University of Arkansas, Fayetteville
ScholarWorks@UARK

Graduate Theses and Dissertations

12-2016

Survey of Nasal Mites (Acari: Rhinonyssidae, Ereynetidae, Turbinoptidae) in Birds from Three States in the United States

Alexis Danel Hilario Perez
University of Arkansas, Fayetteville

Follow this and additional works at: https://scholarworks.uark.edu/etd

Part of the Entomology Commons, Parasitology Commons, and the Zoology Commons

Citation

Hilario Perez, A. D. (2016). Survey of Nasal Mites (Acari: Rhinonyssidae, Ereynetidae, Turbinoptidae) in Birds from Three States in the United States. *Graduate Theses and Dissertations* Retrieved from https://scholarworks.uark.edu/etd/1764

This Thesis is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of ScholarWorks@UARK. For more information, please contact scholar@uark.edu.

Survey of Nasal Mites (Acari: Rhinonyssidae, Ereynetidae, Turbinoptidae) in Birds from Three States in the United States

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Entomology

by

Alexis Hilario Pérez
Autonomous University of Santo Domingo
Bachelor of Science in Biology, 2011

December 2016
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Ashley P. G. Dowling
Thesis Director

Dr. Robert Wiedenmann
Committee Member

Dr. Kimberly G. Smith
Committee Member

ABSTRACT

Avian nasal mites are obligate endoparasites that spend their entire life in the respiratory system of birds. In North America, bird nasal mites are represented by different unrelated families in three different orders of mites: Rhinonyssidae (Mesostigmata), Ereynetidae (Prostigmata), and the Cytoditidae and Turbinoptidae (Astigmata). The most-diverse and most-abundant family of nasal mites is the Rhinonyssidae, in which mite species may have different levels of host specificity from host orders to families or even species level. Nasal mites in North America have been surveyed in different locations, such as studies ranging from the Gulf Coast of the US to Canada. From those surveys, the reported prevalence of nasal mites infesting bird hosts varied from approximately 25-45% of species that were infested.

In this study, I examined birds from three states in the US (Arkansas, Illinois and Texas) for nasal mites. I found levels of mite prevalence that were similar to results reported from other previous studies, and I added 21 new North American host records. I also studied host specificity within the bird families Parulidae and Emberizidae. I examined 149 birds from those two bird families, and 38 % of the species had nasal mites. These two host families were commonly infested by two *Ptilonyssus* nasal mites (*P. sairae* and *P. japuibensis*), which are part of a group of morphologically similar mites called the "*sairae*" complex. This complex suggest that all these related mite species could actually be a single mite species with a broad host range, or could be a related group of species, each of which is highly of specific.

Additionally, I surveyed nasal mites collected from the brood parasite, brown-headed cowbird (*Molothrus ater*), in specimens from Texas and Arkansas. For this survey, 126 individuals were analyzed, and 84 (66.6 %) were found to be infested with nasal mites, which included new host records for the cowbirds. I addressed the question of whether cowbirds

acquire nasal mites when the host parent is feeding its young, or whether mites are transferred during social interaction of related birds that are commonly found in large, multi-species flocks.

ACKNOWLEDGEMENTS

Thanks are extended to the Department of Entomology at the University of Arkansas for all the help and support during my Master's study, and to the University of Arkansas, Division of Agriculture, and the Arkansas Agricultural Experiment Station, for supporting and funding this project.

Special thanks to my great advisor, Dr. Ashley Dowling, who encouraged me to pursue and carry out this project with nasal mites, which I enjoyed very much. Thank you for always being available for mentoring whenever I needed help.

Also, special thanks to Dr. Robert Wiedenmann, who has been not only a member of my committee, but an invaluable help from the beginning to the end of my degree. Thank you for helping me write this thesis and for helping me to get better with all the advice you gave me.

I also thank Dr. Kimberly Smith for being a member of my committee and being of great help in gathering bird specimens for my collection and helping me with bird identifications.

Many special thanks to Dr. Than Boves and Alix Matthews from Arkansas State University in Jonesboro, who granted me access to their collection of birds, which constituted the largest number of birds in this study. Also, many thanks to Mary Carly at the rehab center in Camden, AR, for donating bird carcasses. Thanks to all the people who also collected birds for this study.

Thank you to all members of the Dowling Lab, all of whom helped me at many points during my studies and my work, and I appreciate it.

Finally, I thank especially my wife, Alda Diaz Perez (MS), who has always been my source of support for my every need and helped me in every aspect of my daily life. Thank you for always being there for me in good and bad moments.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

1.1 Introduction to mites

The class Arachnida includes the subclass Acari, a large group also known as the Acarina, which consists of the mites and ticks. The word “mite” is derived from Old English, meaning “small creatures.” Acari are known to be the most diverse and abundant group of arachnids and rival the insects in the number of environments colonized and their ubiquity. Due to their minute size, mites can be difficult to detect and, for a long time, this resulted in a lack of knowledge about the mites. Ticks and spider mites, which may be considered the giants of the Acari due to large body size, have received more attention, both because of their size and also their medical and economical importance. However, recent technology has made research on the Acari more feasible and, in recent decades, many mites have been described. Today, more than 50,000 species of Acari have been described, and one estimate is that there are millions more species unknown or undescribed (Krantz & Walter 2009).

Mite-like arachnids occurred at least 420 million years before present (MYBP) (Walter & Proctor 1999). Extant families of Acari are represented in the fossil record as early as the middle Devonian (412-354 MYBP) (Walter & Proctor 1999). The first and oldest mite fossil described was *Protacarus crani*, which was found in the Devonian Chert of Scotland. This species, described by Hirst in 1923 (Evans 1992), is considered to be in the suborder Prostigmata (Acariformes). Other fossil records after *P. crani* are also from the Devonian period and early in the Jurassic (213-144 MYBP) and the Cretaceous (144-65 MYBP). The first appearance in the fossil record of the order Parasitiformes was during the upper Eocene (55-28 MYBP) (Witalinski 2000, Walter & Proctor 1999).

Mites are capable of living in various types of environments and sometimes can be found in habitats that may be considered unusual. Mites have colonized terrestrial environments, including caves, shrubs, and urban habitats. They abound in forests, and live and feed on organic matter. In forests, mites such as the oribatid mites are important decomposers and are the most abundant group in organic matter (Evans 1992). Acari also occupy aquatic niches, such as fresh water lakes, river and springs. Furthermore, they have been able to successfully colonize salty habitats like oceans, and they even have been collected from thermal waters that occur in volcanic regions (Baker 1952).

The body complex of the Acari consists of one body region, or tagmata called the idiosoma. Four pair of legs (three pair in larvae) originate on the idiosoma and at the anterior end are the mouthparts, which include the chelicerae and pedipalps, and are collectively referred to as the gnathosoma or capitulum. The idiosoma, gnathosoma, and legs are variously modified across the mite tree of life.

Mites have a diversity of sperm transfer methods. Males can have modified appendages that can be used for reproduction. Direct transfer by copulation is relatively uncommon and indirect transfer of sperms packets (spermatophore) is more frequent, in which males have spermodactyl structures on their chelicerae to transfer the sperm into the female's genital opening (Walter & Proctor 1999). Other mite species can deposit a spermatophore on a substrate and these are picked up later by females.

Oviposition in mites may vary, even among closely related species. Mites can lay either single eggs or in masses. Reproductive strategies include species that are oviparous, ovoviviparous, or larviparous (Fain 1969). The complete life cycle of mites includes egg,

hexapod larva, octopod protonymph, octopod deutonymph, octopod tritonymph, and adult. However, this life cycle is variously modified across Acari.

Classification of the Acari has been changing due to the use of molecular data and phylogenetic methods (Murrell et al. 2005), and even the monophyly of Acari is in question (Evans 1992). The current classification (Klompen et al. 2007; Krantz & Walter 2009; Dabert et al. 2010; Beaulieu et al. 2011) divides the Acari into two large superorders, the Acariformes (Actinotrichida) and the Parasitiformes (Anactinotrichida). The classification of the superorders Acariformes and Parasitiformes is the one that will be used for the present study (Table 1.1), following Beaulieu et al. (2011) and Krantz and Walter (2009).

The superorder Acariformes, known as the "the mite-like mites", constitutes the most diverse and oldest group of mites with over 40,000 species described, and having a fossil record that dates from the Devonian period (Walter & Proctor 1999). Species of Acariformes occupy numerous niches, and can be predators, parasites, ectosymbionts, or phytophages. Acariformes is divided into two orders: Sarcoptiformes, with suborders Endeostigmata and Oribatida (currently includes Astigmata); and Trombidiformes, with suborders Sphaerolichida and Prostigmata (Table 1). Acariformes mites differ from mites in the Parasitiformes in having the podosoma divided by a suture called the sejugal furrow, which separates the podosoma from legs I-II and III-IV (Evans 1992).

The superorder Parasitiformes contains the ticks and their relatives. This group is represented by the orders, Opilioacarida, Holothyrida, Ixodida, and Mesostigmata. Of these orders, Ixodida are the ticks. Ixodid mites (ticks) are the most well-known due to their size and blood-feeding habit, and they are recognized as vectors of dangerous diseases. Ticks have chelicerae specialized for cutting into the host skin, and they become anchored to the host by

modified teeth in the anterior part of the gnathosoma to avoid becoming dislodged (Walter & Proctor 1999). Holothyrida are large mites (2-7 mm), that are represented by three families. These mites are scavengers of dead arthropods and feed only on fluids. Holothyrids have been poorly studied and are known only from Australia and New Zealand, the Neotropics, and islands from Pacific and Indian oceans (Evans 1992; Walter & Proctor 1999). The order Opilioacarida (=Notostigmata) is a group of mites represented by one family (Opilioacaridae). The name comes from the resemblance to harvestmen (Opiliones) but without the segmented abdomen. These mites are known to inhabit dry environments, dwelling under rocks and feeding on pollen, fungi, or small arthropods. These mites have been collected from Europe, Africa, Asia, Australia, and North America (Walter & Proctor 1999).

The order Mesostigmata is the most diverse order of Parasitiformes, with currently 100 families distributed across 12 suborders, and approximately 8,000 species described (Beaulieu et al. 2011). Mesostigmata mites have diverse lifestyles. Several of the Mesostigmata are free-living predators, others live in the soil-litter, rotting wood, dung, carrion, nests or house dust (Klompen et al. 2007).

Mite diversification has led to an expansion of feeding behavior and different adaptations. Some mites feed on decaying matter and plant tissue. Other mites are known to be saprophagous and fungivorous. Water mites tend to be predators of microorganisms or parasites of other aquatic organisms. Other mites are free-living predators, parasites of plants, vertebrates and invertebrates.

Unlike other arachnids, mites have developed different kinds of associations with other organisms. Commensalism is common among mite associations. Commensal mites can live on the host or in the nest of the host without causing any harmful effect by their activities. To

illustrate, different species that are commensal on bees may steal some pollen without having any effect on the development of the brood (Houck 1994). Some mites are mutualistic species, that can have positive effects on their host. For example, *Parasitellus* mites act as predators of invertebrates that affect species of *Bombus*; for instance, queen bumblebees carrying *Parasitellus* mites have low levels of parasitic nematodes (Eickwort 1994).

Phoresy, which is the use of another organism as a transport, is very common in mites, because mites are not great dispersers. Some mite species use other, even bigger mites as transport (Walter & Proctor 1999). Also, phoresy is the principal strategy for mites to reach a desirable resource, for instance, mite larvae that are adapted to attach onto adult bees in colonies (Eickwort 1994).

