Marzluff et al., 2009). Not only did the crows display aggressive behavior towards masked individuals, but also did so for at least 2.5 years (Marzluff et al., 2009). Crows also display mobbing behavior more often when nesting and protecting young (Audubon Society of Portland; Lorenz, 1967). American crows are opportunistic. They will feed on a wide variety of food such as grains, seeds, nuts, fruits, a variety of worms, mice, insects, fish, turtles, frogs, clams, birds, bird eggs and nestlings, carrion, litter, and garbage (Cornell Lab of Ornithology, 2015; Kress, 2006). On average, crow families include up to 15 individuals, and up to five generations of crows. Crows will typically breed at four years of age or older, and remain with their family unit to help raise young (Cornell Lab of Ornithology, 2015).

The common raven (*Corvus corax*) is a different species of the *Corvus* genus, appears similar to a large crow, and has many of the same features of the American crow, including physical distribution, intelligence, ability to coexist with humans, and cultural roots (Cornell Lab of Ornithology, 2015). Ravens have shown conflict management strategies, a characteristic of a developed social life (Sima et al., 2015). Ravens choose whom in their group to feed with and, after conflict due to shortages of food occur, ravens engage in allo-preening, which is defined as preening another individual, as a form of post-conflict behavior and resolution (Sima et al., 2015). While the same study

has not been replicated with crows, due to their similarity to ravens it is plausible for crows to display the same conflict management behaviors.

Audio Calls

Crows are vocal animals, using calls and sometimes song for social bonding, reducing aggression within group, and communication (Brown, 1985b; Hauser & Caffrey, 1994). Wild crows (*Corvus brachyrhynchos hesperis*) and other bird species have diverse sensory mechanisms that have evolved to detect predators and for within group communications (Hauser & Caffrey, 1994; Hettena, Munoz, & Blumstein, 2014). When testing wild crows in the field, crows could differentiate between a red-shouldered hawk (*Buteo lineatus*) call and a Madagascar harrier hawk (*Polyboroides radiates*) call (Hauser & Caffrey, 1994). When examined spectrally, the two calls are similar, however, wild crows only encounter red-shouldered hawks in the habitat studied (Hauser & Caffrey, 1994). Crows flew from the red-shoulder hawk call but remained in the testing area when encountering the unfamiliar harrier hawk call (Hauser & Caffrey, 1994). The wild crows were also able to differentiate between the red-shouldered hawk call and a great horned owl (*Bubo virginianus*) call (Hauser & Caffrey, 1994). In response to the owl call, crows flew towards the audio source while performing alarm calls and a mobbing response (Hauser & Caffrey, 1994). Yellow-casqued hornbills (*Certaogymna elata*), great blue turaco (*Corythaeola cristata*), song sparrow (*Melospiza melodia*), and several wren (*Troglodytidae*) species also display changes in behavior (i.e., scanning, flight, vigilance, foraging) when presented with a predator call (Hettena et al., 2014).

Hunters frequently use birdcalls to lure crows into specific areas (CrowBusters, 1999). Hunters' use a variation of "friendly" and "fighting" calls that are tested in the field through trial and error (CrowBusters, 1999). "Friendly" calls reflect welcoming communication between crows, such as a call for another crow's attention (CrowBusters, 1999). "Fighting" calls imitate crows in conflict (i.e., call for help, alarm call) (CrowBuster, 1999; Hauser & Caffrey, 1994; Marzluff et al., 2009). Researchers have also evaluated captive raptors (birds that hunt animals) responses to American crow fighting calls (Consla & Mumme, 2012). When listening to a mobbing call playback, raptors moved their head toward the location of the speakers, raised their feathers, and shifted positions on a perch (Consla & Mumme, 2012). The effect of the mobbing call supports the "move on" hypothesis, mobbing induces stress in predators, causing them to move to a different area (Curio, 1978). American crows exhibit alarm calls, attention calls, and a mix of the two in response to crow friendly and fighting calls (Brown, 1985a). Crows will also communicate with the sender of the call regardless of familiarity (Brown, 1985a). In addition, a study of wild corvid nest predation utilized friendly corvid calls, and predator calls to maximize the likelihood of spotting and hearing crows (Luginbuhl et al., 2001). Overall, the use of audio stimuli including conspecific and heterospecific calls can be successful in attracting bird and crow attention.

Corvid Intelligence

Recent studies have shown high levels of intelligence in corvids through novel multistep problem solving and tool-use (Bird & Emery, 2009; Hunt, 2014). Rooks (*Corvus frugilegus*) are a different species of the *Corvus* genus, similar in size and

behavior to American crows but inhabit urban and rural areas of Europe and Asia (Cornell Lab of Ornithology, 2015). Captive rooks have been shown to adapt to novel problems by manufacturing tools. Rooks will take a piece of wire, fashion it into a hook, and use other tools such as sticks in a sequence to reach a waxworm reward (Bird & Emery, 2009). Captive rooks will also choose a functional hook, a hook that will enable them to reach a waxworm, when deciding between a functional hook and a non-functional hook (Bird & Emery, 2009). When presented with a reward on a platform inside a tube of water along with different sized rocks, rooks are able to select the large rocks before using the small rocks to raise the water level and, thus, raise the platform. When the width of the tube was narrowed, rooks preferred using the smaller rocks and were less likely to try the large rocks, adjusting their problem-solving to the specific requirements of the setting (Bird & Emery, 2009). These studies clearly indicate that captive rooks can create novel tools and select tools based on functionality but, to date, there is no record of them performing these actions in the wild (Bird & Emery, 2009).

New Caledonian crows (*Corvus moneduloides*) are a different species of the *Corvus* genus, similar in size and behavior to American crows and native to New Caledonia (Cornell Lab of Ornithology, 2015). New Caledonian crows differ from other crow species by their unique beak, typically shorter, blunter, and slightly curved upward (Leonard, 2016; Matsui et al., 2016). The New Caledonian crows' distinct beak may be what has allowed the crow to become exceptional at using tools. New Caledonian crows are one of few wild animal species that spontaneously create multiple types of tools out of numerous materials for foraging in the wild (Hunt, 2014). In one area, researchers

found three types of tools made of barbed leaves. First crows would cut into the leaf, and then tear a narrow strip off the leaf so the barbs were on one side of the strip. The crows would cut the strip off and use the barbed strip to dig worms out of trees (Hunt, 2014). Tool use in American crows is uncommon but not unheard of. There has been an observation of a crow widening a hole in a tree, taking a piece of wood that had been removed, sharpening it by pecking at the narrow end and then using the narrow end to probe the original hole (Caffrey, 2000). However, such reports on tool use in American crows are very limited.

Corvids and Urbanization

Based upon their documented tool-use, corvids are considered an intelligent animal and, despite the hazards of living in an urban environment, are moving into urban areas. Studies of crows show evidence of ecological plasticity, the ability of one species to survive in different habitats (Luniak, 2004; Marzluff, McGowan et al., 2001). Researchers have found that American crow population has increased in urban and suburban areas compared to rural population (Marzluff, McGowan, et al., 2001). Between 1960 and 1996, substantial increases in urban population were recorded in many different regions of the United States (Albuquerque, NM: 425%, Hartford, CT: 187%; Sacramento, CA: 122%; Seattle, WA: 57%; Marzluff, McGowan, et al., 2001). Birds in remote areas such as wildland preserves, campgrounds, and woodlands require large areas for foraging and, while their environment has the capacity to accommodate population growth, rural crow populations do not appear to be increasing (Marzluff,

McGowan et al., 2001). The increase in urban crow populations could be explained by the dispersal of breeding populations from rural and wildland areas into urban areas.

