B. Ectoparasites

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INTRODUCTION

Fly ectoparasites that feed on blood include biting midges, blackflies, blowflies, louse flies, mosquitoes, and carnid flies. Additional blood-feeding insects that parasitize raptors include cimicid bugs, fleas, and some chewing lice. Other chewing lice feed on feathers. Although usually nonparasitic, scavenging skin beetle (Dermestidae) larvae have even been found in wounds in Snail Kite (*Rostrhamus sociabilis*) nestlings in Florida, and other raptors in Africa and Europe (Snyder et al. 1984). Arachnid ectoparasites of raptors include blood-sucking ticks and mites, mites that feed on feather material, and mites, including chiggers, that feed on tissue. Most mites are external parasites, but some skin mites burrow into and under the skin, and some mites colonize the respiratory tract. In addition to direct pathological effects, raptor ectoparasites can have indirect pathological effects because a weakened host is more vulnerable to infection. Bacterial and fungal infections caused by ectoparasites can occur in wounds, and many flies, ticks, and mites act as disease vectors as well. Philips (2000, 2006a,b) reviewed the parasitic mites of raptors and the author maintains an online checklist of raptor hosts and their mite ectoparasites.

Levels of ectoparasite infestation vary greatly among and within species of raptors. Raptor ectoparasite management involves collection, preservation, and identification of ectoparasites, followed, when necessary, by treatment of affected birds and control measures to reduce the ectoparasite levels in the nest or local environment. Clayton and Walther (1997) reviewed collection and preservation techniques of avian ectoparasites. Beynon et al. (1996) list ingredient formulas for six ectoparasiticides useful in the treatment and control of insects and mites that parasitize raptors.

Raptors and their nests should be surveyed and monitored for ectoparasites as causes of direct pathology and disease transmission. Raptor ectoparasites, such as the lice of the threatened Galapagos Hawk (*Buteo galapagoensis*), can serve as excellent markers of host population differentiation (Whiteman and Parker 2005). Host-specific ectoparasites of endangered raptor species are themselves endangered species.

Insects and blood-filled ticks and mites are much more noticeable to the naked eye than most mites. Feather mites often look like grains of sand, and 0.25-mm chiggers and skin mites as "specks." Species identification often requires ectoparasite dissection, particular ectoparasite clearing techniques, particular slide-mount media, and specialized taxonomic expertise. The mite fauna of raptors is largely unknown, and many new species remain to be discovered. Below I detail the types of flies, cimicid bugs, fleas, chewing lice, ticks, and mites that parasitize birds of prey.

FLIES (DIPTERA)

Biting Midges (Ceratopogonidae)

Boorman (1993) provides an identification key to adults in blood-sucking ceratopogonid genera.

Biting midges, which often are called "no-see-

ums," transmit filarial nematodes, blood protozoans *Haemoproteus* and *Leucocytozoon*, and the Thimiri arbovirus to birds (Mullen 2002). After a blood meal, female midges lay eggs in habitats ranging from moist compost and manure to water in tree holes, freshwater marshes, and mangrove swamps. Females can be aspirated from hosts or collected by using light-traps with black-light lamps and carbon dioxide. Midges can be preserved in 1–2% formalin or 70–80% alcohol. Controlling these ectoparasites is difficult. Most screens are not effective and neither is general application of insecticides to kill larvae. Eliminating breeding habitat and general application of insecticides as mists or fogs in early evening when adults are most active can reduce populations.

Blackflies (Simuliidae)

Crosskey and Howard (1997) provide an inventory of the blackflies of the world. Blackflies are the main vectors of *Leucocytozoon* in birds, and also they transmit *Trypanosoma* and filarial nematodes (Adler and McCreadie 2002). Adler et al. (2004) list North American blackfly species, their raptor and other hosts, and the species of Leucocytozoon they transmit.