The great differentiation in adaptation of mites to their host has allowed them to utilize as hosts different groups of plants, vertebrates and invertebrates. Some members of the Astigmata and Prostigmata are considered economically important pests, such as the spider mite *Tetranychus urticae* that feeds on many different kinds of plants (Van Den Boom et al. 2004).

Predation is also very common in mites, and their predacious habit allows the use of these mites for biological control. The predatory mite, *Phytoseiulus persimilis,* is a member of the order Mesostigmata and is a natural enemy of spider mites. *Phytoseiulus* mites tend to search for their prey by following volatiles that are released by the plants when they are being attacked by prey (Dicke & Sabelis 1987). Although many species of Mesostigmata are free-living predators, other members represent different life-histories and strategies of feeding and parasitism.

Parasitism has evolved many times in Acari due to the differentiation and diversification of feeding. Parasitism in vertebrates had its beginnings in mite species that switched from

predation and evolved to feeding on a host (Fain 1969; Walter and Proctor 1999). Modified chelicerae adapted for piercing and blood feeding, as in ticks, allowed species to adapt and efficiently funnel the liquid into the mouth. For instance, there have been hypotheses on the evolution of parasitism suggested in Mesostigmata, in the superfamily Dermanyssoidea (Dowling & OConnor 2010). The hypotheses suggest the evolutionary origin is in the association of predators with mouthparts modified for piercing, that can take a blood meal on vertebrates. Also, invasion of vertebrate nests allowed dermanyssoid mites to develop feeding adaptations, such as occurred in the family Laelapidae, that invaded vertebrate nests (Dowling & OConnor 2010). Furthermore, phoresy is suggested as being part of the adaptation of some species that used bigger animals as a way of transport and, also, use these organisms as hosts by lightly feeding or laying eggs; consequently, the mite larvae would feed on the animal host (Walter and Proctor 1999). Parasitism on plants might also have developed from species that were soil-dwellers, such as oribatid mites that began to oviposit in plants. If correct, then larvae began feeding on plants and adapted their life cycle and overwintering strategy (e.g., gall mites), evolving chelicerae needed for the transition to phytophagous feeding (Krantz & Lindquist 1979).

In Mesostigmata, the superfamily Dermanyssoidea is the most ecologically diverse, with members that can be soil dwelling, free-living predators of vertebrates and invertebrates, facultative and obligatory ectoparasites of vertebrates, and respiratory and auditory endoparasites of birds, mammals, and lepidosaurs (Dowling & OConnor 2010). *Varroa destructor* is an example of a parasite of invertebrates, causing damage to honeybee colonies (Guzmán-Novoa et al. 2010). *Ophionyssus galloticolus*is an ectoparasitic mite of the lacertid lizard (Bannert et al. 2000) and the macronyssids and laelapids are common parasites of bats (Radovsky 1966).

Mites are the most diverse symbionts in association with birds (Knee 2008). Every part of the bird's body serves as a microhabitat for different families of mites. By the diversity of the location in birds, they can be separated as skin mites, quill mites, feather mites, subcutaneous mites, down mites, respiratory mites, and others (Proctor & Owens 2000). Some of the orders associated with avian fauna are in Mesostigmata, Astigmata, Prostigmata, or Ixodida. Approximately 3,000 of species of mites distributed in 40 families are known to be associated with birds (Knee & Proctor 2006). These mites are classified depending on their behavior and life cycle. Some mites spend their entire life cycle on a host and can be endoparasites. Others tend to have the reproductive phase in the nest and then get on the bird when they need to feed. Still others are ambushers from the nest, that feed on the bird and return to the nest at night (Proctor & Owens 2000). Some mites in birds are parasitic and others are commensal, feeding on blood, plumage, secretions, or even tissue of their bird hosts.

The effects of mites on birds still needs further research. Some mites are blood and tissue feeders that can transmit pathogens to the host. The most well-known is *Dermanyssus gallinae*, which is a blood feeder of many birds including passerine and domestic poultry birds. This mite is known to be a vector of equine encephalitis (Gaud & Atyeo 1996).

Respiratory mites are obligate endoparasites that sspend their complete life in the respiratory system. Some ticks and chiggers have been reported from the nasal passage, but are not considered nasal mites (Pence 1975). Nasal mites have been studied in different kinds of vertebrates, and are well-known from mammals. Domestic animals, such as dogs, are sometimes infected by *Pneumonyssus caninum*, which tend to cause sinusitis on their hosts. Other groups of mammals with nasal mites that have been studied are: bats, known to be infected by members of Trombidiformes (Fain & Lukoshus 1971), different kinds of rodents (Zabludovskaya 1990), and

even marine mammals (Fay & Furman 1982). In reptiles, nasal mites such as laelapids have been described from the nasal passages of lepidosaurs (reptiles with overlapping scales like snakes or lizards), (Fajfer 2012). Members of the family Ereynetidae (Prostigmata) can occur in the respiratory passages of toads and frogs, as well as being intranasal parasites known from birds and mammals (Krantz 1978).

Coevolution of the nasal mites can be explained by the cospecification and the high degree of host specificity they display (Proctor and Owens 2000). Depending on the species, nasal mites have adapted to live with their host, while some species might use the host for feeding or phoresy. Generally, nasal mites are believed to have evolved from free-living soil-dwelling predators that radiated into an ectoparasitic lifestyle due to feeding and morphological changes associated with vertebrates, and eventually developed into the intranasal endoparasites they are today (Vitzthum 1935, Domrow 1969).

Some effects have been associated with nasal mites on different animals. In mammals, nasal mites are a cause of skin disease and allergies, such as the dog mite *Pneumonyssus caninum*. The mites can also migrate to other organs of the body and cause damage (Tharaldsen & Grondalen 1978). In reptiles, there is little evidence of effects from nasal mites. In the Mesostigmata, some of the species are specialized on reptiles, such as some Entonyssidae and Macronyssidae, that can parasitize nasal passages on lizards and snakes. In a related example, chiggers (Trombiculidae), can cause some allergies on the reptile host (Walter & Proctor 1999). In birds, *Sternostoma tracheacolum* (Rhinonyssidae), is a nasal mite that can invade the lung of some bird species, causing bronchial dilation and can even cause death of the individual (Lawrence 1948; Tidemann et al. 1992). Other effects associated with nasal mites in birds are irritation, anemic reaction, or transmission of pathogenic organisms (Knee & Proctor 2006).

1.2 Nasal mites of birds

The nasal mites in avian fauna are represented by different unrelated, families that belong to the suborders Mesostigmata, Prostigmata and Astigmata. In North America, the intranasal mites are known to be represented by four families: Rhinonyssidae (Mesostigmata), the subfamily Speleognathinae (Prostigmata: Ereynetidae), the subfamily Turbinoptinae (Astigmata: Turbinoptidae), and the family Cytoditidae (Astigmata) (Knee et al. 2008; Beaulieu et al. 2011). One other family, the Ascidae (Mesostigmata), which includes such genera as *Lasioseius*, *Rhynoiseius*, *Proctolaelaps*, and *Tripocoseius*, can infect the nares of hummingbirds (Dusbabek 2007), but are not a true nasal mite. Unlike other nasal mites, hummingbird nasal mites feed on nectar and pollen, and oviposit on the flowers. These mites will get on a bird when it is feeding on the flower infested with nasal mites. The nasal mites are opportunists, and will only use the bird as a phoretic host for dispersal, which increase the mites' mating success for the nasal mites (Colwell & Naeem 1999).

Members of the subfamily Speleognathinae (Prostigmata: Ereynetidae) are well-known as intranasal tissue-feeding mites without a defined niche inside the nasal passage, meaning that these mites can be found in many parts of the respiratory tract (Fain 1994). These mites affect not only birds, but also mammals and reptiles, and have been described from parts of the world other than North America (Krantz 1978). Species of the Speleognathinae are represented by four genera – *Boydaia* Womersley, *Neoboydaia* Fain, *Opthalomophagus* Dubinnin, and *Astrida* Fain – that are known from associations with at least 11 host orders of birds in North America (Knee et al. 2008).

The Turbinoptinae (Astigmata: Turbinoptidae) is a group of obligate tissue-feeding endoparasites that occur in the most superficial cutaneous part of the nasal cavities and only stay

there feeding on corneous of the skin (Fain 1994). These mites are represented in birds of North America by the genera, *Turbinoptes* Boyd, *Colinoptes* Fain, *Schoutedenocoptes* Fain, and *Congocoptes* Fain (Pence 1975).

Cytoditidae (Astigmata), is a small group represented only by two genera, *Cytonyssus* Fain and *Cytodites* Oudemans, and is represented only by three species – *Cytonyssus troglodyti*, *Cytodites therae*, and *Cytodites nudus*. These can occur in the sinuses and the deepest part of nasal cavities and also reach the air sacs (Fain 1960).

Host specificity for the Speleognathinae, Turbinoptinae and Cytoditidae varies, with some species being frequently found in some orders of birds (Table 1.2), such as woodpeckers (Piciformes) that are infected by *Colinoptes* (Turbinoptinae) species, or *Cytodites nudus* feeding on of Galliformes hosts (Fain 1960, Pence 1975). However, these groups of nasal mites are not very diverse compared to Rhinonyssidae.

1.3 Family Rhinonyssidae

Rhinonyssidae is the most diverse family of nasal mites. The family is currently classified into eight genera and approximately 510 known species (Beaulieu et al. 2011). This is a group of slow-moving, endoparasitic, blood-feeding mites that live in the intranasal passage of birds, although some species may invade the bird's lungs (Lawrence 1948). Generally, rhinonyssids do not cause significant harm to the host, but there have been some documented cases in which nasal mites have caused irritation to the nasal epithelium (De Rojas et al. 2002). Compared with other mites, rhinonyssids have a significant reduction of the number and length of setae, a great reduction or loss of peritremes from the stigmata, which in mesostigmatans are microtubules connected to the dorso-lateral respiratory openings (stigmata). Rhinonyssids may have

fragmentation of podosomal plates, or may have lost the opisthosomal plate (Pence 1975). The modifications in this family seem to show a regression in organs as an adaptation that is more obvious in endoparasites than in ectoparasites. For example, rhinonyssids have more marked chaetotaxy (rearrangement of setae) compared to their sister group, Macronyssidae, which contains ectoparasites of several vertebrate groups (Fain 1969). Rhinonyssids can remain inside the nasal passage due to modifications like claws and suckers that allow them to walk without being dislodged, but also mucus in the host nasal cavities might help considerably (Fain 1969). Another adaptation of rhinonyssids living in the nasal passages is an accelerated life cycle, and also producing offspring in great numbers by ovoviparity (Mitchell 1963; Bell 1996), or viviparity in some species, where females can produce developed nymphs instead of larvae (Fain 1969).

The family Rhinonyssidae has been a subject of debate for many years. Most disagreement is due to morphological similarities that have led to different views on naming genera or species (De Rojas 2002). First, the family was considered to be a subfamily of the Dermanyssidae (Pence 1975; Domrow 1969), whereas some others considered Rhinonyssidae as a separate family (Fain 1969; Brooks & Strandmann 1959). Second, the descriptions of several genera of rhinonyssids that were based on morphology led to 39 names proposed for different genera (Spicer 1987). Eventually, Domrow (1969) suggested a new classification for the group. Currently these eight genera are used as the accepted taxonomy for rhinonyssids: *Sternostoma, Ptilonyssus, Ruandanyssus, Rhinoecius, Larinyssus, Rallinyssus, Rhinonyssus, Tinaminyssus* (Beaulieu et al. 2011). This is the taxonomy that I am following for Rhinonyssidae.