The impact of urbanization on bird physiology and behavior may be multifold. Researchers argue that urban birds begin breeding earlier and breed for a longer duration than rural birds (Beck & Heinsohn, 2006; Lowry, Lill, & Wong, 2012; Marzluff, McGowan, et al., 2001). However, some researchers believe breeding space to be oversaturated in urban populations making early breeding unlikely (Lowry et al., 2012; Marzluff, McGowan, et al., 2001). Urban birds keep smaller territories, and sometimes have territorial overlap with conspecifics, possibly due to the volume of birds in one area (Lowry et al., 2012; Marzluff, McGowan, et al., 2001). Productivity and survivorship are low in urban environments, and may be influenced by poor food quality, interference by humans during breeding, and nest predators such as hawks, owls, kestrels, and other crows (Heiss et al., 2009; Marzluff, McGowan, et al., 2001). Low productivity could also be an adaptation to a stressful and limited environment (Chamberlain et al., 2009; Marzluff, Bowman et al., 2001). An observational study found American crows in urban territories to have lower brood sizes and significantly lower body mass than rural conspecifics (Heiss et al., 2009). To survive in an urban environment, a bird must display behavioral plasticity, which is defined as the ability to display alternative behaviors in response to environmental changes (Slabbekoorn, 2013). One potential example of such plasticity has been noted by Slabbekoorn (2013) in that urban birds have been recorded as louder than their rural counterparts, which was theorized to be a response to the loudness of city environments.

The above physiological and behavioral differences could be an adaptive response to the urban environment. However, low weight and mass, changes in nest-site selection and structure, poor productivity, and decreased survivability could also be the consequence of exposure to toxic chemicals and changes in circadian rhythms due to artificial lighting (Hamer & McDonnell, 2009; Nordt & Klenke, 2013; Russ et al., 2015; Schlesinger et al., 2008; Smith, Bosakowski, & Devine, 1999; Stracey & Robinson, 2012; Yeh, Hauber, & Price, 2007). Dichloro-diphenyl-trichloroethane (DDT) is a common insecticide and an ingredient in aerosols, candles, vaporizers, and lotions (Bignert et al., 1995; Ehrlich, Dobkin, & Wheye, 1988). DDT's variant dichloro-diphenyl-dichloroethylene (DDE) is a common pesticide (Bignert et al., 1995; Ehrlich et al., 1988). Polychlorinated biphenyl (PCB) is a pesticide and is commonly used in building materials (Bignert et al., 1995; Ehrlich et al., 1988). As DDT, DDE, and PCB breakdown and decay, they pass through several levels of food chains, from animals to plants, and travel through the air and water.

The above chemicals can alter a bird's calcium metabolism, which results in thin eggshells essentially breaking eggs before birth (Bignert et al., 1995). In response to eggshell thinning and other health hazards such as cancer in humans, in 1972 the United States Environmental Protection Agency (EPA) banned, restricted, and reduced the use of DDT and other persistent organic pollutants (POP) like DDT (EPA, 2015). As a result of regulating the use of POPs, bird populations have recovered to population levels similar to pre-DDT bird populations. However, the impact of these chemicals may not be fully understood as individual differences within and between species can make it difficult to

track hazardous chemical levels, especially when there are large ranges of chemical concentrations that are considered acceptable by the EPA (Bignert et al., 1995; Ehrlich et al., 1988; EPA, 2015). Human initiated environmental modifications and use of toxic chemicals in animal habitats can negatively affect animal physiology.

Avian Synanthropes

Few species are able to adapt and exist in increasingly urban environments (Lowry et al., 2012; Meillère, Brischoux, Parenteau, & Angelier, 2015). Some birds such as magpies, jays, and crows of the Corvidae family, are considered synanthropes, as they appear to thrive in urban settings and live in large populations compared to other bird species in their respective areas, dominating the habitat (Lowry et al., 2012; Luniak, 2004; Meillère et al., 2015). However, the way these species are able to adapt is still largely debated (Lowry et al., 2012; Luniak, 2004; Meillère et al., 2015). The mechanisms involved in this process are explained through several theories including phenotypic plasticity, genetic adaptation, or certain temperaments and personalities being favored in a new environment (Lowry et al., 2012). Currently, the specific mechanism by which Corvidae survive is unknown but clues are provided by similar bird families that are also successful at adapting to an urban environment from a rural environment.

In one study, European blackbirds (*Turdus merula*) were captured from a city and forest environment, then hand-raised and exposed to the same environment and stress-induced handling procedure (Partecke, Schwabl, & Gwinner, 2006). Stress levels were measured by baseline and stress-induced corticosterone concentrations (Partecke et al., 2006). European blackbirds born in a city had a lower stress responses than those born in

a forest (Partecke, et al., 2006). Researchers explained the lowered stress response as a genetic mechanism or possibly due to the early experiences in urban or rural nests (Partecke et al., 2006). A comparison of newly hatched, fledging, and adult Magellanic penguins (*Spheniscus magellanicus*) that were exposed to a tourist-visit area or were left undisturbed found higher glucocorticoid levels in tourist-visited young (Walker et al., 2005). However, tourist-visited chicks did not flee when approached by humans and had a lower stress response compared to adult tourist-visited and adult undisturbed penguins. This study indicates both that anthropogenic influences can alter glucocorticoid concentrations and that the Magellanic penguin shows adaptations to these influences (Walker et al., 2005). In addition, the study demonstrates that mismatches between behavior and physiological indicators are possible and highlight the complexity of the relationship between behavior and physiology.

Caching

Caching is an adaptive behavior in birds that is used as a response to seasonal changes (Bugnyar et al., 2007; Salwiczek et al., 2009). By caching food in preparation for seasonal changes, birds increase their chances of survivability by increasing their food storage (Bugnyar et al., 2007; Salwiczek et al., 2009). When food supply is unpredictable, birds cache more possibly to increase survivability (Pravosudov, Kitaysky, Wingfield, Clayton, 2001). An animal will hide, store, or even ripen food by hiding the food into a crevice or substrate such as dirt or rocks and cover the item with that substrate (Bugnyar et al., 2007; Salwiczek et al., 2009). Caching can differ depending on a species' physical characteristics, intelligence, environment, and the purpose of cache

(Bugnyar et al., 2007; Salwiczek et al., 2009). Caching could reflect a desire to hide more food, a behavior more motivated by environmental stress than by the need for cache protection (Van der Vaart Verbrugge, & Hemelrijk, 2012). A behavioral study using computational bird modeling based on the cognitive abilities, memory, and caching in corvids hypothesized that corvids cache significantly more when being observed compared to when alone, when faced with poor environmental conditions, and when corvids have low body weights (Van der Vaart et al., 2012). The number of observers, possibly including conspecific observers, also affects birds' caching behavior (Van der Vaart et al., 2012). Urban birds have previously been shown to inhabit poor quality environments, and have lower body mass and weights (Heiss et al., 2009; Marzluff, McGowan et al., 2001). Urban corvids generally have small territories and share small areas of land with their conspecifics. It is currently unknown how a conspecific observer would affect caching compared to a predator observer (Lowry et al., 2012; Marzluff, McGowan, et al., 2001).

However, increased caching could elevate corticosterone levels, causing stress (Pravosudov et al., 2001). Conversely, studies have found elevated hormone levels to increase survivability and caching (Pravosudov, 2003; Wingfield et al., 1998). Due to the correlational nature of studies, the direction of the caching and cortisol relationship is uncertain. When studied in the field, Mountain chickadees (*Poecile gambeli*) exposed to long-term elevations in corticosterone via hormone implants cached significantly more than chickadees with a placebo implant. The corticosterone-implanted chickadees also spent significantly less time inspecting caches in a memory task, suggesting that stress

enhanced spatial memory of caches and allowed birds to cache more frequently, and effectively (Pravosudov, 2003). In a laboratory-based behavioral study, caching was found to be significantly higher in blue jays (*Cyanocitta cristata*) faced with a poor habitat than a simulated rural environment, poor defined by unpredictable availability of food (Wein & Stephens, 2011). The environment of the Carolina chickadee (*Poecile carolinensis*) has also been shown to affect caching behavior (Lucas, Freeberg, Egbert, & Schwabl, 2006). Captured chickadees from a disturbed area due to recent logging exhibited significantly higher baseline corticosterone levels than chickadees from undisturbed forests with little human contact (Lucas et al., 2006). Disturbed birds also had lower body mass than the undisturbed birds but not compared to the residential birds in a human residential community. Chickadees from the disturbed area also cached significantly fewer seeds compared to those in undisturbed or residential area.

