Effect of the blood-sucking mite *Ornithonyssus bursa* on chick growth and fledging age in the North Island robin

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Abstract: Pathological consequences of the blood-sucking mite *Ornithonyssus bursa* vary between species, with its impact ranging from no measurable effect, to significant blood loss and chick mortality. In New Zealand, where several bird species are known to be parasitised by *O.bursa*, the effect of this mite on host fitness is unclear, as few studies have been carried out. During a three-year study of the North Island robin *Petroica longipes* on Tiritiri Matangi Island, the prevalence of *O. bursa* in robin nests and on chicks and its impact on robin chick growth and survival was measured. The presence of mites was correlated with both time of the season and humidity of the habitat, with infestation being positively correlated with later nesting attempts and more humid microclimates. Robin chicks in infested nests were significantly smaller and fledged at an earlier age than chicks in nests where no mites were detected. Despite this effect, no significant difference in body size or survival was detected between the two groups at one month post-fledging. This was most likely because chicks from mite-infested nests compensated for their retarded growth once they left the nest environment. On mainland New Zealand, where ground-dwelling mammalian predators are present, chicks forced to leave the nest at an earlier age with less developed flying skills may be at an increased risk of predation.

Keywords: ectoparasite; mite; blood-sucking; haematophagous; growth rate; fledging age; population density; micro-climate; juvenile survival; *Petroica*

Introduction

Birds are hosts to many different blood-sucking ectoparasites (Loye and Zuk, 1991), with these having diverse and wide-ranging effects on the health, reproductive success and behaviour of their hosts (Norris, 1991; Oppliger *et al.*, 1994; Weddle, 2000). Direct effects of haematophagous parasitism are: significant blood loss (Szép and Møller, 2000); local tissue damage; and the transferral of toxins, irritants or pathogens to the birds via the mite's saliva (Walter and Proctor, 1999; Wikel *et al.*, 2001). Mechanical irritation and local immune reactions can irritate the bird to such a degree that it compromises the bird's ability to forage and avoid predators (Walter and Proctor, 1999).

One common avian ectoparasite is the blood-sucking mite *Ornithonyssus bursa*: Macronyssidae, Gamasida, which is being found on bird species world wide (Walter and Proctor, 1999). These mites live on the host and within the nesting material, from where they infect and feed on chicks in the nest (Burtt Jr *et al.*, 1991). Because of this life cycle, their presence is affected by both host and environmental conditions; being negatively correlated with the quality of an individual bird (Darolová *et al.*, 1997), and positively correlated with humidity (Walter and Proctor, 1999) and the density of breeding sites (Poiani, 1992).

In New Zealand, where several bird species are known to be parasitised by *O. bursa*, the effect of this mite on host fitness is unclear. No effect of the parasite was found on breeding success in the North Island saddleback (*Philesturnus carunculatus rufusater*) (Stamp *et al.*, 2002) or the European starling (*Sturnus vulgaris*) (Powlesland, 1977). But in the endemic New Zealand stitchbird (*Notiomystis cincta*) the mites are suspected as being so detrimental to chick development that management for this species includes treating active nests with a pesticide when mites are detected (Taylor and Castro, 2000). Negative effects of parasitism by *O. bursa* from studies in other countries suggest that the impact of parasitism may vary between bird species (Møller, 1990; 1993).

The North Island robin (*Petroica longipes*) displays common avian anti-ectoparasite behaviours such as auto-grooming, sun-bathing and anting (Kinsky, 1957; Walter and Proctor, 1999), and *O. bursa* has been

observed in its nests (Å. Berggren, unpublished data). During a long-term study of robins on Tiritiri Matangi Island (36° 36' S, 174° 53' E), located off the northeast coast of New Zealand's North Island, the presence and impact of *O. bursa* on robin chick growth and survival was measured. Because the robin population was closely monitored during the years of this study, it offered an excellent opportunity to answer the following questions. (1) What proportion of nests have detectable levels of blood-sucking mites? (2) does the incidence of mite-infestation change during the season? (3) Are the number of chicks in the nest, and the time between renesting attempts correlated with the likelihood of mite presence? (4) Do habitat characteristics (micro-climate, number of pairs in a habitat patch) influence the likelihood of mite presence? And (5) is mite presence correlated with chick growth and survival?