Blackflies have killed nestling Red-tailed Hawks (*B. jamaicensis*) (Brown and Amadon 1968, Smith et al. 1998), nestling Merlins (*Falco columbarius*) (Trimble 1975), and have weakened nestling Cape Vultures (*Gyps coprotheres*) (Boshoff and Currie 1981). Blackflies tend to feed on the crown, back, and shoulders of raptors. Biting occurs during the day in the open, and adult blackflies can be collected from hosts with an aspirator, or with sticky silhouette or carbon dioxide traps. After a blood meal, females lay their eggs in running water. Fluid preservation destroys important taxonomic features, so adults should be micropinned through the thorax after they dry in a freezer for 5 weeks (Crosskey 1993).

Blackfly control, which mainly targets the larvae, uses the entomopathogenic bacterium, *Bacillus thuringiensis var. israelensis*, applied to bodies of water by hand or from the air. Providing shelters for captive birds helps protect them from blackflies.

Mosquitoes (Culicidae)

The mosquitoes of the world are listed in Knight and Stone (1977) and its supplements (Knight 1978, Ward 1984, Gaffigan and Ward 1985, Ward 1992). There are many regional identification keys, including that of Darsie and Ward (2005) to species of the U.S. and Canada, and a key to world genera by Mattingly (1971).

Mosquitoes transmit many viruses to birds, including encephalomyelitis viruses, West Nile virus, and poxvirus (Foster and Walker 2002). They also are vectors of avian malaria (*Plasmodium*) and filarial nematodes. After a blood meal, female mosquitoes lay eggs on water or wet surfaces under floating vegetation or in the walls of wet tree-holes (Service 1993). Mosquitoes can be collected from hosts and in shaded resting places using aspirators, and with carbon dioxide traps and light-traps. Specimens should not be preserved in liquids but micropinned through the thorax.

Approaches to control of mosquito populations include reducing their breeding habitat; using light mineral oils, organophosphates, insect-growth regulators, or *Bacillus thuringiensis var. israelensis* to kill the aquatic larvae; applying residual insecticides to adult resting surfaces; and direct contact spraying or fogging of organophosphates, carbamates, pyrethrins and synthetic pyrethroids. Screens can protect captive birds.

Louse Flies (Hippoboscidae)

Maa (1963) lists the louse flies of the world and provides genera and species-group identification keys.

Avian louse flies, often called flat flies, tend to remain on their host unless disturbed, and they sometimes bite humans that handle infested birds. Larvae develop in the female and pupate in birds' nests and roosts immediately when born. Louse flies transmit the blood protozoans, *Haemoproteus* and *Trypanosoma*, through biting, and carry lice and the ectoparasitic skin mites, *Strelkoviacarus*, *Microlichus,* and *Myialges*, on their exterior to new bird hosts (Philips 1990, Lloyd 2002). Louse flies have tested positive for West Nile virus, but their role as vectors of this and other viruses is unconfirmed. Infestation of several dozen louse flies does not seem to harm raptors, but when levels exceed 80, raptors become emaciated and too weak to hunt. Louse flies, which range in size from 4 to 7 mm, can be caught with air nets and by hand, and can be pinned or preserved in ethanol. Infested birds can be treated with pyrethroid dust.

Myiasis Flies (Calliphoridae, Muscidae)

Sabrosky et al. (1989) provides a key and a host list for Nearctic *Protocalliphora*, and lists the Palearctic

species. Whitworth (2003, 2006) provides a species key to *Protocalliphora* pupae. Furman and Catts (1982) designed a key to a variety of myiasis-causing fly genera.

Nest flies of raptors include the Holarctic and Oriental blow flies *Protocalliphora* (Calliphoridae), the European carrion flies *Lucilia sericata* and *Calliphora* (Calliphoridae), and the tropical flies *Philornis* and *Passeromyia* (Muscidae), all of which lay their eggs in nests or on nestlings. The maggots of these flies cause myiasis by burrowing into host tissues and sucking blood (Baumgartner 1988). Ear cavities, noses, the ventral surface, and feather sheaths are preferred sites. After feeding, larvae drop off the host to digest their blood meal and pupate.