Even if birds are adapting their stress responses (by unknown mechanisms) to their environment, the long-term consequences of these strategies are still unknown. Stress can be an advantage when caching but the extent of that advantage is unclear as well as to which species it applies (Pravosudov, 2003). Difficulties arise in observing and interpreting results of these studies due to differences between species. There is limited research on caching in crows in response to their environment and the current study hopes to explore potential differences between urban and rural crows.

Preening

Preening is defined as any movements made by a crow to clean itself on any part of the crow's body, such as using its beak to groom (Edgar et al., 2015; Griggio

& Hoi, 2006; Randler, 2005). Preening acts as a social activity for birds as well as a method of grooming, and is performed for comfort (Edgar, Lowe, Paul, & Nicol, 2011; Griggio & Hoi, 2006; Randler, 2005). Some bird species use physical health to choose a mate, and feather quality, maintained through preening, matters when looking at physical health (Griggio & Hoi, 2006). Preening can also serve as a displacement activity, a normal motor activity that occurs out of the usual grooming, comfort, and social context, or performed when an animal is stressed (MacFarland, 1966; Tinbergen, 1952). Thus, in research, preening frequency or duration could be used as measure of stress.

However, Edgar et al. (2011) found that female hens (*Gallus gallus domesticus*), that witnessed their chicks being subjected to puffs of air, showed decreases in preening and increases in heart rate and alertness (Edgar et al., 2011). Thus, a tradeoff occurs in which preening is secondary to other survival behaviors (Edgar et al., 2011). Similarly, chicks spent less time preening and more time distress calling when witnessing their mother expecting a potential threat (Edgar et al., 2011). Maintaining feathers through preening is important in mate choice in birds but also a potential cost of time and energy (Griggio & Hoi, 2006). In an urban environment, a bird might not have enough time to preen and this could then affect offspring productivity. In contrast, a bird that has more successfully adapted to their environment may have time to groom via preening and, thereby, enhance or improve their social connections. Urban and rural birds face different issues and challenges in

their respective environments; it is possible that there would be a difference in their preening behaviors due to stress response.

Vigilance

Preening and caching have also been linked to vigilance in birds (Randler, 2005). A bird scanning its surroundings defines vigilance (Boukhriss et al., 2006; La Saout et al., 2015; Randler, 2005). Vigilance is generally in response to a predator and occurs to protect birds from predators when engaging in other behaviors such as preening, caching, and foraging (Boukhriss et al., 2006; La Saout et al., 2015; Randler, 2005). In an observational study, Eurasian coots (*Fulica atra*) were found to have higher rates of vigilance when preening (Randler, 2005). The study defined vigilance as birds looking up to visually scan their surroundings and measured by the rate at which they scanned the area. When in a preening group, vigilance was decreased, except for members on the physical edge of the group (Randler, 2005). Greater rheas (*Rhea americana*) in large flocks were found to have decreased individual vigilance and increased feeding as group size increased (Fernandez, Capurro, & Rebores, 2003). Large flock sizes may provide protection from predators who may not risk attacking a large group (Fernandez et al., 2003). When birds are in a larger group they can allocate more time to feeding and preening due to the low risk of predation as a result of intimidatingly large numbers (Fernandez et al., 2003; Randler, 2015). Because an increase in vigilance in large flock sizes would not aid birds in detecting predators due to their large numbers, there is an inverse

relationship between vigilance and foraging in larger flocks (Fernandez et al., 2003; Randler, 2015).

Flock size in urban and rural environments can vary, especially in corvids (Marzluff, McGowan, et al., 2001). Urban corvids typically have smaller clutches and, therefore, a smaller group (Marzluff, McGowan, et al., 2001). A smaller group would need to display high vigilance due to a lack of protection (Fernandez et al., 2003, Randler, 2005). There may also be a cost to having a larger clutch as younger members of a Greater flamingo (*Phoenicopterus roseus*) flock have been found to be less vigilant than adults as flock size increases (Boukhriss et al., 2006). While this does allow more foraging time for offspring to satisfy growing nutritional needs, it also possibly increases stress in adults by allowing less time for other activities such as preening (Boukhriss et al., 2006). Thus, having a large clutch in an urban environment could be a disadvantage, requiring more time dedicated to watching over young (Boukhriss et al., 2006). However, in an urban environment, American crows may have fewer predators to worry about, more coverage to hide, and more artificial light to detect predators (Heiss et al., 2009; Krausman et al., 2014). Similar to measuring other physiological and behavioral changes in birds, vigilance is a multifaceted behavior that is associated with many variables such as flock size, age of individuals in the flock, number of youth in the flock, the environment, and the need to perform other behaviors (Boukhriss et al., 2006; Heiss et al., 2009; Krausman et al., 2014; La Saout et al., 2015; Randler, 2005). Due to the differences in the

above variables between rural and urban birds, differences in vigilance behaviors are feasible but remain uninvestigated in American crows.

Boldness

Boldness is defined by how a bird approaches or avoids certain environments or situations and has been studied in several species of birds but not yet explored in American crows (Echeverria & Vassallo, 2008; Scales et al., 2011; Seltmann et al., 2014). In a study of song sparrows, urban birds were more aggressive and bold than rural birds when encountering an unknown song sparrow song or a human observer in their territory (Scales et al., 2011). In that study, aggressiveness was measured by a closer approach to the audio stimuli by the sparrow and boldness was measured by how close an observer was able to get to a sparrow before the sparrow would flee, a measure also known as flight-initiation distance (FID; Scales et al., 2011). However, in that study, there was no correlation between boldness and aggressiveness in an urban environment, indicating that urban environments may select for certain traits but that these traits can vary independently of one another.

House sparrows have been shown to be less bold in urban environments compared to shiny cowbirds (*Molothrus bonariensis*) (Echeverria & Vassallo, 2008). In that study, boldness was measured by latencies to forage in the presence of novel objects such as yellow boxes, purple tubes, and metallic garlands. Differences in willingness to take risks could be an indicator of survival in urbanized birds and further research on each species is necessary to explore adaptation to urbanization (Echeverria & Vassallo, 2008).

Boldness measured by nest-site selection closer to human/animal activity and FID in female eider ducks (*Somateria mollissima*) was found to be significantly higher when compared to ducks nesting in concealed areas (Seltmann et al., 2014). These results indicate that adaptive traits such as boldness in eider ducks may be related to nest-site selection, therefore, affecting clutch survivability, and could be an indicator of stress coping style (Seltmann et al., 2014). The above could translate to heterospecific behavior, however, studies in corvids are lacking.

Risk-taking is also suggested to be a measure of boldness (Seress, Bókony, Herzberger, & Liker, 2012). Older house sparrows in an urban environment are less bold than younger house sparrows. In that study, boldness was operationally defined as latency to return to a feeding area after being startled by a moving dummy. The age discrepancy in their findings did not occur in rural birds although rural birds had, overall, lower latencies to return to the feeding area than did urban sparrows. These differences in boldness suggest older urban birds may be warier and exhibit less risk-taking than younger birds, possibly due to experience and exposure to more city stressors (Seress et al., 2012). To date, there is no research on behavioral differences in boldness between urban and rural American crows.

Current Proposal

The purpose of the current study was to explore behavioral differences in urban and rural American crow. Little is currently known about crow behavioral adaptation to urban environments. Adaptive behavior by urban crows may be a consequence of natural selection. By observing behavioral differences in these two groups, the goal of the

current study was to better understand how urbanization affects crows. The study was originally designed to investigate behavioral differences in urban and rural crows as measured by caching, preening, vigilance, (i.e., stress) and approach-avoidance (i.e., boldness) in response to attractive and aversive audio stimuli. It was predicted that: (a) urban American crows and rural crows would differ in behavior; specifically, that urban crows would cache more frequently, preen more frequently and for longer periods of time, and would be vigilant less frequently and for shorter /periods of time compared to rural crows; (b) urban American crows and rural crows would be attracted to the area by an approach crow call and that an aversive predator call would induce stress in crows; and (c) in response to the approach crow call and the aversive predator call, urban crows would frequent the area more often, enter the area more quickly, and stay in the area for a longer period compared to rural crows.