Rhinonyssids are variable in their degree of host specificity in certain orders of birds (Table 1.2). Some genera of rhinonyssids are restricted to a specific order of birds, or even

specific families or species of birds. In North America, the genus *Ptilonyssus* have only been found in species of Passeriformes, Caprimulgiformes, Falconiformes, and Apodiformes. *Sternostoma* is restricted to Passeriformes, Piciformes and Charadriiformes. *Rhinonyssus* has been found infesting the Anseriformes, Podicipediformes, and Charadriiformes. *Tinaminyssus* are found in Charadriiformes, Ciconiformes, and Columbiformes. Some genera are known from only one family of birds. *Rallinyssus* infest birds in the family Rallidae and *Larinyssus* infect members of the family Laridae. In contrast with general associations, species in the genus *Rhinoecius* are host specific, each occurring in a single species of Strigiformes (Strandtmann 1958; Knee 2008).

Within the same mite genus, some species can show great host specificity (Pence & Casto 1976). Members of the genus can have similar morphological characteristics, such as the "*sairae*" complex, which is a set of closely related species infecting passerine members of the families Parulidae and Fringillidae. Each of those mites could have a diverse degree of specificity within a host species or could be a single highly variable species with low host specificity and found in many hosts (Pence & Casto 1976). After *Ptilonyssus sairae* and *P. japuibensis* were described, some other species were described from the same group of birds, and were reported to have similar morphological characteristic, thus, making the "*sairae*" complex (Pence & Casto 1976).

Host specificity has been considered a function of gregariousness of the host, in which species of gregarious birds will have morphologically similar species of nasal mites. As a result, it would be expected that these mites would have more morphological similarities than those that parasitize more isolated host species (Strandmann 1958).

Transmission of nasal mites among the hosts is still unclear. Bell (1996) observed in Gouldian finches that non-gravid, female mites migrated from the nasal passage to the plumage and also to the bill and nares of the bird host. Porter and Strandtmann (1952) found that House Sparrow (*Passer domesticus*) nests were infested with *Ptilonyssus nudus* and *P. hirsti.* Approximately 40% of young House Sparrows were infested by mites, whereas 70% of the parents were infested with mites, suggesting that nasal mites are transmitted when parents feed their young. However, other mechanisms of transmission have been suggested. TerBush (1963), showed nasal mites of gulls were related to patterns of aging by change in the plumage. First-year birds were infected with *Larinyssus orbicularis* at a rate of 1%, second-year birds had a mite infestation rate of 40%, whereas adult birds showed a 55% rate of infestation (Morelli & Spicer 2007). Amerson (1967) found Sooty Terns (*Sterna fuscata)* infected with the *Sternostoma* and *Larinyssus*, and he suggested that the mites were transferred during courtship billing.

1.4 Background

Early descriptions of avian nasal mites were reported by European workers, such as Giebel (1871), Berlese &Trouessart (1889), Trägärdh (1904), and Hirst (1921, 1923) . The early descriptions were later reviewed by Vitzthum (1935). A great contribution to the literature of nasal mites worldwide has been done by Fain and colleagues. Their research included surveys from Brazil, South Africa, Europe, and a more extensive collection from Australia, publishing a total of 184 species described in 56 papers (e. g., Fain 1958; Fain & Johnson 1966; Fain & Aitken 1971). In North America, contributions have included reports from Texas, which has the richest avifauna in the USA (Brooks & Strandmann 1959). In Texas, Strandmann and colleagues started contributing to the literature of nasal mites in different group of birds (Strandmann 1948,

1951). Spicer (1987), contributed to the research of nasal mites in his study of 335 birds, including 74 species from Texas. Pence (1975) completed a series of studies in nasal mites from Louisiana (Pence 1973), and a monograph summarizing all knowledge on US nasal mites. In these studies, he recorded 51 species of Rhinonyssidae, seven species of Turbinoptinae, 13 species of Speleognathinae, and two Cytoditidae from a total 1900 birds representing 193 species collected in Southern Louisiana (Pence 1975). A Canadian study (Knee 2005) yielded information from Manitoba and Alberta provinces. The birds were represented by 16 orders, 44 families, 136 genera and 230 species. (Table 1 in Knee et al. 2008). In that study 38% percent of species of birds were found to be infested from Manitoba. Similar percentages have been recorded in other studies. For example, Spicer (1987) reported values of 39% of birds infested with nasal mites and Domrow (1969) recorded a 36% infestation rate of Australian birds examined. Most importantly, Knee's work discovered many new species and a large number of new host associations, clearly showing that there is still much to learn about the nasal mite fauna in North American birds.

1.5 Objectives

The main objective of this study was to carry out a survey of bird nasal mites in host birds from Arkansas and other locations of the United States.

Specific objectives included:

- To provide lists of the nasal mites found with orders and families the hosts.
- To report any new host records for nasal mites in North America.
- To compare percentage of nasal mites' prevalence with other studies.
- To conduct a survey of the nasal mites of Brown-Headed Cowbirds in specimens from Fort Hood, Texas, and Arkansas.

Table 1.1 Classification (Superorder, Order, Suborder) of the Subclass Acari.

Superorder	Order	Suborder
Acariformes		
	Sarcoptiformes	
		Endeostigmata*
		Oribatida (includes Astigmata)
	Trombidiformes	
		Sphaerolichida
		Prostigmata
Parasitiformes		
	Mesostigmata	
		Monogynaspida
		Trigynaspida
		Sejida
	Ixodida	
	Holothyrida	
	Opilioacarida	

*Known to be a paraphyletic group (Krantz & Walter 2009)

Table 1.2. Classification of Avian nasal mites and different host orders in which they parasitize in North America.

Order	Suborder	Family	Subfamily	Genera	Host order
Trombidiformes	Prostigmata	Ereynetidae	Speleognathinae	*Boydaia*	Passeriformes, Galliformes
				Neoboydaia	Strigiformes, Podicipediformes
				Opthalomophagus	Columbiformes, Anseriformes
				Astrida	Cuculiformes, Caprimulgiformes
Sarcoptiformes	Astigmata	Turbinoptidae	Turbinoptinae	*Turbinoptes*	Charadriiformes
				Colinoptes	Galliformes
				Schoutedenocoptes	Cuculiformes
				Congocoptes	Piciformes
		Cytoditidae	-----------------	*Cytodites*	Galliformes
				Cytonyssus	Cuculiformes
Parasitiformes	Mesostigmata	Rhinonyssidae	Rhinonyssinae	*Sternostoma*	Passeriformes, Piciformes and Charadriiformes
				Ptilonyssus	Passeriformes, Caprimulgiformes, Falconiformes and Apodiformes
				Rhinoecius	Strigiformes
				Larinyssus	Charadriiformes (in Laridae)
				Rallinyssus	Gruiformes (in Rallidae)
				Rhinonyssus	Anseriformes, Podicipediformes and Charadriiformes

CHAPTER 2. MATERIALS AND METHODS

2.1 Bird Collection

I gathered a total of 556 birds for this study (Table 2.1). All were North American species, collected from the US states of Arkansas, Texas and Illinois. Two primary sources of specimens were: 1) salvage of specimens that died from striking windows or vehicles, or died while in the care of bird rehabilitation professionals; and 2) an avian collection maintained in a freezer in the laboratory of Dr. Than Boves at Arkansas State University (ASU), in Jonesboro. The birds in the ASU collection were used for projects on feather mites and window strikes.

2.2 Sample Processing

Bird specimens were maintained in a freezer at -20°C until they could be processed in a laboratory in the Department of Entomology at the University of Arkansas, Fayetteville. Specimens were removed from the freezer to allow thawing. Specimens that were not already identified to species level were identified using images in the Sibley (2000) Field Guide to Birds, or the web site (Allaboutbirds.org) from the Laboratory of Ornithology at Cornell University.

The respiratory passages of the birds were flushed using a mixture of ethanol and warm water. For smaller specimens (<16cm body length), I used a 3 ml syringe; for larger specimens (>16 cm body length), I used a 5 ml syringe. The syringe was used to push the water/ethanol solution through the nasal passages. Mite collections were made by making four consecutive flushes using hard water pressure applied to each nostril, alternating between sides of the nasal cavities. The flushed liquid was collected in a 9-cm Petri dish, and was examined for nasal mites using a Leica MZ16 stereomicroscope at 20-25x magnification. Nasal mites were collected and stored in vials containing 70% ethanol.

2.3 Slide-mounting Nasal Mites

To identify nasal mites, a subset of collected mites were slide-mounted for observation under the compound microscope. Mites were cleared in 85% lactic acid at 70°C for one hour. They were then placed on the slide in a drop of Hoyer's mounting medium, positioned correctly, and a cover slip was put in place. Species-level identifications of both larval and adult mites were made using published keys (Pence 1975, Knee & Proctor 2006).

Nasal mite specimens were deposited in the Acarology Collection at the University of Arkansas.

2.4 Collecting Ectoparasites of Birds

Feather mites and other ectoparasites were collected following the methods of Knee & Proctor (2006). Individual birds were placed in plastic containers and washed in a mixture of ethanol, water, and soap to soak the plumage. The container was then sealed with a plastic lid and was shaken vigorously for five minutes. Birds were then rinsed thoroughly with water and massaged to dislodge all remaining parasites. The remaining liquid in the container was then filtered using a 63 um filter and decanted into a petri dish to examine for mites. From those processed birds, I collected feather mites and other ectoparasites for future research on bird symbionts.

CHAPTER 3. RESULTS

3.1 Counting bird hosts and prevalence of nasal mites

I examined a total of 556 birds as hosts for nasal mites. The birds were collected from three locations: 284 collected in Arkansas, 152 from western Illinois and 120 *Molothrus ater* in a collection originating from Fort Hood, Texas. The hosts were distributed in 15 orders, 34 families and 106 species (Appendix).

From the 556 birds examined, 126 were *M. ater*, which are discussed in Chapter 5 and results are not reported here. The remaining 430 individuals were examined for nasal mites, and 63 birds (14.7%) were infested with nasal mites. The 430 specimens were divided in 106 species and 31 (29 %) of these were infested. The 63 infested birds (Tables 3.1 and 3.2) belonged to 4 different orders, and represented 12 families, including one whose placement is unknown, listed as *Incerta sedis.* Infested birds were distributed across 25 genera and 31 species. The greatest number of species of infested birds were from the Passeriformes, with 26 species in 9 families. In my survey, 11 of the 15 orders examined did not contain infested hosts.

3.2 Nasal mite species distribution and abundance

Twenty-four species of nasal mites were identified in this survey, belonging to three orders and one family in each order – Ereynetidae (Prostigmata), Turbinoptidae (Astigmata) and Rhinonyssidae (Mesostigmata). Ereynetidae was represented by the genera *Boydaia* and *Astrida* (Table 3.1). Two species of *Boydaia* were found from *Molothrus ater* (Passeriformes: Icteridae) and *Catharus ustulatus* (Passeriformes: Turdidae), whereas one species of *Astrida* was collected from *Coccyzus americanus* (Cuculiformes: Cuculidae). Turbinoptidae was represented by three species of mites from two genera (Table 3.1). Two species of *Congocoptes* were found from two

woodpecker hosts (Piciformes: Picidae), whereas one species of *Schoutedenocoptes* was found infesting two different hawk species – *Accipiter cooperii* and *Buteo jamaicensis* (Acciptriformes: Accipitridae).

Eighteen of the mite species found belonged to the family Rhinonyssidae (Table 3.2). The genus *Ptilonyssus* was represented by 14 species and the genus *Sternostoma* had 4 species. The four species of *Sternostoma* were collected from two orders (Piciformes and Passeriformes) and four different families (Table 3.2). The 26 species of Passeriformes that were infested yielded 14 species of *Ptilonyssus*, including two that could not be identified to species (Table 3.2).