Myiasis is known to kill nestling Northern Harriers (*Circus cyaneus*) (Hamerstrom and Hamerstrom 1954), Sharp-shinned Hawks (*Accipiter striatus*) (Delannoy and Cruz 1991), Verreaux's Eagles (*Aquila verreauxii*) (Gargett 1977), Gyrfalcons (*F. rusticolus*) (Poole and Bromley 1988), and Prairie Falcons (*F. mexicanus*) (White 1963), and to weaken nestling Red-tailed Hawks (Tirrell 1978) and prolong their development (Catts and Mullen 2002). Burrowed larvae will evacuate nestlings if the breathing opening of the larvae is blocked with petroleum jelly or if nestling orifices are flushed with saline solution. Mineral oil can be used to remove them from ear cavities. Maggots should be relaxed before being preserved in ethanol (Hall and Smith 1993). This can be accomplished by placing them into water just below the boiling point, or into acetic alcohol (one part glacial acetic acid to three parts 90% ethanol). Dissecting nest material can yield pupae. Treatment involves removing larvae and applying antibiotics to the wound to prevent infection. Nests can be dusted with pyrethroids.

Carnid Flies (Carnidae)

Carnid flies can be identified using the fly family key of Arnett (2000). Grimaldi (1997) discusses the species, of which the most well known is *Carnus hemapterus*, and lists all avian hosts.

Carnus larvae scavenge in nests. Wingless adults either suck the blood of nestlings or feed on their skin secretions. Infestations are characterized by scabby axillae. Heavy infestations cause reduced pack-cell volumes in Barn Owls (*Tyto alba*) (Schulz 1986), reduced body mass in Common Kestrels (*F. tinnunculus*) (Heddergott 2003), and nestling mortality in Northern Sawwhet Owls (*Aegolius acadicus*) (Cannings 1986). The fly seems harmless to American Kestrels (*F. sparverius*) (Dawson and Bortolotti 1997). *Carnus* occurs in North America, Europe, Africa, and Malaysia. Specimens can be collected from hosts by hand or from nests by Tullgren funnel extraction of nest material (Mullen and O'Connor 2002), and then preserved in ethanol. Insecticide dusts can be used to treat hosts and control infestations in nests.

CIMICID BUGS (BED BUGS)

Cimicid bugs (Cimicidae) lay eggs where hosts live. Both adults and nymphal stages suck blood. One species in particular regularly attacks raptors. The Mexican chicken bug (*Haematosiphon inodorus*) has killed nestling Bald Eagles (*Haliaeetus leucocephalus*) (Grubb et al. 1986) as well as nestling Red-tailed Hawks and Prairie Falcons (Platt 1975, McFadzen and Marzluff 1996), and has caused nestling California Condors (*Gymnogyps californianus*) to fledge prematurely (Brown and Amadon 1968). The swallow bedbug (*Oeciacus vicarious*) occurs in Prairie Falcon aeries. The bugs hide in nests or cracks near hosts during the day, and feed mainly at night near the eyes and at the base of the host's legs and wings. Cimicid bugs can be collected with forceps, Tullgren funnel extraction, or dissection of nest material, or be forced out of cracks with pyrethroid or kerosene sprays (Schofield and Dolling 1993). Specimens can be preserved in ethanol. Usinger (1966) provides species identification keys for the family and an avian host list. Treatment and control involve spraying hosts, nests, and surfaces near the host with insecticides including pyrethrins.

FLEAS (SIPHONAPTERA)

Regional identification keys with host lists include Holland (1985) for Canada, and Benton and Shatrau (1965) and Lewis et al. (1988) for parts of the U.S. Lewis (1993) provides a key to medically important flea genera globally. Arnett (2000) provides an identification key to families, and Lewis (1993) provides more detailed keys to some of the taxa.