CHAPTER III

METHODS

Subjects

Subjects were American crows most likely ranging in age from three to six years of age. Previous studies have shown that crows normally do not move far from their original nest and will stay with their original nest for two years after birth and sometimes up to six years after birth (Cornell Lab of Ornithology, 2015; Marzluff, McGowan et al., 2001). The origins of subjects were unknown yet it is likely that crows were from their respective surrounding area (Cornell Lab of Ornithology, 2015; Marzluff, McGowan, et al., 2001).

In keeping with definitions used in previous research, birds on the property of a private landowner within the residential area of Ellensburg (i.e., Site 1) and birds from the Central Washington University (CWU) campus (i.e., Site 2) represented urban crows. The term urban was defined in the current study as land majorly covered by buildings and buildings that are used for commerce, service, or industry; multi-family, multi-storied buildings are present and single-family homes are rare, and development or construction is occurring (Chamberlain et al., 2009; Grunst, Rotenberry, & Grunst, 2014; Marzluff, Bowman, et al., 2001; Seress, et al., 2011; Stacey & Robinson, 2012).

Birds on the property of private landowners represented rural birds (i.e., Site 3 and Site 4). The term rural is more broadly defined across past literature; rural has been used interchangeably with countryside, exurban areas, or wildlands. For the purposes of this study, rural was defined as land largely unsettled by humans but not absent of the

presence of humans (See Appendix A for map of site locations and predicted territories; Chamberlain et al., 2009; Grunst et al., 2014; Marzluff, Bowman, et al., 2001; Seress, et al., 2011; Stacey & Robinson, 2012).

Materials

Independent variables. The urban/rural individual differences variable was the first independent variable. The second independent variable was the presentation of audio stimuli. The three levels for the second independent variable included: a) No stimulus (i.e., to act as a control); b) an audio recording of an American crow; and c) an audio recording of a Red-tailed hawk (*Buteo jamaicensis*). Previous studies have evaluated the use of different stimuli to illicit a reaction in corvids (Hauser & Caffrey, 1994; Hettena et al., 2014). The Red-tailed hawk was also chosen in consultation with local birders (K. Buchanan, personal communication, May 3, 2016; M. Fallshore, personal communication, February 1, 2016).

Custom-built audio playing, audio recording, and video recording units (henceforth referred to as “RAUs”) projected the audio stimuli and captured bird behavior. Four crow calls and four hawk calls that were recorded within the Pacific Northwest, as close as possible to the Ellensburg, were used. All calls were attained through the Macaulay Library, a scientific archive of audio and visual recordings of numerous species. All calls were edited using the open source audio editing software Audacity to best mimic repeating bird calls and provide variability within calls. Calls were played at similar frequencies to that of human hearing; birds have also been shown to be most sensitive to sounds from about 1 to 4 kHz (Beason, 2004). The audio stimuli

played for ten minutes every hour from 10:00AM to 2:00PM and, during that time, RAUs recorded all motion (Aldredge, LeClair, & Bowman, 2012; Cristol, 2004; Hauser & Caffrey, 1994; Hettena et al., 2014; Luginbuhl et al., 2001).

Dependent variables. The current study was originally designed to assess the first dependent variable, stress, with three behaviors commonly reported in the literature: a) frequency of caching; b) frequency and length of preening; and c) frequency and length of vigilance. Caching behavior was defined as picking up a piece of food, and flying away with the food (Bugnyar, et al., 2007; Cristol, 2004; Salwiczek, et al., 2009). Preening was defined as any movements made by a crow to clean itself, on any part of the crow's body such as using the beak to groom (Edgar et al., 2015; Griggio & Hoi, 2006; Randler, 2005). Vigilance was defined by either a perching crow scanning the area (i.e., moving its head in sweeping motions) and/or engaging in head-ups (i.e., a look up disturbing the crows gaze; Boukhriss et al., 2006; La Saout et al., 2015; Randler, 2005). Additionally, the second dependent variable, boldness, was originally planned to be measured by approach/avoidance in response to the audio stimuli. Boldness was defined by frequencies of birds entering and exiting the area as well as duration of each visit to the perch (Echeverría & Vassallo, 2008; Scales et al., 2011; Selmann et al., 2014; Seress et al., 2012).

As discussed more thoroughly in the statistical analysis section, these proposed behaviors were not observed or could not be properly assessed in the recorded video data. Thus, results of the current study focus on durations of visits of crows and all non-crow

birds. Visit durations were defined by the time from which a bird, either crow and non-crow, entered the video frame and then exited the frame.

In order to record behavior for later coding, custom audio/video units (i.e., RAUs) were built. Six RAUs were constructed. Each RAU was housed in a white 5-gallon utility bucket with a removable watertight lid. Inside each bucket were two Arduino UNO R3 units; one was employed as system controller and the other served as a MP3 player for storing and generating calls. Each bucket was also equipped with a microphone for recording surrounding noise, a motion detector, two 32 Gb SD cards, an internal clock, and a battery pack. RAUs could record for five days at a time, from 10:00AM to 3:00PM. Internal hard drives stored recorded video between intermittent downloads. Above the watertight lid were two USB plugs for downloading data as well as two black cameras for recording birds. Cameras were approximately 4 cm x 4 cm in size and placed in front of the bucket. The position of the cameras allowed for approximately a 200-degree perspective with adjustments available. A clear dome top covered the USB plugs and cameras for recording and further protection from inclement weather.

A separate unit housed speakers used to project calls. Eight speakers were housed between two 5-gallon bucket lids and lined the perimeter of the lids. Black plastic mesh lined the gap between lids and covered the speakers, protecting them from wind. Speaker units plugged into the top of a RAU for use. The speakers produced omnidirectional calls at 105 dB sound pressure level at 1 meter. (See Appendix B for RAU photographs).

To provide a focal point with food for caching, baited perches were used to attract birds to the area (Becker, Bednekoff, Janis, & Ruthven, 2009; Grosch, 2004; Meunier, Verheyden, & Jouventin, 2000; A. H. Taylor, personal communication, February 29, 2016; Taylor, Knaebe, & Grey, 2012). Based upon designs presented in prior research, perches were constructed with plywood (Grosch, 2004). Four perches were constructed following a table-top design, with one perch placed in each study site. Final perches were approximately 120 cm x 120 cm x 60 cm in size. Two pieces of plywood approximately 120 cm x 120 cm x 2.5 cm in size were separated and supported by five spacers made from acrylonitrile butadiene styrene piping, 60 cm x 10 cm in size. Each pipe stood up vertically between the two horizontal pieces of wood, one on each corner and one in the middle of the perch. Each pipe was secured with 1 cm threaded rods through the top and bottom of the perch with washers and locking nuts. A hinged lid was added to aid in changing bait and to cover bait. The lid was approximately 160 cm x 160 cm x 2.5 cm in size with a center cutout of approximately 160 cm x 160 cm in size and covered in 2.5 cm wide hexagon shaped mesh wire. Each corner of the hinged lid was reinforced with a 30 cm x 30 cm x 10 cm piece of plywood along the outer edges, acting as gussets. Each perch weighed approximately 75 pounds and was further weighted down with sandbags to avoid displacement. At the topside corner space of each perch was a squared off area, approximately 45 cm x 45 cm, for placing the RAUs. Speaker units were placed in the space between the top and bottom pieces of plywood. (See Appendix C for perch photographs).

Perches are successful in providing a space for birds to stand and for researchers to observe behavior (Becker, Bednekoff, Janis, & Ruthven, 2009; Grosch, 2004; Meunier, Verheyden, & Jouventin, 2000; A. H. Taylor, personal communication, February 29, 2016; Taylor, Knaebe, & Grey, 2012). Successful perches usually mimic a bird's natural environment but studies have found birds will perch on simple perches made of natural materials that do not precisely mimic trees (Becker et al., 2009; Grosch, 2004; A. H. Taylor, personal communication, February 29, 2016; Taylor et al., 2012). Urban birds will also perch on a wider range of perch type structures as evidenced by urban raptors perching on trees and powerlines (Meunier et al., 2000). In the current study, perches were baited with peanuts to attract birds as well as provide caching material consistent with prior studies (Cornell Lab of Ornithology, 2015; Jones & Reynolds, 2008; Kress, 2006; Lynn & Porter, 2008).