Numbers of individual nasal mites found in each specimen were variable and ranged from 1 to 15. Most nasal mites found were female or larvae, with few males collected. Although not quantified, host specimens collected soon after death (e.g., window strike) yielded more mites than those that were beginning to deteriorate. At the species level, 7 bird species were host to more than one species of nasal mite (Table 3.2), but only one individual of one species (*Melospiza melodia*) had a co-infestation of more than one species of nasal mite.

In total, 21 infested bird species from the three orders Passeriformes, Piciformes, and Accipitriformes produced new host records for nasal mites. The new host records were distributed among four mite genera and occurred in all three mite orders (Tables 3.1 & 3.2).

3.3 Diversity and host specificity of *Ptilonyssus* in Parulidae and Emberizidae.

Passeriform birds represented the majority of nasal mite hosts, and two families, Parulidae and Emberizidae, contained the majority of mites. I examined 80 individuals of Parulidae, representing 23 bird species, and 69 individuals of Emberizidae from 14 species

(Appendix). Eight of the 23 species of Parulidae were infested with nasal mites and, of those 8 species, 16 of 53 individuals were infested with nasal mites (30 % prevalence). The 6 species of Emberizidae that were infested yielded 13 infested individuals of 38 examined (34 % prevalence) (Table 3.1). Birds from these two families yielded 11 of the 21 new host records found.

Seven species of *Ptilonyssus* were each collected from only one host species (Table 3.2). Three species of *Ptilonyssus* showed a differing degree of host specificity at the family level (Figure 3.1). *Ptilonyssus morofskyi* was found in four species of Emberizidae plus *Passer domesticus* (Passeridae) (table 3.3). *Ptilonyssus japuibensis* was collected from 10 host species from five families. In contrast, *Ptilonyssus sairae* was only collected from Parulidae, but was found infesting seven parulid species.

Table 3.1. Avian hosts (Order: Family: Species), species of nasal mites of the families Ereynetidae (Prostigmata) and Turbinoptidae (Astigmata), numbers of avian hosts found containing nasal mites, and new host records.

Host Order and Family	Host Species	Mite Family	Mite Species	Hosts Examined	Hosts Infested	New Host Records
Accipitriformes						
Accipitridae	*Accipiter cooperii*	Turbinoptidae	*Schoutedenocoptes americanus*	4	1	yes
	Buteo jamaicensis	Turbinoptidae	*Schoutedenocoptes americanus*	6		yes
Cuculiformes						
Cuculidae	*Coccyzus americanus*	Ereynetidae	*Astrida coccyzae*	6	1	no
Piciformes						
Picidae	*Melanerpes carolinus*	Turbinoptidae	*Congocoptes furmani*	7	1	no
	Sphyrapicus varius	Turbinoptidae	*Congocoptes sphyrapicicola*	11	2	no
Passeriformes						
Turdidae	*Catharus ustulatus*	Ereynetidae	*Boydaia spatulata*	22	1	yes
	Molothrus ater	Ereynetidae	*Boydaia quiscali*	126	2	no

Table 3.2. Avian hosts (Order: Family: Species), species of nasal mites of the family Rhinonyssidae (Mesostigmata), numbers of avian hosts found containing nasal mites, and new host records.

Host Order and Family	Host Species	Mite Species	Hosts Examined	Hosts Infested	New Host Records
Piciformes					
Picidae	*Sphyrapicus varius*	*Sternostoma hylandi*	11	1	yes
Passeriformes					
Vireonidae	*Vireo flavifrons*	*Ptilonyssus vireonis*	1	1	no
	Vireo olivaceus	*Ptilonyssus vireonis*	8	2	no
Bombycillidae	*Bombycilla cedrorum*	*Sternostoma hirundinis*	12	1	no
Turdidae	*Catharus ustulatus*	*Ptilonyssus* sp. 1	22	1	?
		Sternostoma spatulatum		1	yes
	Hylocichla mustelina	*Ptilonyssus euroturdi*	2	1	no
Passeridae	*Passer domesticus*	*Ptilonyssus hirsti*	13	4	no
		Ptilonyssus morofskyi		1	yes
Parulidae	*Seiurus aurocapilla*	*Ptilonyssus sairae*	14	1	no
		Ptilonyssus japuibensis		1	yes
	Mniotilta varia	*Ptilonyssus sairae*	6	4	no
	Leiothlypis peregrina	*Ptilonyssus sairae*	9	3	yes
	Leiothlypis celata	*Ptilonyssus sairae*	2	1	no
	Leiothlypis ruficapilla	*Ptilonyssus sairae*	9	2	yes
	Geothlypis philadelphia	*Ptilonyssus sairae*	3	1	yes
	Geothlypis trichas	*Ptilonyssus sairae*	5	2	yes
	Setophaga pensylvanica	*Ptilonyssus japuibensis*	5	1	yes
Incertae sedis	*Icteria virens*	*Ptilonyssus japuibensis*	2	1	yes

Table 3.2. (continued) Avian hosts (Order: Family: Species), species of nasal mites of the family Rhinonyssidae (Mesostigmata), numbers of avian hosts found containing nasal mites, and new host records.

Host Order and Family	Host Species	Mite Species	Hosts Examined	Hosts Infested	New Host Records
Passeriformes					
Icteridae	*Molothrus ater**	*Ptilonyssus icteridius*	126	64	no
		Ptilonyssus aegelaii		17	no
		Ptilonyssus richmondinae		1	yes
		Ptilonyssus japuibensis		1	no
		Ptilonyssus sp. 2		1	?
	Icterus galbula	*Ptilonyssus icteridius*	6	1	no
		Sternostoma pirangae		1	yes
Emberizidae	*Melospiza melodia***	*Ptilonyssus morofskyi*	4	1	no
		Ptilonyssus japuibensis		1	yes
	Zonotrichia albicollis	*Ptilonyssus morofskyi*	25	1	no
		Ptilonyssus japuibensis		4	no
		Ptilonyssus agelaii		1	yes
	Zonotrichia atricapilla	*Ptilonyssus morofskyi*	2	1	no
		Ptilonyssus japuibensis		1	yes
	Passerculus sandwichensis	*Ptilonyssus japuibensis*	4	1	yes
	Pooecetes gramineus	*Ptilonyssus morofskyi*	1	1	yes
	Pipilo erythrophthalmus	*Ptilonyssus japuibensis*	2	1	no
Cardinalidae	*Piranga rubra*	*Ptilonyssus pirangae*	1	1	no
	Piranga olivacea	*Ptilonyssus troglodytis*	1	1	yes
	Passerina cyanea	*Ptilonyssus japuibensis*	17	5	no

* *Molothrus ater* is not calculated in the total of hosts examined or number of hosts with mites.

** Double infestation – two species of nasal mites were found in the same bird specimen

Table 3.3. Host specificity of three species of *Ptilonyssus* nasal mites as represented by the host species and family (Order Passeriformes).

Mite species	Host species	Host family
P. japuibensis		
	Seiurus aurocapilla	Parulidae
	Setophaga pensylvanica	
	Icteria virens	*Incertae sedis*
	Melopiza melodia	Emberizidae
	Zonotrichia albicollis	
	Zonotrichia atricapilla	
	Passerculus sandwichensis	
	Pipilo erythrophtalmus	
	Molothrus ater	Icteridae
	Passerina cyanea	Cardinalidae
P. sairae		
	Seiurus aurocapilla	Parulidae
	Mniotilta varia	
	Leiothlypis celata	
	Leiothlypis peregrina	
	Leiothlypis ruficapilla	
	Geothlypis philadelphia	
	Geothlypis trichas	
P. morofskyi		
	Passer domesticus	Passeridae
	Melospiza melodia	Emberizidae
	Zonotrichia albicollis	
	Zonotrichia atricapilla	
	Pooecetes gramineus	

Figure 3.1. Most common *Ptilonyssus* nasal mites In Emberizidae and Parulidae. 1. *P. sairae*, 2. *P. japuibensis*, 3. *P. morofskyi*.

CHAPTER 4. DISCUSSION

4.1 The prevalence of nasal mites in bird hosts

In this study, I examined a total of 556 bird specimens, including the 126 brown-headed cowbirds (*Molothrus ater*), detailed in chapter 5. That total number included birds collected from three states in the US -- Arkansas, Texas and Illinois. Excluding cowbirds, I examined 430 specimens of 106 species. Currently, there have been 914 species of birds recorded from North America, north of the Mexican border (birdwatching.com 2014). My collection (106 species) constituted 11% of the total species in North America. Although only a fraction of the total bird species was analyzed, the results I found in this survey are similar to those reported from previous studies of nasal mites in birds.

Including cowbirds, I found nasal mites in 147 individual birds, or a prevalence of 26.4%. Because the number of cowbirds alone represented 22.6% of the total individuals, a better representation of prevalence excludes cowbirds. Of the remaining 430 individuals examined, 63 (14.7%) of the specimens were infested by nasal mites. Also, 31 of the 106 species (29%) were infested. Both percentages of individuals and species infested in my study were similar to previous North American studies. Knee et al. (2008) reported 13% of individuals and 23% of 154 species in Alberta, Canada were infested, similar to their findings of infestations of 16% of individuals and 35% of 196 species from Manitoba. In a survey from Texas, Spicer (1987) reported 17% of individuals and 39% of 103 species infested. Pence (1973) reported 16% of individuals and 48% of 193 bird species from Louisiana had nasal mites. In a study from Australia, Domrow (1969) reported 39% of species had nasal mites.

From this collection, 75 species did not host any nasal mites, 29 species had individuals infested by a single species of mite, and only two species were found to have individuals infested

by two different species (double infestation) of nasal mites. One individual of the song sparrow, *Melospiza melodi*, was infested by two species of *Ptilonyssus* (*P. japuibensis* and *P. morofskyi*). Four individual *M. ater* had double infestations -- two birds hosted *P. icteridius* and *P. agelaii*, and one each contained *P. icteridius* and *Boydaia quiscali* and *B. quiscali* and *P. agelaii*. These results were similar to those found in previous surveys. Knee et al. (2008) reported 3.5% of species with multiple infestation, Clark (1963) reported two individuals of *M. ater* with double infestation, and Spicer (1987) reported a flycatcher (unidentified species) with double infestation of nasal mites. Interestingly, my results showed the double infestations of *M. ater* included representatives of both *Ptilonyssus* (Mesostigmata:Rhinonyssidae) and *Boydaia* (Prostigmata:Ereynetidae), which are from different mite families and orders.

The most abundant order of birds in my collection was Passeriformes (Tables 3.1 and 3.2). Nearly all infested passerines hosted species of Rhinonyssidae. Only two species of Passeriformes hosted species of *Boydaia* (Prostigmata:Ereynetidae). As a result, most of the nasal mites identified in this survey were the rhinonyssid genera *Ptilonyssus* and *Sternostoma*. There were eleven different orders of birds in which I could not find any nasal mites. The numbers of individuals examined from those orders were minimal (Appendix), which may have led to the lack of infestations by nasal mite species. Three of those orders, the Galliformes, Gruiformes and Caprimulgiformes, were represented by only one individual of one species. A total of 43 species in which only one individual was examined yielded no nasal mites. Thus, the level of species infested was likely affected by small sample sizes. Another factor related to finding nasal mites was the state of the birds when collected. I could anticipate infestation by looking at the state of the frozen birds: those that were in better shape when collected (i.e., less decomposed) were more likely to have nasal mites.

Some authors have suggested that dissection of beak and the nasal cavities can yield better results for recovering nasal mites, as opposed to using nasal flushes (Pence 1973, Spicer 1987). However, other studies have shown no difference when comparing the two methods. Wilson (1964) showed that very few additional nasal mites were collected by doing dissections after doing nasal flushes. Knee (personal communication 2016) mentioned that he did not find any difference in mites collected by using the two techniques. Dissection would definitely require more time, thus would be limiting when examining a large number of specimens.