Fleas of adult raptors bite hosts to obtain blood and lay their eggs on their hosts or in nests, where larvae are scavengers. Typically, more fleas are found in nests than on hosts. One exception is the sticktight flea (*Echidno-*

phaga gallinaacea), which remains attached to hosts in unfeathered places around the head. Burrowing Owls (*Athene cunicularia*) in particular seem to be infested with fleas when nesting (Smith and Belthoff 2001). Fleas can be collected from hosts with insecticide dusts, and by dissecting nest material or via extraction in a Tullgren funnel. They can be preserved in 80% ethanol. Treatment and control involve pyrethrin dusts and insect growth regulators (Lewis 1993, Durden and Traub 2002).

CHEWING LICE (MALLOPHAGA)

Price et al. (2003) provide a list of avian lice globally, their hosts, and identification keys to genera by host.

Chewing lice usually are transferred by direct contact and, less frequently, by louse flies. Their feeding can damage feathers, and scratching in response to infestation can cause additional damage. Heavy louse infestations cause anemia, weight loss, and death. Lice can be collected from hosts with forceps, or by ruffling feathers after dusting with insecticidal powder (Clayton and Drown 2001). During necropsy, carcasses can be washed with detergent or skinned, and skin and feathers dissolved using trypsin or potassium hydroxide (Furman and Catts 1982). Detergent washes also will yield mites, whereas dissolving tends to destroy most mites. Resulting solutions are sieved or filtered to collect specimens. Specimens should be preserved in 95% ethanol. Insecticidal dusts and resin strips are useful in treatment and control (Durden 2002).

TICKS (IXODIDA)

Varma (1993) provides an identification key to tick families and genera.

Larval, nymphal and adult ticks all suck blood, often from different hosts. Individuals remain attached to hosts for as long as two days (Sonenshine et al. 2002). Eyelids and the bases of beaks are usual feeding sites. Most ticks are ambush parasites found in litter and soil that latch on to passing hosts. Avian soft ticks (Argasidae — *Argas* and *Ornithodoros*) and some hard ticks (Ixodidae — *Ixodes*) live in nests and burrows. Ticks transmit avian spirochetosis and Lyme disease, and are vectors for *Babesia* spp., an anemia-causing protozoan known to occur in Prairie Falcons (Croft and Kingston 1975). They also transmit viruses and tularemia bacteria to birds. Some species produce a toxin in their saliva that induces paralysis. Ticks have killed nestling Prairie Falcons (Webster 1944, Oliphant et al. 1976) and Peregrine Falcons (*F. peregrinus*) (Schilling et al. 1981), and tick paralysis killed an adult Powerful Boobook (*Ninox strenua*) (Fleay 1968) in Australia. Ticks can be collected directly from hosts by dissecting nest material by extraction with a Tullgren funnel, by dragging a blanket or sheet over vegetation, and with carbon-dioxide traps. Ethanol preserves soft ticks, and Pampel's fluid (2 ml glacial acetic acid, 6 ml 40% formalin, 30 ml distilled water, and 15 ml 95% ethanol) prevents hard tick scutal patterns from fading.

Ticks should be removed carefully from hosts with forceps, making certain to avoid leaving the mouthparts embedded in the skin. A drop of ethanol or oil can be used to detach individuals. Antibiotics should be applied to the point of attachment once the tick has been removed. Pyrethroid dusts are useful in control.

MITES (ACARINA)

Blood-sucking Mites

Varma (1993) provides an identification key to the most important species of *Dermanyssus* and *Ornithonyssus*.