Design

The current experiment was a 2 (Setting: Urban, Rural) x 3 (Stimulus: Control/Baseline [A], Approach [B], Avoidance [C]) factorial design and followed an ABCBC presentation. The baseline logic (ABCBC) design was chosen to best eliminate carryover effects, allowed data to reflect comparisons between the audio stimuli in rural and urban groups, and allowed comparisons between the rural and urban groups without identifying individual crows (Bloom, Fisher, & Orme, 2006; Cooper, Heron, & Heward, 2007; Pierce & Cheney 2013). The time period for the study, from September to November, was chosen to decrease nest desertion and maximize behaviors (Bugnyar et

al., 2007; Cristol, 2004; Seltnann et al., 2014). From June through August, preliminary testing was conducted to identify effective testing areas.

Procedure

Testing began in September and, then, occurred in two-week periods. The first two weeks consisted of in-person observation of perches for the baseline condition with no auditory stimuli (A). Perches were baited from this point onward and RAUs were deployed. For two weeks, a crow call (B) was presented followed by two weeks of the hawk call (C). That sequence was then repeated in a modification of a standard reversal design. After data collection ended, two weeks of crow call were conducted at the perches before they were disassembled in order to end the study with a stimulus that was hypothesized to be positive to the subjects. The design and timeline for the current study are presented in Table 1.

Data from video recordings were coded by the primary investigator using a modified version of Xine, a multimedia playback engine. Since RAUs recorded activity for five hours a day, a computer program was first used to detect any motion in videos. Following the use of the program, the primary investigator further consolidated data with instances of animal activity, creating a playlist of videos for coding. After consolidating data appropriate for behavioral coding, videos were logged using computer keyboard keystrokes for American crows and frequency and duration of visits for all other bird species. Each video was watched in two-times normal speed; once a bird was identified the video speed was returned to its normal speed until the bird was shown exiting the area; the video was then rewound and speed was reduced to half its normal speed; the

bird visit was then coded using key strokes for when the bird entered and exited the video frame. This coding procedure was followed for all bird, crow and non-crow, visits.

Coding logs were then compiled into an Excel spreadsheet and a separate Excel spreadsheet was created combining data from all videos. Data were then analyzed using R, open source software for statistical computing.

Table 1

Protocol Design and Timeline of Experiment

Protocol Phase	Label	Timeline	Data	Missing Data
1. Equipment			In	
constructed/tested		June; July;	person	
2. Scouted testing areas		Aug.; Sept.		
3. Set up	Prep			
Baseline	A	Sept. 1-15	Video	None
Crow call	B	Sept. 16-Oct. 3	Video	Sept. 17-22 (All sites)
Hawk call	C	Oct. 4-15	Video	Oct. 5-8 (All sites)
Crow call	B	Oct. 16-30	Video	Oct. 22-24 (Site 2)
Hawk call	C	Nov. 1-15	Video	None

Statistical Analysis

As mentioned previously, the current study originally intended to measure behaviors that contribute to the concepts of stress and boldness. However, only 10 total

crow visits occurred during friendly and unfriendly birdcall playbacks. Therefore, due to the small sample size, the target behaviors were not coded and data analysis for crow visits focused on descriptive statistics. Inferential statistical analyses beyond descriptive statistics were not possible due to the limited number of crow visits and difficulties in coding planned behaviors during those visits. All crows that were visible on the videos were passing through the observation area, too far away to be viewed clearly on the video, or had their backs to the camera. Thus, the only behaviors that could be coded were the frequency of visits and the duration of each visit of all birds recorded.

Thus, the following data were collected from each visit: (a) the IV₁ site of the visit (i.e., rural or urban); (b) which IV₂ the visit fell under (i.e., crow call or hawk call); (c) identification of crow or other bird; (d) presence of a call; and (e) total length of visit measured in seconds (i.e., time from which a bird enters the frame to exiting the frame). Excluded from analysis were: (a) missing data; (b) unidentifiable birds; (c) baseline data; and (d) all nonbird animal visits. Approximately 13 days of data were lost due to equipment malfunctions, such as equipment overheating, wind damage, and premature battery drainage. Out of the 13 days, six occurred during the first crow phase across all sites; four occurred during the first hawk phase across all site; and three occurred during the second crow phase in urban Site 2. Unidentifiable birds were defined as birds that were not in frame long enough to be definitively identified as an American crow or other bird.

Prior to the completion of study equipment (i.e., audio and visual recorded systems), two weeks of baseline data was collected in person by the primary investigator.

All four sites were visited daily for a total of an hour per site. Behavioral observations were conducted by alternating ten-minute focal sampling and scan sampling methods. During this time, durations and frequencies of target behaviors were recorded. During the two weeks of baseline data collection, no crow visits were observed. While there were other non-crow bird visits during baseline data collection, these were not recorded as the decision to include non-crow bird data was made later in the study. Due to the lack of crow visits and data on non-crow bird visits, baseline conditions were not included in subsequent analyses.

Crow statistical analysis. Originally, two separate 2 (Setting: Urban, Rural) x 3 (Stimulus: Approach, Avoidance, Control or Baseline) MANOVAs were to be used to analyze the behaviors that contribute to the concepts of stress and boldness. However, due to the small crow sample size, data should be interpreted with caution and the statistical analyses presented focuses on descriptive statistics. As previously mentioned, the only behaviors that could be coded were the frequency of visits and the duration of each visit. Baseline data were not included due to the lack of crow visits.

Overall bird statistical analysis. Considering the large differences in sample sizes among conditions as well as the lack of visits in some conditions (e.g., Baseline), 2 (Setting: Urban, Rural) x 3 (Stimulus: Approach, Avoidance) factorial ANOVAs measuring bird visit durations could not be conducted. Instead, an independent two-group *t*-test was utilized to compare the effect of the setting IV (i.e., Urban or Rural) on duration of all bird visits, including crows. A *t*-test was used to assume unequal variance and apply the Welsh modification. A one-way ANOVA was conducted to analyze differences

in projected calls on duration of all bird visits, including crows. The IV (stimulus phase/call) represents the call phase the bird was recorded in (Approach/Crow, Avoidance/Hawk) and whether the call was playing at the time the bird was captured, creating 4 levels; (a) crow phase, call playing; (b) crow phase, call not playing; (c) hawk phase, call playing; and (d) hawk phase, call not playing. The above independent variable (stimulus phase/call) was combined in order to conduct a one-way ANOVA as opposed to a 2 (Approach/Avoidance) x 2 (Call playing/Call not playing) factorial ANOVA due to the unequal group sizes and therefore unequal variance between groups. A summary of descriptive statistics by setting and audio stimuli for all bird data including crow and non-crow birds is presented in parentheses in Table 2.

Due to the small sample size of crows and the shift in focus to that of the frequency and duration of visits, the current study only utilized one coder for all measurements due to the lack of coding complexity. Target behaviors such as preening, caching, vigilance, and boldness which would have required an assessment of interrater reliability could not be coded due to lack of visibility of the birds as previously noted. In contrast, coding a bird entering and exiting the observation area removed ambiguity and only the primary investigator coded frequency and duration of bird visits.

Table 2

Mean Duration of American Crow Visits (in Seconds) by Setting and Auditory Stimuli with Overall Bird Durations in Parentheses

Auditory Stimuli	Urban			Rural		
	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>
Crow Phase + Call	19.33	30.89	3	-	-	-
	(1	-	1)	(16.78	26.98	98)
Crow Phase + No Call	-	-	-	25.33	24.82	3
	-	-	-	(19.93	29.91	665)
Hawk Phase + Call	2.00	-	1	10.00	-	1
	(17.61	30.28	28)	(22.08	24.93	286)
Hawk Phase + No Call	2.00	-	1	4.00	-	1
	(7.4	9.40	10)	(19.13	19.79	72)

CHAPTER IV

RESULTS

The current study was designed to examine the effects of audio stimuli and environment on stress and boldness in American crows. As a result of the small sample size of American crows during the study's duration, statistical analysis was focused on descriptive statistics of crow data and overall non-crow bird recordings. Out of 300 hours of recorded data across the four collection sites, 168 hours of footage identified as containing animal movement were recovered and coded. A total of 1254 birds were captured on video, approximately 93.6% were other bird species (i.e., magpies, doves, blackbirds, cowbirds), 6.3% were unidentifiable, and 0.79% were American crows. In addition, several cats ($N = 4$) and deer ($N = 2$) were captured on camera, but data from those visits were excluded from analysis.