4.2 Nasal mite counting

There are four families of intranasal mites found in North America, and three of those were found in this study, with the Rhinonyssidae being the most abundant. As shown in other studies (Pence 1973, Knee et al. 2008), Rhinonyssidae is the most diverse family with host specificity at the order level (Passeriformes). In my collection, most of the infested Passeriformes hosts were infested by two genera of rhinonyssids -- *Ptilonyssus* and *Sternostoma,* I only found one species of non-passerine (*Sphyrapicus varius*, Piciformes; Table 3.2) infested by a rhinonyssid (*Sternostoma*).

Species of *Ptilonyssus* are blood and tissue feeders that dwell in the nasal passages of hosts, whereas *Sternostoma* includes some species, such as *S. tracheacolum*, that can invade the host's lung (Lawrence 1948). A different extraction technique, such as dissection of the tracheae and lungs, might show greater prevalence of *Sternostoma* than I found by using only nasal flushes in this study.

4.3 New host records for Ereynetidae and Turbinoptidae

From the subfamily Speleognathinae (Prostigmata: Ereynetidae), the genera *Astrida* and *Boydaia* were found only in Passeriformes and Cuculiformes. *Boydaia spatulata* Fain was found as a new record from *Catharus ustulatus* (Passeriformes: Turdidae). This nasal mite has only been previously reported from *Piranga rubra* (Passeriformes: Cardinalidae) and *Sialis sialis* (Passeriformes: Turdidae).

The family Turbinoptidae (Astigmata) was represented by three species found in four host species (Table 3.1). Two species of *Congocoptes* were collected from two woodpecker species (Piciformes), neither of which was a new record. *Schoutedenocoptes americanus* was collected from two different species of hawks, representing new host records for the Red-tailed hawk (*Buteo jamaicensis*) and Cooper's hawk (*Accipiter cooperii*). Interestingly, *S. americanus* was described from and only previously found in the yellow-billed cuckoo (*Coccyzus americanus*). This cuckoo sometimes lays eggs in other bird nests, but it is not an obligate parasite as is the common cuckoo (*Cuculus canorus*) that may parasitize several closely related host species (Cornell Laboratory of Ornithology 2015).

4.4 New host records for Rhinonyssidae

In all, there were 21 new host records from this study. Two new host records (Table 3.1) were the two host species in the Accipitriformes cited above. Nineteen new records were from the family Rhinonyssidae. One record was from a woodpecker (Piciformes) infested by a rhinonyssid (Table 3.2) and the remaining 18 new records in the Rhinonyssidae were from the host order Passeriformes. The greatest number of new host records occurred in the families Parulidae and Emberizidae, with 13 new host records.

Ptilonyssus morofskyi was a new record for the house sparrow, *Passer domesticus* (Table 3.2). This nasal mite is a common parasite of birds in the families Emberizidae and Cardinalidae (Pence 1975), but has not been found in the Passeridae. *Ptilonyssus agelaii* is a nasal mite that has only been recorded from blackbirds and cowbirds (Icteridae) (Pence 1975), and I recorded it from 17 cowbirds. In this study, I also am reporting a new host record for this mite species from *Zonotrichia albicollis*, in the family Emberizidae (Table 3.2). There were two other *Ptilonyssus* specimens (Table 3.2), which could not be identified to species level, that might represent new host records for *Catharus ustulatus* and *Molothrus ater*.

Only four individuals of the genus *Sternostoma* were collected, representing four different species (Table 3.2). Three of the four species found represent new host records. One new record was infestation of *Sphyrapicus varius* (Piciformes: Picidae) by *Sternostoma hylandi*, which is a nasal mite previously reported for *Dendrocopos* (Piciformes), now classified as *Picoides*. Another new record was found in *Catharus ustulatus* (Turdidae), which was infested by *S. spatulatum*. This nasal mite has only been reported previously from the genus *Hylocichla* (Turdidae). Although both are new records, those records are in host species that are closely related to species from previous reports (same family). In contrast, I found *Sternostoma pirangae* in the Baltimore oriole, *Icterus galbula*. Previously, *S. pirangae* was only reported from the summer tanager, *Piranga rubra*, in the family Cardinalidae (Pence 1975).

4.5 Host specificity of *P. sairae* and *P. japuibensis*

Eleven of the new host records were found from the passerine families Parulidae and Emberizidae (warblers and sparrows). A total of 149 birds were examined from these two families. Of the Parulidae, 30% of individuals and 35% of the 23 species had nasal mites. In the Emberizidae, 34% of individuals and 43% of 14 species had nasal mites. The Parulidae were

infested by *P. sairae* and *P. japuibensis*, whereas the Emberizidae were infested by *P. japuibensis*, *P. morofskyi* and *P. agelaii*.

In my study, *P. japuibensis* was the most abundant and was distributed in four families with most hosts belonging to sparrows (Table 3.2). *Ptilonyssus japuibensis* also has been reported for different families in other studies (Pence 1975). In my study, 6 new host records belonged to this nasal mite. *Ptilonyssus sairae* was the second-most abundant and it was only found in warblers (Parulidae). This nasal mite has been reported in different families, being a common parasite in Fringillidae and Cardinalidae (Pence & Casto 1976, Morelli & Spicer 2007). However, in my study I could not find any Fringillidae infested by nasal mites, and I found no Cardinalidae infested by *P. sairae*.

Ptilonyssus sairae and *P. japuibensis* have been recognized as closely related species, comprising the "*Sairae*" complex, due to morphological similarities (Pence & Casto 1976). At least ten different nasal mites belong to this group, and new descriptions of nasal mites have been added to this complex (Knee 2008). These mites commonly parasitize Parulidae, Fringillidae, Emberizidae, and can infest other closely related families, such as Cardinalidae and Icteridae (Pence 1975, Pence & Casto 1976). Castro first reported *P. sairae* and *P. japuibensis* from tanagers (Cardinalidae) (Pence & Casto 1976).

The question regarding the *P. sairae* complex is whether this group of nasal mites represents a single species with low host specificity or is a related grouped species each of which is highly specific (Pence & Casto 1976). Morelli and Spicer (2007), showed evidence to support host-specific-driven speciation of *P. sairae* by conducting molecular analyses from different hosts. However, their analysis used only one locus in the nuclear genome (ITS), thus the result might be misleading. It is difficult to interpret host specificity of nasal mites and their hosts

partly because the ecology and transmission of these nasal mites is still not clear. Morelli and Spicer (2007) also suggested that every bird host might have its own specific nasal mite. Based on the number of rhinonyssids reported in bird hosts, and because the great number of tropical birds have yet not been surveyed, probably fewer than half of the potential species have been described.

CHAPTER 5. NASAL MITES FROM SPECIMENS OF THE BROWN-HEADED COWBIRD

5.1 The Brown-headed Cowbird (*Molothrus ater*) description

The Brown-headed Cowbird (BHCB) (*Molothrus ater*) is a member of the bird family Icteridae, in the order Passeriformes. Icteridae also includes the Blackbirds, Grackles, Meadowlarks, Orioles, Cowbirds, and Bobolinks. Some BHCB are migratory, breeding in northern parts of North America with winter migration into Mexico, whereas other BHCB populations are local residents in southern parts of North America (Sibley 2000). BHCB are small (16 to 19 cm, ~44 g), with a short tail and finch-like bill. Males are black in color, with a dark-brown head. Females are almost completely pale brown, with lighter color on the throat (Cornell Lab of Ornithology 2015). BHCB are gregarious birds, sometimes in mixed flocks with other blackbirds and starlings in open areas such as fields, pastures, meadows, forest edges, and lawns (Cornell Lab of Ornithology 2015).

Molothrus ater is the most abundant species of cowbird in the United States and the most studied in the genus (Dufty 1982). Species of the genus *Molothrus* are all obligate brood parasites, which means that cowbird females lay eggs in the nests of different species of birds that will serve as hosts. The female BHCB will remove one egg from the nest and lay one of her own. Many hosts will accept the BHCB egg as if it was its own. The female can lay an egg in a host nest early in the morning and spend the rest of the day looking for new nests to lay the remaining eggs. *Molothrus ater* can lay a least 40 eggs during a breeding season (Sherry et al. 1993).

Brood parasites can be divided into specialists and generalists. Species like the Common Cuckoo (*Cuculus canorus*) are specialists that tend to parasitize a single host species (Vogl et al.

2002), whereas the brown-headed cowbird is a generalist, parasitizing 221 known hosts (Friedman et al. 1985). Parasitism by BHCB may negatively impact some host species. Parasitism rates by BHCB are increased due to habitat fragmentation, providing greater access to host and the nests. For example, Kirtland's Warbler (*Dendroica kirtlandii),* which is an endangered species in the US, has been negatively impacted by parasitism (Trail & Baptista 1993; Al-jabber 2003)

BHCB is one of the most successful brood parasites because few of its hosts can recognize the BHCB eggs and either abandon the nest or remove the BHCB egg; these host that frequently reject the parasite are termed "rejecters" (Underwood & Sealy 2007). One way birds recognize their own eggs is by the eggs appearance in light from the UV spectrum. Under UV light, BHCB eggs may not appear different than the host egg, thus the host accepts the egg as its own. The inability of these host to distinguish BHCB eggs from their own make these host "accepters". The success of BHCB suggest they use UV reflectance as part of a strategy of mimic host eggs. Several bird species, such as blue jays, gray catbirds, brown thrashers, and robins are able to detect the parasites eggs, thus they use some other cues to detect parasitic eggs (Abernathy & Peer 2005).

5.2 Parasitic nasal mites on brown-headed cowbirds

Birds are ideal hosts for multiple kinds of symbionts, with an array of different ectoparasites and endoparasites feeding on secretions, blood or tissue, and oils on the birds. Among these symbionts, mites are the most diverse group with approximately 40 families and 3000 species described associated with birds (Proctor & Owens 2000; Knee et al. 2008).

The tendency of gregariousness and brood parasitism of the cowbirds suggests nestlings might be infested with parasites from foster parents. Furthermore, the large number of host parasitized also might suggest a diverse array of parasites, including nasal mites, which are intranasal parasites. For this reason, nasal mites could be an interesting subject for the study of the diversity of parasites in the cowbirds.

Some mite species described from cowbirds are also represented in other icterid birds, and passeriform birds, as is the case of *Ptilonyssus icteridius*. This species of nasal mite can be found in the Western Tanager or in the Baltimore Oriole (Pence 1975). Other species found in the BHCB are *P. agelaii*, *Sternostoma tracheacolum, and Boydaia quiscali* (Pence 1975). Some ideas on the transmission of nasal mites have been suggested in the past. One idea is that parents can transmit nasal mites when they feed their young (Murray 1966), another idea is that birds can obtain nasal mites when they socialize in groups, by preening, or courtship billing (Amerson 1967).

Here in this study I examined the nasal cavities of specimens of *Molothrus ater* with the aim of addressing some questions, such as what percent of this collection of BHCB is infected by nasal mites? Are birds infested by only one species of nasal mite at a given time? Do the patterns of infestation suggest the predominant mechanism of transmission?

5.3 Objective of the study

To analyze a collection of BHCB for nasal mites and compare with previous results in other analyses of the BHCB.

5.4 Materials and methods

This study is based on *Molothrus ater* collected at Fort Hood, Texas, in the years 2014 and 2015. This collection was donated to the laboratory of ornithology of Dr. Than Boves at Arkansas State University (ASU) in Jonesboro. Dr. Boves granted me access to the cowbird collection, which consisted of 120 individuals. In addition, 6 cowbirds collected in Arkansas were also examined for nasal mites, to compare to the Texas birds.