Nidicolous mites in the genera *Dermanyssus* and *Ornithonyssus* and their less common relatives, as well as rhinonyssid nasal-cavity mites, feed on blood. Rhinonyssid nasal-cavity mites that cause rhinitis or sinusitis usually are limited to a few individuals per host (Mullen and O'Connor 2002). *Sternostoma* can clog air sacs, causing wheezing and mortality. *Dermanyssus* and *Ornithonyssus* populations can mass on hosts, causing anemia and weight loss. Tropical fowl mites (*Ornithonyssus bursa*), which usually feed near the vent, have killed nestling Snail Kites (Sykes and Forrester 1983) and a captive adult Eurasian Sparrowhawk (*A. nisus*). *Ornithonyssus* transmits encephalitis viruses, and *Dermanyssus* transmits the white blood cell-infecting protozoan *Lankesterella* (Box 1971). Nasal mites can be collected from live hosts by flushing the nares with water, whereas *Dermanyssus* and *Ornithonyssus* can be obtained by ruffling feathers dusted with insecticide powder, or from nest material by dissection or extraction using a Tullgren funnel. Mites should be preserved in Oudemans' fluid (5 parts glycerine, 8 parts glacial acetic acid, and 87 parts 70% alcohol) to prevent hardening. Treatment and control of external mites involves

pyrethroid and other insecticide dusts or sprays. Rhononyssid mites can be controlled with dichlorvos pest strips or pyrethrin-piperonyl butoxide spray (Ritchie et al. 1994).

Skin and Tissue-eating Mites

Skin-mite identification keys are outdated, incomplete, scattered or in some cases, nonexistent. Krantz (1978) provides family keys for mites, overall.

Skin or tissue-eating mites on raptors include *Pneumophagus* in the lungs and air sacs, Ereynetidae in the nasal cavity, Turbinoptidae in the outer nares, Hypoderatidae under thigh and underbody skin, Syringophilidae in quills, and Analgidae, Cheyletiellidae, Epidermoptidae, Harpirhynchidae, Knemidocoptidae, and Trombiculidae (chiggers) on or in the skin. Cheyletiellid mites also feed on blood, and, as with epidermoptid and harpirhynchid mites, can cause edema, hyperkeratosis, and feather loss, with secondary infections in skin lesions. *Knemidocoptes* can cause development of scaly-face and scaly-leg encrustations. Females of *Strelkoviacarus* and *Microlichus* are phoretic on louse flies, whereas *Myialges* females lay their eggs on these flies. Hypoderatid mites reproduce in nests, but their adults are nonfeeding and short-lived. Chiggers, often a cause of dermatitis, are larval mites whose nymphal and adult forms are soil predators. Skin mites can be collected from hosts in skin scrapings, and with detergent washes during necropsies. Hypoderatid mites may be revealed as lumps under the skin. Chiggers can be collected by placing a black disk on the ground below the bird, which will attract them (Mullen and O'Connor 2002). Skin and tissue-entry mites can be preserved in Oudemans' fluid. Ivermectin can be used to treat infestation of nasal, skin and syringophilid quill mites.

Feather-eating Mites

Thirteen families and 22 genera of feather-eating mites parasitize raptors. Gaud and Atyeo (1996) provide keys to genera of the feather mites of the world.

Many mites live on feathers where they scavenge fungi, lipids, bacteria, and feather fragments. A few live in the rachis and quill and eat medulla tissue. Feather and quill mites are most abundant on wing feathers. Feather mites can be collected by ruffling feathers dusted with insecticides. Most quill mites require dissection of shed feathers or quills during necropsy. Oudemans' fluid can be used for preservation. Pyrethrin dusts reduce feather mite populations, while dichlorvos pest strips or ivermectin can be used to treat quill mite infestations (Ritchie et al. 1994).

Feather Microbiology

The microbiology of raptor feathers is poorly known. Hubalek (1974a,b, 1981) surveyed the keratinophilic and other fungi on Common Kestrels and European owls, whereas Rees (1967) found two fungal genera on the feathers of Australian raptors. Pinowski and Pinowska (unpubl. data) have reviewed the feather fungal literature, and concluded that feather fungi are not very important in that they remain mostly dormant and rarely destroy feathers, and do not regulate the numbers of other feather ectoparasites. Bacteria also degrade feathers (Goldstein et al. 2004), but Cristol et al. (2005) found no evidence that they affect feathers on living birds. Although many North American birds have been examined for these bacteria (Burtt and Ichida 1999, Muza et al. 2000), raptors have yet to be studied in this regard.

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