Overall Bird Results

All assumptions of an independent samples t -test had been met while considering the unpredictable nature of the data used. The dependent variable was measured at the ratio level (i.e., time), the independent variable included the two categorical conditions of urban and rural. This study did not identify or band individual birds. Therefore, it was difficult to assess independence of observations, and each visit was counted as a separate bird. As a result, these data should be interpreted with caution. The assumptions of no significant outliers, normality, and homogeneity of variances were also met considering a t -test is a highly robust statistical method. An independent-sample t -test was conducted to compare duration of visits in rural and urban condition. There was a significant

difference, $t(75) = -3.26$, $p = 0.001$, $d = 0.49$, in the duration of visits between the urban ($M = 39.59$ seconds, $SD = 55.50$) and rural environments ($M = 18.57$ seconds, $SD = 24.10$).

All assumptions of a one-way ANOVA had been met while considering the uncontrollable nature of the data used. The dependent variable was measured at the ratio level (i.e., time), the independent variable consisted of four categorical conditions (i.e., crow phase playing, crow phase not playing, hawk phase playing, hawk phase not playing). Again, as previously noted, due to a lack of identification of individual birds, it was difficult to assess independence of observations. The assumptions of no significant outliers and normality were also met within reason considering robustness. Levene's test indicated equal variances, $F = 0.50$, $p = 0.61$. The ANOVA revealed no effect of call condition on the duration of visits, $F(3, 1154) = 1.13$, $p = 0.33$.

American Crow Results

Urban Site 1 had no crow visits. The majority of crow visits occurred at urban Site 2 ($N = 5$), followed by the rural sites, Site 3 ($N = 4$), and Site 4 ($N = 1$), respectively. Crow visit durations did not appear to differ by site based upon visual inspection of the data in response to friendly and predator calls. A summary of descriptive statistics by setting and audio stimuli is presented in Table 2.

CHAPTER V

DISCUSSION

Overall Bird Data

The results of current study reveal that setting influenced the duration of bird visits to baited perches with birds in urban areas having longer visits to the observation areas than birds in rural areas. This finding suggests that urban birds spend more time in a single visit in one area compared to rural birds. However, it is unknown if the same birds were revisiting the same area and, therefore, differences in visit duration were actually due to individual bird differences rather than to the location of the perch. The results of the current study also indicate that the different audio stimuli consisting of approach crow calls and avoidance hawk calls did not impact the duration of visits; a finding that suggests that artificial audio calls may be inappropriate for use in research in naturalistic settings.

Past research has indicated that urban environments have better access to food, protection from competitors and predators, and result in differences in feeding styles compared to birds living in rural areas (Hamer & McDonnell, 2009; Heiss et al., 2009; Krausman et al., 2014; Nordt & Klenke, 2013; Prange et al., 2003; Russ et al., 2015; Schlesinger et al., 2008; Seferta et al., 2001). Also, urban birds tend to keep smaller territories (Lowry et al., 2012; Marzluff, McGowan, et al., 2001). In the current study, urban birds may have been able to maintain longer visit durations to the perches due to less competition compared to birds in rural areas. Urban birds may also have found the perch more easily if they did, in fact, have smaller territories and were aware of sites of

food availability. In contrast, rural birds may have had larger territories, requiring shorter visits in order to visit more areas.

American Crow Data

The current study was originally designed to examine behavioral differences (i.e., caching, preening, vigilance, and boldness) in urban versus rural American crows in response to an approach versus aversive stimulus (i.e., a crow call versus a predator hawk call). It was predicted that: (a) urban American crows and rural crows would differ in behavior with urban crows caching and preening more frequently, and being less vigilant compared to rural crows; (b) crows would be attracted by an approach crow call whereas an aversive predator call would induce stress; and (c) in response to the approach crow call and the aversive predator call, urban crows would frequent the area more often, would enter the area more quickly, and would stay in the area for a longer period compared to rural crows. However, due to the small crow sample recorded, the data did not allow for statistically evaluating differences in stress and boldness due to setting or in response to the audio calls. Rather than focusing on these more complex behaviors, the current study utilized data on the number and duration of site visits to yield potential conclusions that might be used to design future investigations on the impact of urbanization on crows and other birds.

Overall, across species, there was an effect of environment on duration of perch visit but no effect of audio recordings. Visual inspection of the crow data suggests that there was no difference between sites in response to approach and aversive calls.

However, due to small sample size of crow visits, the study was unable to evaluate the effects of bird calls on stress and boldness in urban versus rural American crows.

Alternate Theories

Ultimately, the current study was unable to examine the effects of the approach and avoidance birdcalls or the perch location on stress and boldness in American crows. There are several potential explanations for the lack of perch visits from crows. Initially, crows seemed interested in the calls and perch, particularly in Site 3. Landowners of Site 3 reported that crows were visiting the observation perch but, after approximately a week, ceased visiting the observation area (C. Buchanan, personal communication, May 11, 2017). Due to equipment malfunction, video data from this time is unavailable. Nevertheless, based on past research, the novelty of the calls should have attracted birds in the current study (Hauser & Caffrey, 1994; Wascher et al., 2012). For example, in a study of Carrion crows (*Corvus corone*), higher attention was paid to unfamiliar humans than familiar human playbacks and less attention to unfamiliar jackdaws (*Corvus monedula*) compared to familiar jackdaws (Wascher et al., 2012). Past studies suggest birds do discriminate between novel stimuli, an ability that can be beneficial for identifying preferred groups and avoiding competitors and predators (Brown, 1985a; Consla & Mumme, 2012; Hauser & Caffrey, 1994; Luginbuhl et al., 2001; Wascher et al., 2012).

One potential explanation for the lack of recorded perch visits during the current study is that intraspecies interactions are more complicated than indicated by previous studies. American crows have been shown to have at least 20 structured call sequences

(Thompson, 1982). In that study, structured call sequences were defined as sequences that were organized in average duration, duration of pauses between calls, and average number of caws per call (Thompson, 1982). American crows also produce unstructured calls and a third type of vocalization (i.e., songs; Thompson, 1982). Past studies have used playbacks to attract crows; however, it is possible that over long periods of audio playback the attraction ends, explaining the current findings regarding low visitation rate (Brown, 1985a; Consla & Mumme, 2012; Hasuer & Caffrey, 1994; Hettena et al., 2014; Luginbuhl et al., 2001; Wascher, Szipl, Boeckle, Wilkinson, 2012).

In contrast to crow visits, other bird species continued to visit the perches. The non-crow bird visits suggest that either these birds were unconcerned with the calls, became habituated to the calls, and/or came to understand the calls were artificially generated and, therefore, posed no immediate threat. Overall, the continued engagement of non-crow bird species with the baited perches suggests several possibilities regarding interspecies communication. Considering past research in crow intelligence, it seems unlikely that non-crow birds would be unconcerned with the projected calls and that crows would show higher aversion. If the non-crow birds could understand that no threat existed, it is plausible that the crows would display similar reactions. On the other hand, perhaps the crows were warier of the calls initially (Seress et al., 2012) with the unrelenting calls having been viewed as competition by the crows and resulted in them abandoning their territory.

As noted, based upon non-recorded, anecdotal recall provided from Site 3, it appears that crows showed initial interest in the perches, supporting findings from past

studies (Becker et al., 2009; Grosch, 2004; Meunier et al., 2000; A. H. Taylor, personal communication, February 29, 2016; Taylor et al., 2012). There are several possibilities for the lack of crow visits, including unknown complexities in intraspecies and interspecies communication, intelligence, and evolution. Further research would be valuable in understanding the cognition underlying communication and behavior.