The BHCB were maintained and stored in a -20 freezer at the ASU laboratory (Texas specimens) or UA laboratory (Arkansas specimens) until processed. The respiratory passages of the birds were flushed using a mixture of warm water with ethanol. A 5cc syringe was used to push water through the nasal passages. Typically, mite collections were made by four consecutive flushes using hard water pressure applied to each nostril, alternating to flush both sides of the nasal cavities. The flushed liquid was collected in a 9 cm Petri Dish, and was examined for nasal mites using a Leica MZ16 stereomicroscope at 20-25x magnification. Nasal mites were collected and stored in vials of 70% ethanol.

For the identification of nasal mites, some mites were slide-mounted for observation under the compound microscope. Mites were cleared in 85% lactic acid at 70°C for one hour. Then, they were placed on the slide in a drop of Hoyer's mounting medium and once positioned correctly, a cover slip was put in place. Identification of both larval and adult mites was made using keys (Pence 1975, Knee & Proctor 2006).

Mite specimens were deposited in the Acarology Collection at the University of Arkansas.

5.5 Results

The nasal mites found in the BHCB consisted primarily of four species of *Ptilonyssus* (Mesostigmata: Rhinonyssidae). The order Prostigmata was represented by one species of *Boydaia* (Ereynetidae: Speleognathinae) (Table 5.1).

A total of 84 out of 126 BHCB were infested with nasal mites for a prevalence of 66.6%. For the Texas specimens, the prevalence was 65% (78 of 120), whereas the Arkansas cowbirds showed 6 out 6 (100 %) individuals with nasal mites (Table 5.2).

The genus *Ptilonyssus* was the most common and abundant nasal mite, infecting 82 BHCB individuals. Five different *Ptilonyssus* species were recovered from BHCB (*P. icteridius* Strandmann, *P. agelaii* Fain and Aitken, *P. japuibensis* Castro, *P. richmondinae* George, *Ptilonyssus* sp.). The genus *Boydaia* was represented only by one species (*B. quiscali* Clark) and was only found in 2 cowbirds from Texas. For the Arkansas specimens, all the individuals (6) were infested by *Ptilonyssus*.

From all the nasal mites found in both Texas and Arkansas, *P. icteridius* was the most commonly found, infesting 64 of 126 BHCB (50.8% infestation). The second most numerous mite was *P. agelaii*, which was found in 18 BHCB from Texas (15%). In Arkansas 6 bird specimens contained *P. icteridius* (Table 5.2). There was one nasal mite species of *Ptilonyssus* that could not be identified to species from the Texas birds.

The number of nasal mites varied from 1 to 15 nasal mites per bird. Double infestation was also observed with three species of nasal mites in BHCB (Figures 5.1). BHCB were infested by two mite species in different ways – 2 BHCB contained *P. icteridius* and *P. agelaii* and one each contained *P. icteridius* and *B. quiscali*, and *B. quiscali* and *P. agelaii*.

From the Texas specimens, only one species, *Ptilonyssus richmondinae*, was found to be a new host record for the BHCB. (Table 4.2).

5.5 Discussion

The BHCB in my study showed a high rate of infestation by nasal mites. My sampling of nasal mites in cowbirds from Texas and Arkansas yielded a 66.6% prevalence of infestation overall, similar to previous studies on the BHCB. Clark (1963), found up to 55% of birds from Pennsylvania in 1960-62 were infested by nasal mites at different times of the year. That study had similar numbers of birds (188 from Pennsylvania) as my study. This prevalence of infestation is greater comparing to previous surveys of nasal mites in non-brood parasites, in which infestations of nasal mites from 15 to 40 prevalence (Domrow 1969, Pence 1973, Spicer 1987, Knee et al 2008).

In my study, mites from two orders were found, Mesostigmata and Prostigmata. Each order was represented in the sample by only one family, the Rhinonyssidae and Ereynetidae. The genus *Ptilonyssus* (Rhinonyssidae) was the most common, found in 82 of the 84 infected BHCB. *Ptilonyssus* is the most common nasal mite genus found in Passeriformes (Pence 1975, Knee et al 2008). My results are similar to reports in previous studies of cowbirds (Strandmann & Furman 1956)

Of the five species of *Ptilonyssus* collected, *Ptilonyssus icteridius* was the most common nasal mite in my samples from the two locations. As shown in other studies (Strandmann & Furman 1956, Pence 1973) *P. icteridius* is commonly found parasitizing members of the family Icteridae. This nasal mite appears to show specificity, largely at the family level, and can infest blackbirds, grackles, and orioles (Pence 1975). The only non-icterid host described has been a

western tanager (*Piranga ludoviciana*, Cardinalidae), which family is closely related to the *icterids* (Strandmann & Furman 1956).

The second most common nasal mite in my study with 18 specimens was *P. agelaii*, which was originally described from species of *Agelaius* and has been only recorded only from the red-winged blackbird (*Agelaius phenicius*) and in cowbirds. One species was identified as *P. japuibensis*, which is a species that is commonly found in warblers, sparrows and buntings (Parulidae, Cardinalidae, Emberizidae), which are also parasitized by BHCB. The remaining two *Ptilonyssus* specimens included one each of *P. richmondinae* and an unidentified *Ptilonyssus* sp.

Two specimens of *Boydaia quiscali* were collected, representing the only individuals of the order Prostigmata and family Ereynetidae (Speleognathinae) I found. *Boydaia quiscali* has been described from black birds (*Ageilaius*), grackles (*Quiscalus*), and BHCB and, along with *B. agelaii*, are the only species in the family that parasitize cowbirds and other members of the Icteridae (Pence 1975). Curiously, I only found *B. quiscali* in two cowbirds, and both were birds that were double infested – one bird was infested by *P. icteridius* and one was infested by *P. agelaii*. It is not known whether initial infestation by *Ptilonyssus* may be necessary for subsequent infestation by *Boydaia*. Only two other double infestations were found, both birds infested by *P. icteridius* and *P. agelaii*. These double infestations in my findings were similar to double infestations in Clark (1963), where he found birds infested by *Boydaia* and *Ptilonyssus*.

A lone individual of *P. richmondinae* was found from Texas. This species represented a new record for the BHCB and it has only been recorded from the northern cardinal (Cardinalidae). The anomalous host record requires further scrutiny. The morphology of *P. richmondinae* is very similar to that *P. agelaii* and *P. japuibensis*. Similarity of some mites from the genus *Ptilonyssus*, such as species in the "*sairae*" complex, to which *P. agelaii* and *P.*

japuibensis belongs, suggest additional analyses to be conducted. Molecular analysis could determine whether the genus *Ptilonyssus* is less diverse and speciose than previously considered, or whether commonly encountered species, such as *P. icteridius*, may represent a set of cryptic species, which has been suggested by Morelli and Spicer (2007). In addition to clarifying some species identifications, molecular analyses might also shed light on the diversity of host associations seen in this study and before.

One species of nasal mite reported for BHCB in other studies that was not found in my study is *Sternostoma tracheacolum* (Mesostigmata: Rhinonyssidae). The lack of records in my study most likely reflects the sampling method I used. In my study, I used flushes of the nasal cavities to extract mites. As the specific name suggest, *S. tracheacolum* is a nasal mite that migrates to the lungs of the host species (Lawrence 1948). Consequently, a proper technique such as bird dissection of the respiratory tracts would be required to obtain this species, which I did not do.

Interestingly, cowbirds are brood parasites of other birds, whereas nasal mites frequently parasitize cowbirds, thus this can be seen as nasal mites being parasites of parasites. As a result, it is not simple to determine the means of transmission. Transmission of mites from foster parents is one means suggested, as is lateral transfer when multiple species flock together. Cowbirds certainly flock with some other icterids – e.g. *A. phoenicius*, *Quiscalus* spp., *Euphagus* spp., – but not with some other icterids, such as orioles (*Icterus* spp.). Therefore, specific records and careful identification of mites are both necessary to determine mechanisms of transmission. According to Strandmann (1956), cowbirds seem to not support nasal mites from non-icterid birds. Although, a new host record was found for a mite previously only known from a norther cardinal. Also, I found an unidentified species that might represent a new host record or a new

species. Furthermore, descriptions of nasal mites from cowbirds have been made only in small number of samples (20 birds from AL, 188 in Pennsylvania, and descriptions of nasal mites in random studies). A larger amount of sampling and different locations might yield different results. Also, determination of the year-round species versus the migratory species also might show yield results.

My findings suggest that both mechanisms of transmission of nasal mites cannot be ruled out for these specimens. On one hand, BHCB are parasites of a great number of Icteridae, however BHCB can parasitize species that flock and also species that do not flock together, and these species can share the same kind of nasal mites. New record in the BHCB also might suggest cross transmission of opportunist nasal mites from foster parents.

5.6 Conclusions

This study from 126 BHCB yielded a great percent of infestation of nasal mites, which is greater than percentages found in previous surveys of nasal mites in non-brood parasites. Perhaps this can relate to the fact that cowbirds can be parasites of a great number of hosts. My findings did not give me sufficient evidence to rule out any mechanism of transmission. Future directions of this subject might be addressed to compare cowbird populations at different locations and overlapping of local and migratory individuals. The use of molecular techniques could be used for the study of cryptic species and cospecification.

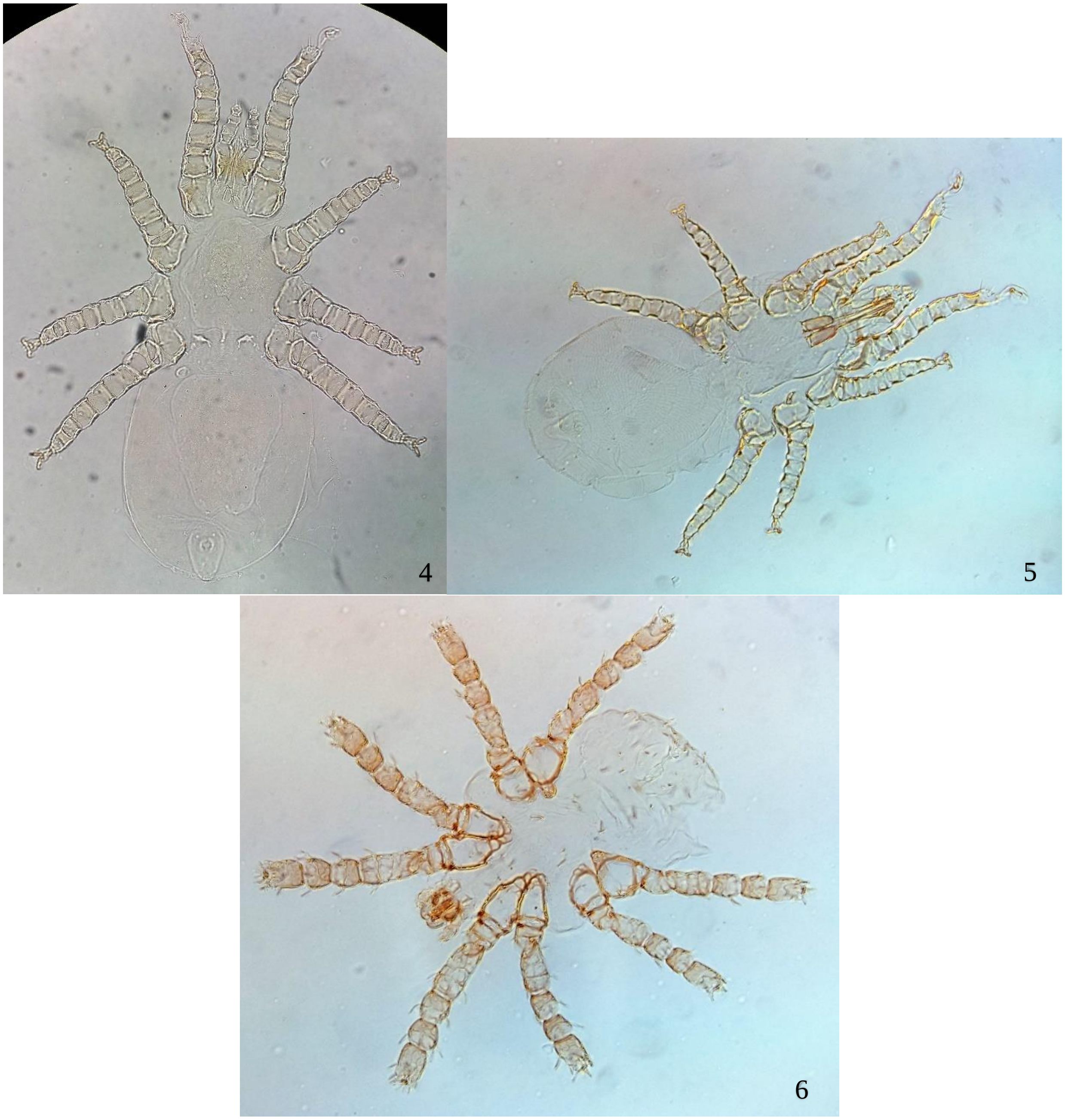
Table 5.1 Species of nasal mites found in brown-headed cowbirds from Texas and Arkansas