Study Limitations

There are several limitations to the current study, including the small sample size of crows, equipment malfunction and modifications, and environmental factors. Throughout the current study, technological malfunctions occurred that reduced the data collected and, therefore, available for analysis. Approximately 13 days of data were lost due to equipment overheating, wind damage, and premature battery drainage. Missing data occurred during the first B (crow phase) and first C (hawk phase) for all sites. These malfunctions raise the issue of the advantages and disadvantages of in-person versus camera field studies.

The use of cameras allows for more data collection since cameras can stay focused on one area for days at a time. Cameras and recorded data allow researchers to review animal behavior and interactions repeatedly while in-person observations only allow for a single viewing. Observing multiple animals at one time is also a difficult task for an in-person observation procedure and may be better suited to video recording. Depending on the location of the research and the difficulty in transporting equipment, checking on equipment, and access, it may be more convenient to perform observations in-person. The use of cameras versus in-person observations also raises ethical issues

regarding potential intrusions that may disrupt behavior. In the current study, a combination of in-person and camera field procedures may have allowed the collection of more crow behavior data. For example, the description of behavior from the landowners of Site 3 could have been used for data analysis if that behavior had been recorded via an established in-person collection protocol.

In the current study, the location of the camera equipment in relation to the perches may have contributed to the limited bird visits. While the perch designs were consistent with prior research, the impact of the positioning of the camera equipment on the perches was not investigated prior to the study (Becker et al., 2009; Grosch, 2004; Meunier et al., 2000; A. H. Taylor, personal communication, February 29, 2016; Taylor et al., 2012). For powering purposes and protection against inclement weather, the cameras and associated equipment were housed in buckets placed in a corner of the tabletop of each perch. The buckets housing the audio and camera equipment were, therefore, visible to the birds as they approached the perches. It is possible that birds quickly learned that the audio calls were artificially produced by the equipment and that the area posed no real threat. Future studies should consider moving audio equipment away from the perch into the surrounding tree coverage to minimize the potential confusion caused by bird calls clearly emanating from an artificial rather than biological source.

The location of the buckets on the perch also limited the optical range of the cameras. Cameras were placed in the buckets and on the perches in order to provide an approximately 200-degree perspective of birds flying from a distance to the perch and a

closer view of birds on the perch. Audio calls that can be heard but not localized on the video recordings indicate that birds were gathered in the trees above and surrounding the perch. Birds could also be heard responding to the recorded crow and hawk calls. The majority of natural birdcalls that occurred out of visual range of the cameras appear to have been between the recorded crow calls and other corvids in the area. Unfortunately, without video capture, the bird species could not be determined for data analysis. Future studies could overcome this limitation by including a camera in the distance or mount a secondary camera at another angle on the perch to capture video of birds around but not directly on the perches.

The types of calls used for the audio stimuli in the current study may have also resulted in difficulties in collecting data. Past studies have utilized birdcalls to attract birds to and from observation areas (Brown, 1985b; Consla & Mumme, 2012; Hauser & Caffrey, 1994; Luginbuhl et al., 2001). However, these studies provided only limited descriptions of the calls that were used often lacking details such as length, variation, pitch, and origin of calls. For the current study, calls were edited to best mimic natural bird calls by averaging the length of calls and varying the time between calls. Calls selected as audio stimuli were also limited to birds from the Pacific Northwest region. It is also noteworthy that the author of the major article used in developing the hawk calls for the current study has been found guilty of scientific misconduct (Hauser & Caffrey, 1994; National Institutes of Health, 2010; Newcomer & Spitzer, 2010). In 2010, following a multi-year investigation, Harvard University found Dr. Marc Hauser guilty of eight counts of misconduct (Newcomer & Spitzer, 2010). While the Hauser article that

was utilized to select birdcalls for the current protocol was not part of Harvard University's investigation, it is possible that data from that article were falsified and/or the results manipulated (Hauser & Caffrey, 1994). Thus, the resulting use of similar materials for the current study may not have been appropriate for the study's goals.

The perches used for observation underwent several modifications during the course of the study that may have inadvertently affected bird behavior. While the weather during the study remained relatively dry, precipitation caused mold to grow in the center of the perch on the bait. Perches were disinfected and modified to reduce precipitation build up; however, it is possible this affected bird behavior. Previous studies have differed in their conclusions regarding avian olfactory abilities; it is unknown how birds might react to cleaning products or how often they may naturally interact with cleaners (Bang & Cobb, 1968; Bonadonna, Miguel, Grosbois, Jouventin, & Bessiere, 2007). Furthermore, the perches were visited by other animals, such as groups of deer and cats that may have influenced bird visitation. Throughout the study, bait at Site 4 was often consumed by deer. However, because the cameras did not record past 3:00 p.m., it is possible the perches were visited by other wildlife. Future use of barriers to terrestrial animals could exclude visits from non-target animals. Additionally, during in-person observations at Site 4 for baseline measurement, two dogs could be heard barking continuously. The noise created by these dogs could have caused fewer birds and crows to investigate that perch.

The current study could also have benefitted from more observation locations with greater environmental differences. The urban and rural locations used in the current

study fit the definitions used in past literature (Chamberlain et al., 2009; Grunst, Rotenberry, & Grunst, 2014; Marzluff, Bowman, et al., 2001; Seress, et al., 2011; Stacey & Robinson, 2012). These definitions focus on human activity, the use of human environments, and human contact with wildlife (Chamberlain et al., 2009; Grunst et al., 2014; Marzluff, Bowman, et al., 2001; Seress, et al., 2011; Stacey & Robinson, 2012). Definitions using population and population density are less commonly used but, for the purposes of the current study, could be useful in determining differences between crow populations. The city of Ellensburg is classified as an Urban Cluster (UCs), defined by a population of at least 2,500 and less than 50,000 by the U.S. Department of Health & Health Service (HRSA; 2017) and the U.S. Department of Agriculture (USDA; 2017). Ellensburg census data recorded a population of 19,001 as of 2015 (U. S. Census Bureau). A study between Ellensburg and an area with a population of 50,000 or more people (i.e., Urbanized Area) could be useful (HRSA, 2017; USDA, 2017).

Finally, without a large enough sample size and in the absence of a hormonal assay, it is difficult to assess the construct validity of the sole behavior, duration of perch visit, that was ultimately used in the current study. Past research has indicated that the procedures followed in the current study were appropriate for exploring behavioral differences between corvids and, in particular, stress and boldness (Aldredge, LeClair, & Bowman, 2012; Chamberlain et al., 2009; Cristol, 2004; Grunst, Rotenberry, & Grunst, 2014; Hauser & Caffrey, 1994; Hettena et al., 2014; K. Buchanan, personal communication, May 3, 2016; Luginbuhl et al., 2001; M. Fallshore, personal communication, February 1, 2016; Marzluff, Bowman, et al., 2001; Seress, et al., 2011;

Stacey & Robinson, 2012). However, the results of this study showed little capability to measure complex behaviors due to the small sample size of crow visits and the finding that crow visits that did occur could not be measured because crows were passing through the area or facing away from cameras.

Future Studies

While the current study can address only limited aspects of the impact of urbanization due to the small sample size, it has provided information that could be used to improve future field studies. In particular, the use and setup of the cameras and audio playback devices offer a remarkable tool for future field studies. Overtime, the equipment used for this study to record animal behavior and project audio stimuli has provided an affordable, customizable, and reliable method of observing animals in the field. Further modifications could enable the unit to be solar-powered, Wi-Fi enabled, and completely weather resistant. The bucket system could be used in all types of environments and for several species, maximizing data collection and minimizing human interference. Future studies focusing on noninvasive surveying techniques (i.e., behavioral assays) versus invasive surveying techniques (i.e., hormonal assays) would be beneficial for establishing the validity of using only behavior to assess stress and personality differences.

Future studies could also benefit from pre-testing different types of birdcalls and perches used in order to maximize crow visits. Considering communication is a complex act between birds, it is worth testing how different sounds affect bird behavior. Testing how birds react to calls from different areas could be especially helpful for finding

differences between urban and rural birds. For example, playing the same call to both groups may engender different behaviors but these differences could include several factors such as the origin of the call or the message conveyed in the call. Future studies should also investigate intraspecies communication to isolate important variables in calls such as frequency, duration, and repetition of patterns. Studies focusing on these and other methods can help to validate techniques used in future studies. The perch used in the study was visited by other bird species but, perhaps, testing different perches to find what is most attractive to birds would be beneficial depending on the research question.

A breadth of possibilities exists for studying birds under different timelines. An extended study could observe birds throughout the year or at different times of the year. A study of this nature would gain insight into how behavior potentially changes under different conditions such as raising young, times of high tourist activity, changing seasons, or specific stressors such as artificial light and noise. In addition, it would be worth investigating how a stressful environment can affect young in different species. Furthermore, the research question of the current study could be applied to other synanthropes and growing synanthropic populations such as coyotes, deer, raccoons, cougars, rats, bats, and other birds (Hamer & McDonnell, 2009; Krausman, Christensen, McDonald, & Leopold, 2014; McKinney, 2002; Murray et al., 2015; Prange, Gehrt, & Wiggers, 2003).

Conclusion

The current study was unable to find an effect of setting or audio stimuli on American crow behavior due to small sample size and difficulties in coding complex

behaviors. In contrast, overall bird data (i.e., crow and all other birds) showed that perches in urban areas were visited for significantly longer periods of time compared to rural areas. Past research has shown that urban birds keep smaller territories, have less competition, and different feeding styles (Hamer & McDonnell, 2009; Heiss et al., 2009; Krausman et al., 2014; Lowry et al., 2012; Marzluff, McGowan, et al., 2001; Nordt & Klenke, 2013; Prange et al., 2003; Russ et al., 2015; Schlesinger et al., 2008; Seferta et al., 2001). The current data on overall bird visits suggest that urban birds may have kept smaller territories, were possibly experienced with easy access to food, and had less competition compared to their rural conspecifics. Unexpectedly, the findings also show that perch visit frequency and duration did not differ in response to audio birdcalls. The alternate theories and study limitations include, but are not limited to, environment factors and complexities in intra- and interspecies communication. By building on the current findings, future studies may be able to better investigate the original goals of the current study and aid in understanding the effects of urbanization on wildlife in order to improve their quality of life.

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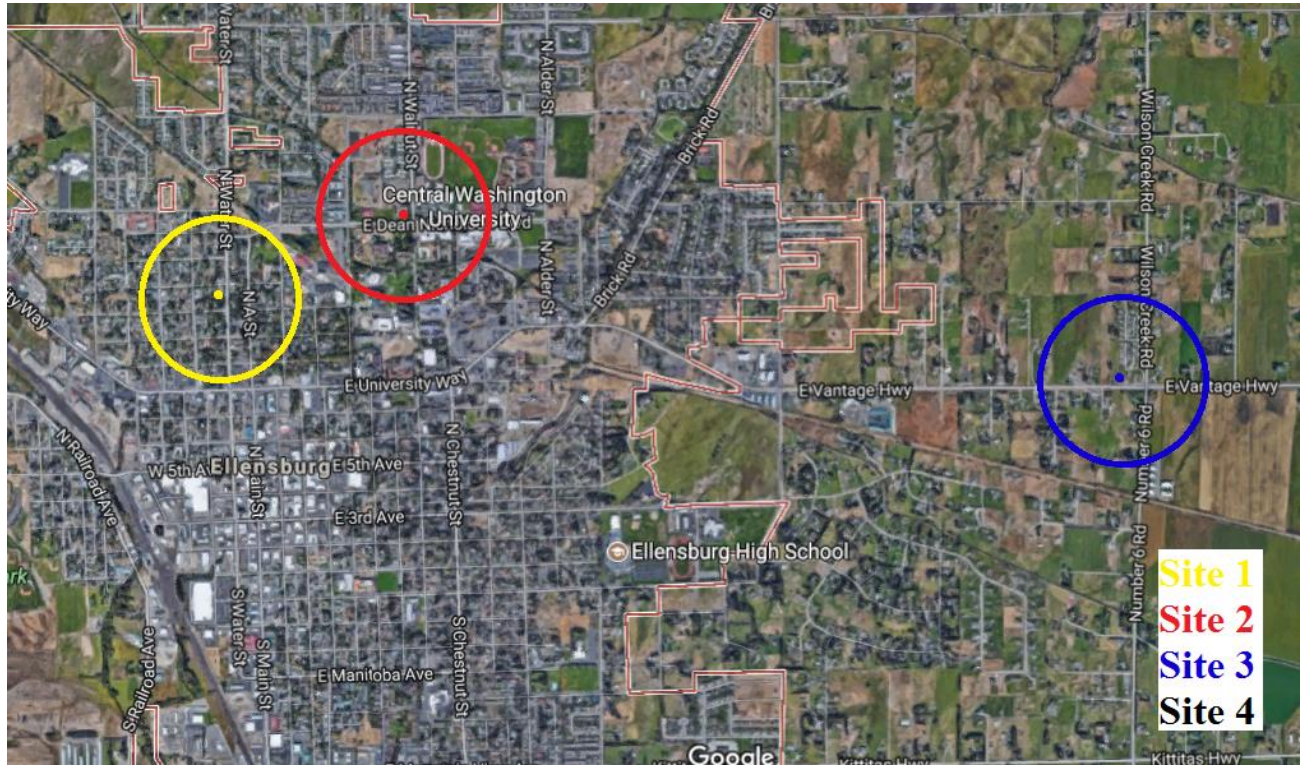
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APPENDIX A

Site Location Map and Predicted Territories

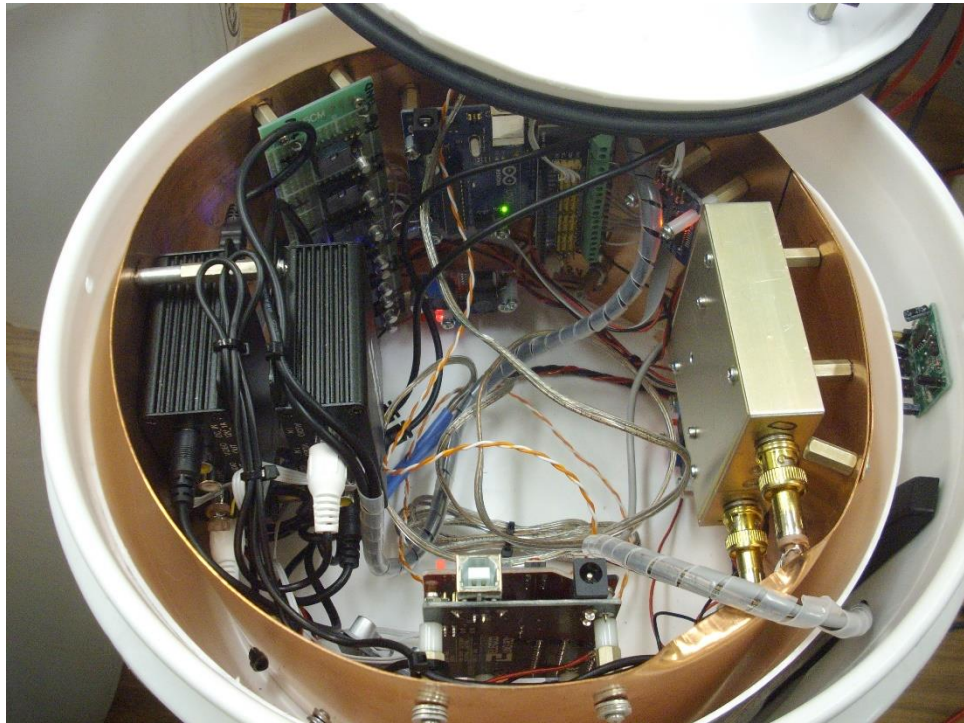




APPENDIX B

Audio/Video Recording Units Photographs





APPENDIX C
Perch Photographs