Mite family	Subfamily	Species
Rhinonyssidae	Rhinonyssinae	*Ptilonyssus icteridius*
		Ptilonyssus agelaii
		Ptilonyssus japuibensis
		Ptilonyssus richmondinae
		Ptilonyssus sp.
Ereynetidae	Speleognathinae	*Boydaia quiscali*

* This mite species represents new host record for the BHCB

Table 5.2 Prevalence of nasal mite species collected from brown-headed cowbirds from Texas and Arkansas in years 2014-2015.

	Nasal mite species	Number of hosts infested	
		Texas	Arkansas
Single Infestations	*Ptilonyssus icteridius*	55	6
	Ptilonyssus agelaii	16	
	Ptilonyssus japuibensis	1	
	Ptilonyssus richmondinae	1	
	Ptilonyssus sp.	1	
Double Infestations	*Ptilonyssus icteridius / Ptilonyssus agelaii*	2	
	Boydaia quiscali / Ptilonyssus agelaii	1	
	Boydaia quiscali / Ptilonyssus icteridius	1	
Total		78	6



Figures 5.1. Species of nasal mites infesting brown-headed cowbirds in double infestation, that is when two different nasal mite species were infesting one bird at the same time. 4. *Ptilonyssus icteridius*, 5. *P. agelaii*, 6. *Boydaia quiscali*.

CHAPTER 6. REFERENCES

Abernathy, V.E. and Peer, B.D. 2015. Mechanisms of egg recognition in brown-headed cowbird hosts: the role of ultraviolet reflectance. Animal Behaviour, 109: 73-79.

Al-jabber, J.M., 2003. Habitat Fragmentation: Effects and Implications. King Saud University. Saudi Arabia.

Amerson, A. B. 1967. Incidence and transfer of Rhinonyssidae (Acarina: Mesostigmata) in sooty terns (*Sterna fuscata*). Journal of Medical Entomology. 4: 197-199

Baker E. 1952. An Introduction to Acarology. New York: The MacMillan Company

Bannert, B., Karaca, H.Y. and Wohltmann, A. 2000. Life cycle and parasitic interaction of the lizard-parasitizing mite *Ophionyssus galloticolus* (Acari: Gamasida: Macronyssidae), with remarks about the evolutionary consequences of parasitism in mites. Experimental & Applied Acarology, 24: 597-613.

Beaulieu, F., Dowling, A.P.G., Klompen, H., De Moraes, G.J. and Walter, D.E. 2011. Superorder Parasitiformes Reuter, 1909. Animal biodiversity: an outline of higher-level classification and survey of taxonomic richness. Zootaxa, 3148: 123-128.

Bell, P.J. 1996. The life history and transmission biology of Sternostoma tracheacolum Lawrence (Acari: Rhinonyssidae) associated with the Gouldian finch *Erythrura gouldiae*. Experimental & Applied Acarology, 20: 323-341.

Berlese, A., and Trouessart, E., 1889. Diagnoses d'acariens nouveaux ou peu connus. Bull. Biblioth. Scient. Quest 2: 121-143.

Birdwatching.com 2016. The 914 wild bird species of North America. http://www.birdwatching.com/software/birdlists/north_amer98.html. retrieved on 10-17-16

Brooks, D.L., and Strandtmann, R.W. 1969. The nasal mites (Acarina) of some West Texas flycatchers (Tyrannidae). Journal of Parasitology 46: 418-432.

Colwell, R.K. and Naeem, S. 1999. Sexual sorting in hummingbird flower mites (Mesostigmata: Ascidae). Annals of the Entomological Society of America, 92: 952-959.

Cornell Lab of Ornithology. 2015. Brown-headed Cowbird, Life History, All About Birds – Allaboutbirds.org. retrieved on 8/18/16

Clark, G.M. 1963, January. Observations on the nasal mites of the eastern brown-headed cowbird (*Molothrus ater ater*). In Proc. Helm. Soc. Wash, 30: 173-176.

De Rojas, M., Mora, M., Ubeda, J., Cutillas, C., Navajas, M. and Guevara, D. 2002. Phylogenetic relationships in rhinonyssid mites (Acari: Rhinonyssidae) based on ribosomal DNA sequences: insights for the discrimination of closely related species. Parasitology Research, 88: 675-681.

Dicke, M. and Sabelis, M.W. 1987. How plants obtain predatory mites as bodyguards. Netherlands Journal of Zoology, 38: 148-165.

Domrow, R. 1969. The nasal mites of Queensland birds (Acari: Dermanyssidae, Ereynetidae, and Epidermoptidae). Proc. Linnean Soc. New S. Wales 93: 297-426.

Dowling, A.P. and OConnor, B.M. 2010. Phylogeny of Dermanyssoidea (Acari: Parasitiformes) suggests multiple origins of parasitism. Acarologia, 50:.113-129

Dufty Jr, A.M. 1982. Movements and activities of radio-tracked Brown-headed Cowbirds. The Auk, 316-327.

Dusbabek, F., Literak, I., Capek, M. and Havlicek, M. 2007. Ascid mites (Acari: Mesostigmata: Ascidae) from Costa Rican hummingbirds (Aves: Trochilidae), with description of three new species and a key to the *Proctolaelaps belemensi*s species group. Zootaxa, 1484: 51-67.

Evans, G.O. 1992. Principles of Acarology. CAB International, Cambridge.

Eickwort, G.C. 1994. Evolution and life-history patterns of mites associated with bees. In Mites, 218-251. Springer US.

Fain, A., 1960. Revision du genre Cytodites (Megnin) et description de deux espèces et un genre nouveaux dans la famille Cytoditidae Oudemans. Acarologia, 2: 238-49.

Fain, A. 1969. Adaptation to parasitism in mites. Acarologia, 11: 429-49

Fain, A. 1994. Adaptation, specificity and host-parasite coevolution in mites (Acari). International Journal for Parasitology, 24: 1273-1283.

Fain, A., Lukoshus, F. S. 1971. " Parasitic mites of Surinam part 15 nasal ereynetid mites of bats with a key of the known species trombidiformes" Bulletin et Annales de la Societe Royale d' Entomologie de Belgique, 107: 284-297.

Fain, A., and Johnson, D.E. 1966. Nouveaux acariens nasicoles d'oiseaux nord-americains (Acari: Rhinonyssidae). Bull. Soc. R. Zool. Anvers 38: 25-41

Fain, A., and T.H.G. Aitken. 1971. Acariens nasicoles d'oiseaux et de mammiferes du bresil V. Nouveaux Rhinonyssidae de la region de belem (Nord Bresil). Bull. Ann. Soc. R. Ent. Belg. 107: 27-46.

Fay, F.H., Furman, D.P. 1982. Nasal mites (Acari: Halarachnidae) in the spotted seal, *Phocalargha pallas*, and other pinnipeds of Alaskan waters. Journal of Wildlife Diseases, 18: 63-68

Fajfer, M., 2012. Acari (Chelicerata)-parasites of reptiles. Acarina, 20: 108-129.

Friedman and Kiff, Herbert and Lloyd F. (1985). "The parasitic cowbirds and their hosts". Proceedings of the Western Foundation of Vertebrate Zoology, 2: 225–304.

Gaud, J. and Atyeo, W.T. 1996. Feather mites of the world (Acarina, Astigmata): the supraspecific taxa. Annales-Musee Royal de l'Afrique Centrale. Sciences Zoologiques (Belgium).

Giebel, C. 1871. Ueber einige Milben. Z. Ges. Naturw. 38: 29-32.

Gill, F. & D. Donsker (Eds). 2016. IOC World Bird List (v 6.3). DOI: 10.14344/IOC.ML.6.3

Guzmán-Novoa, E., Eccles, L., Calvete, Y., Mcgowan, J., Kelly, P.G. and Correa-Benítez, A. 2010. *Varroa destructor* is the main culprit for the death and reduced populations of overwintered honey bee (*Apis mellifera*) colonies in Ontario, Canada. Apidologie, 41: 443-450.

Hackett, S.J., Kimball, R.T., Reddy, S., Bowie, R.C., Braun, E.L., Braun, M.J., Chojnowski, J.L., Cox, W.A., Han, K.L., Harshman, J. and Huddleston, C.J. 2008. A phylogenomic study of birds reveals their evolutionary history. science, 320: 1763-1768.

Hirst, S. 1921b. On some new parasitic mites. Proc. Zool. Soc. Lond. 1921: 769-802,

Hirst, S. 1923. On some new or little-known species of Acari. Proc. Zool. Soc. Lond. 1923: 971-1000.

Houck, M.A. 2012. Mites: ecological and evolutionary analyses of life-history patterns. Springer Science & Business Media.

Klompen, H., Lekveishvili, M. and Black, W.C. 2007. Phylogeny of Parasitiformes mites (Acari) based on rRNA. Molecular Phylogenetics and Evolution, 43: 936-951.

Knee, W. and Proctor, H., 2006. Keys to the families and genera of blood and tissue feeding mites associated with Albertan birds. Canadian Journal of Arthropod Identification, 2: 1-18.

Knee, W. 2008. Five new species of Rhinonyssidae (Mesostigmata) and one new species of Dermanyssus (Mesostigmata: Dermanyssidae) from birds of Alberta and Manitoba, Canada. Journal of Parasitology, 94: 348-374.

Knee, W., Proctor, H. and Galloway, T. 2008. Survey of nasal mites (Rhinonyssidae, Ereynetidae, and Turbinoptidae) associated with birds in Alberta and Manitoba, Canada. The Canadian Entomologist, 140: 364-379.

Krantz, G.W. and Lindquist, E.E., 1979. Evolution of phytophagous mites (Acari). Annual Review of Entomology, 24: 121-158.

Krantz G. W. & Walter D. E. 2009. A Manual of Acarology (3rd ed.). Texas Tech University Press. ISBN 978-0-89672-620-8.

Krantz G. W., 1978. Fish, amphibians, reptiles and the mystery of mite pockets. In: Walter, D. E., & Proctor, H. C. 1999. Mites: ecology, evolution and behavior: (p. 322). Sydney: UNSW Press. ISBN 0868405299

Lawrence, R. F. 1948. Studies on some parasitic mites from Canada and South Africa. The Journal of parasitology, 34: 364-379.

Lovette, I. J., J. L. Pérez-Emán, J. P. Sullivan, R. C. Banks, I. Fiorentino, S. Córdoba-Córdoba, M. Echeverry-Galvis, F. K. Barker, K. J. Burns, J. Klicka, S. M. Lanyon, and E. Bermingham. 2010. A comprehensive multilocus phylogeny for the wood-warblers and a revised classification of the Parulidae (Aves). Molecular Phylogenetics and Evolution 57: 753-770.

Mitchell, R.W. 1963. Comparative morphology of the life stages of the nasal mite *Rhinonyssus rhinolethrum* (Mesostigmata: Rhinonyssidae). The Journal of Parasitology, 506-515.

Morelli, M. and Spicer, G.S., 2007. Cospeciation between the nasal mite *Ptilonyssus sairae* (Acari: Rhinonyssidae) and its bird hosts. Systematic and Applied Acarology, 12: 179-188.

Murray, M.D. 1966. Control of respiratory acariasis of Gouldian finches caused by Sternostoma tracheacolum by feeding carbaryl. Australian Veterinary Journal, 42: 262-264.

Murrell, A., Dobson, S.J., Walter, D.E., Campbell, N.J., Shao, R. and Barker, S.C. 2005. Relationships among the three major lineages of the Acari (Arthropoda: Arachnida)

inferred from small subunit rRNA: paraphyly of the Parasitiformes with respect to the Opilioacariformes and relative rates of nucleotide substitution. Invertebrate Systematics, 19: 383-389.

Ottenburghs, J., P. van Hooft, S. E. van Wieren, R. C. Ydenberg and H.H.T. Prins. 2016. Hybridization in geese: a review. Frontiers in Zoology, 13: 20. DOI: 10.1186/s12983-016-0153-1

Pence, D.B. 1973. The nasal mites of birds from Louisiana. IX. Synopsis. Journal of Parasitology 59: 881-892

Pence, D.B. 1975. Keys, species and host list, and bibliography for nasal mites of North American birds (Acarina: Rhinonyssinae, Turbinoptinae, Speleognathinae, and Cytoditidae). Special Publications of the Museum Texas Tech University 8: 1-148.

Porter, J.C. and Strandtmann, R.W. 1952. Nasal mites of the English sparrow. Texas Journal of Science, 4: 393-399.

Proctor, H. and Owens, I. 2000. Mites and birds: diversity, parasitism and coevolution. Trends in Ecology & Evolution, 15: 358-364.

Prum, R. O., J. S. Berv, A. Dornburg, D. J. Field, J. P. Townsend, E. M. Lemmon and A. R. Lemmon. 2015. A comprehensive phylogeny of birds (Aves) using targeted next-generation DNA sequencing. Nature, 526. DOI: 10.1038/nature15697

Radovsky, F.J. 1966. Revision of the macronyssid and laelapid mites of bats: outline of classification with descriptions of new genera and new type species. Journal of Medical Entomology, 3: 93-99.

Spicer, G. S. 1987. Prevalence and host-parasite list of some nasal mites from birds (Acarina: Rhinonyssidae, Speleognathidae). Journal of Parasitology 73: 259-264.

Strandtmann, R.W. 1948. The mesostigmatic nasal mites of birds. I. Two new genera from shore and marsh birds. Journal of Parasitology 34: 505-514

Strandtmann, R.W., 1951. The mesostigmatic nasal mites of birds. II. New and poorly known species of Rhinonyssidae. The Journal of Parasitology, 37: 129-140.

Strandtmann, R. W. 1958. Host specificity of bird nasal mites (Rhinonyssidae) is a function of the gregariousness of the host. Proc. X Int. Congr. Ent. 1: 909-911.

Strandtman, R. W., and Wharton, G. W. 1958. A manual of mesostigmatid mites parasitic on vertebrates. Contr. Inst. Acar. Univ. Md. 4: 1-330.

TerBush, L.E. 1963. Incidence of nasal mites in different age classes of herring gulls (*Larus arengentatus*). Journal of Parasitology, 49, 525.

Tharaldsen, J. and Grondalen, J. 1978. The nasal mite of dogs, *Pneumonyssus caninum*. A case report from Norway. Journal of Small Animal Practice, 19: 245-250.

Tidemann, S.C., McOrist, S., Woinarski, J.C.Z. and Freeland, W.J. 1992. Parasitism of wild Gouldian finches (*Erythrura gouldiae*) by the air-sac mite *Sternostoma tracheacolum*. Journal of Wildlife Diseases, 28: 80-84.

Trail, P.W. and Baptista, L.F. 1993. The Impact of Brown-Headed Cowbird Parasitism on Populations of the White-Crowned Sparrow. Conservation Biology, 7: 309-315.

Underwood, T.J. and Sealy, S.G. 2008. UV reflectance of eggs of brown-headed cowbirds (*Molothrus ater*) and accepter and rejecter hosts. Journal of Ornithology, 149: 313-321.

Van Den Boom, C.E., Van Beek, T.A., Posthumus, M.A., De Groot, A. and Dicke, M. 2004. Qualitative and quantitative variation among volatile profiles induced by *Tetranychus urticae* feeding on plants from various families. Journal of chemical ecology, 30: 69-89.

Vitzthum, H.G., 1935. Milben aus der Nasenhöhle von Vögeln. Journal of Ornithology, 83: 563-587.

Vogl, W.; Taborsky, M.; Taborsky, B.; Teuschl, Y.; Honza, M. (2002). "Cuckoo females preferentially use specific habitats when searching for hot nests". Animal Behaviour. 64: 843–850.

Walter, D. E., & Proctor, H. C. 1999. Mites: Ecology, Evolution and Behavior: Life at a Microscale (p. 322). Sydney: UNSW Press. ISBN 0868405299

Wilson, N. 1964. An evaluation of Yunker's technique for the recovery of nasal mites from birds. Journal of Medical Entomology, 1: 117-117.

Witalinski, W. 2000. *Aclerogamasus stenocornis* sp. n., a fossil mite from the Baltic amber (Acari: Gamasida: Parasitidae). Genus, 11: 619-626.

Zabludovskaya, S.A. 1990. Mites of the genus Yunkeracarus (Acariformes, Gastronyssidae) - parasites of the nasal cavity of rodents. Vestnik Zoologii, 4: 32-35.

APPENDIX

Appendix. Avian hosts Order, family, Species, and number of each examined, with notes on changes in taxonomic placement or nomenclature as per Gill and Donsker (2016).

Order	Family	Species	Number	Note
Anseriformes	Anatidae	*Branta canadensis*	2	
		Anser caerulescens	1	A
		Aix sponsa	1	
		Anas platyrynchus	3	
		Anas discors	1	
		Anas acuta	1	
Galliformes	Phasianidae	*Colinus virginianus*	1	
Pelicaniformes	Ardeidae	*Butorides virescens*	1	
		Ardea herodias	3	
Cathartiformes	Cathartidae	*Cathartes aura*	1	B
		Coragyps atratus	1	
Accipitriformes	Accipitridae	*Accipiter striatus*	2	
		Accipiter cooperii	4	
		Buteo jamaicensis	6	
Gruiformes	Rallidae	*Rallus limicola*	1	
Charadriiformes	Charadriidae	*Charadrius vociferus*	1	
	Scolopacidae	*Scolopax minor*	1	
Columbiformes	Columbidae	*Columba livia*	1	
		Zenaida macroura	8	
Cuculiformes	Cuculidae	*Coccyzus americanus*	6	
Strigiformes	Strigidae	*Otus asio*	1	
		Megascops asio	2	
		Bubo virginianus	4	
		Strix varia	12	
Caprimulgiformes	Caprimulgidae	*Chordeiles minor*	1	
Apodiformes	Apodidae	*Chaetura pelagica*	1	
	Trochilidae	*Eugenes fulgens*	1	
		Archilochus colubris	17	

Order	Family	Species	Number	Note
Piciformes	Picidae	*Melanerpes carolinus*	7	
		Sphyrapicus varius	11	
		Dryocopus pileatus	1	
Falconiformes	Falconidae	*Falco sparverius*	1	C
		Falco columbarius	1	
Passeriformes	Tyrannidae	*Sayornis phoebe*	2	
		Contopus virens	1	
	Vireonidae	*Vireo flavifrons*	1	
		Vireo olivaceus	8	
	Corvidae	*Cyanocitta cristata*	2	
	Bombycillidae	*Bombycilla cedrorum*	12	
	Paridae	*Baeolophus bicolor*	2	
		Poecile atricapillus	1	
	Hirundinidae	*Hirundo rustica*	1	
	Troglodytidae	*Cistothorus palustris*	1	
		Thryothorus ludovicianus	4	
		Troglodytes aedon	2	
	Sittidae	*Sitta carolinensis*	2	
	Certhiidae	*Certhia americana*	7	
	Mimidae	*Dumetella carolinensis*	15	
		Toxostoma rufum	4	
	Sturnidae	*Sturnus vulgaris*	4	
	Turdidae	*Sialia sialis*	1	
		Catharus minimus	2	
		Catharus ustulatus	22	
		Catharus guttatus	4	
		Hylocichla mustelina	2	
		Turdus migratorius	24	
	Passeridae	*Passer domesticus*	13	

Order	Family	Species	Number	Note
	Fringillidae	*Carduelis tristis*	4	
		Spinus tristis	1	
	Parulidae	*Seiurus aurocapilla*	14	
		Helmitheros vermivorum	1	
		Parkesia noveborascensis	1	
		Vermivora chrysoptera	1	
		Mniotilta varia	6	
		Protonaria citrea	1	
		Leiothlypis peregrina	9	D
		Leiothlypis celata	2	E, F
		Leiothlypis ruficapilla	9	D
		Geothlypis philadelphia	3	
		Geothlypis formosa	1	
		Geothlypis trichas	5	
		Setophaga citrina	1	
		Setophaga ruticilla	5	
		Setophaga tigrina	1	
		Setophaga americana	1	
		Setophaga magnolia	4	
		Setophaga fusca	1	
		Setophaga pensylvanica	5	
		Setophaga palmarum	2	
		Setophaga coronata	5	
		Setophaga nigrescens	1	
		Cardelina pusilla	1	
	Incertae sedis	*Icteria virens*	2	G
	Icteridae	*Icterus galbula*	6	
		Molothrus ater	126	
	Emberizidae	*Passerella iliaca*	3	
		Melospiza melodia	4	
		Melospiza lincolnii	2	
		Melospiza georgiana	4	
		Zonotrichia leucophrys	1	
		Zonotrichia albicollis	25	
		Zonotrichia atricaapilla	2	
		Junco hyemalis	11	
		Passerculus sandwichensis	4	
		Ammodramus nelsoni	1	
		Ammodramus leconteii	11	
		Spizella passerina	1	

Order	Family	Species	Number	Note
	Emberizidae (cont'd)			
		Pooecetes gramineus	1	
		Pipilo erythrophthalmus	2	
	Cardinalidae	*Piranga rubra*	1	
		Piranga olivacea	1	
		Pheucticus ludovicianus	3	
		Cardinalis cardinalis	11	
		Passerina cyanea	17	

Notes:

A. Moved from the genus *Chen* to *Anser* (Ottenburghs et al. 2016)

B. Order Cathariformes created, supported by Prum et al. (2015)

C. Falconiformes separated from Accipitriformes (Hackett et al. 2008)

D. Moved from *Oreothlypis* to *Leiothlypis* (Lovette et al. 2010)

E. Moved from *Vermivora* to *Leiothlypis* (Lovette et al. 2010)

F. Incorrectly labeled *Geothlypis celata* (non-existent) -- counted as *Leiothlypis celata*

G. *Icteria virens* is moved from Parulidae, labeled as *Incertae sedis* (Lovette et al. 2010)