Methods

Species and study population

The North Island robin is an endemic medium-sized (26–32 g) New Zealand passerine (Higgins and Peter, 2002), which is long-lived (12+ years) and socially monogamous with long-term bonds and clearly defined territories that they occupy year-round (Armstrong *et al.*, 2000). The pair usually remains together until one bird dies and both one-year-old males and females breed successfully (Armstrong *et al.*, 2000). Females usually lay two or three clutches of between 2–3 eggs per breeding season, and the pair successfully raises an average 2.5 chicks per year to fledgling age (Armstrong *et al.*, 2000). Chicks fledge approximately 17 days after hatching, and then remain dependent on the parents for food for one month after leaving the nest (Å. Berggren, unpublished data). The species is non-migratory, and dispersal usually occurs when juveniles move away from their parents' territory to establish their own territories.

This study was conducted during three breeding seasons from September to March of 2000/2001, 2001/2002 and 2002/2003 on the North Island robin population on Tiritiri Matangi Island. The island is located off the northeast coast of New Zealand's North Island east of the Whangaparoa peninsula. The population is geographically isolated, with no recorded immigration or emigration to or from the island. The island is the site of a major revegetation project and is a patchwork of mature and young regenerating forest. The robins on Tiritiri Matangi prefer old forest to regenerating forest (Armstrong and Ewen, 2002), resulting in robin numbers being unevenly distributed between the forest fragments. Approximately 92 birds were present at any time during the study, with 95% of these being uniquely colour banded with their ages and

social parentage known. Chicks were individually banded in the nest usually around 11 days of age with a combination of one metal and three colour plastic bands. No parasiticides have been applied to the birds or their nests since the population was introduced.

Data collection

At banding, individuals were weighed (±0.5 g) and had their tarsometatarsal length (±0.05 mm) measured. The presence of mites in a nest was determined by inspecting the chicks and the hands of the person handling the chicks during the banding procedure, which took approximately 10 minutes. A hand was held in the nest when removing and replacing the chicks during banding. This took approximately 20 seconds (similar to nest census time by Powlesland, 1977; Stamp *et al.*, 2002) and the hand was then inspected for mites. Hands and instruments were checked for mites after the banding was completed, and were cleaned with alcohol to minimise the chance of spread between nests. The method did not generate data on number of mites present and therefore no analyses using density of mites could be performed. As earlier studies have found that numbers of mites are usually very high when established in nests (Powlesland, 1977; Møller, 1993), the use of presence/absence of mites was determined to be sufficient to indicate a level of parasite load that could affect the birds.

Forty-nine fledglings were caught approximately one month after leaving the nest, using a hand net or spring-loaded trap, as a part of a parallel study. For this, mealworms were placed on the ground as a lure and a net brought down over the bird when it came to feed on them. These birds were weighed (±0.5 g), and measured for tarsometatarsal length (±0.05 mm). This provided data allowing a comparison of body size of one-month old fledglings from nests with and without mites. The residuals from body weight and tarsus length were used for analyses on body size, as these measurements often have a non-isometric relationship (Sánchez-Guzmán *et al.* 2004). All pairs on the island were followed during the three breeding seasons and all reproductive efforts were noted. All territories were censused on average every fourth day during the breeding season. This provided data on nesting dates, chick numbers, fledging dates and post-fledging survival.

To measure robin local population density, the number of individuals occupying the same bush fragment was counted and divided into three categories. This created an index ranging from 1–3 where the lowest category contained pairs who solely occupied that bush patch, category 2 containing bush patches with two robin pairs, and category 3 having >2 pairs in the same patch. A simple index of territory micro-

climate was derived from the site of the territory and the presence of wet areas within the territory. If a territory was situated on the edge of a forest patch and facing wet winds from the surrounding sea, or it incorporated an area that was continuously wet throughout the breeding season, it was given a value of 1. Territories within forest patches and without a wet area were given a value of 0. Habitat quality may be positively correlated to wet areas within the habitat as these may become refuges for insect prey during the dry summer, but negatively correlated to habitat edges. Birds on edges may suffer a higher predation risk relative to the interior of the forest because of predation from the native owl (*Ninox novaeseelandiae*) within the forest (Brown *et al.*, 1998) and the Australasian harrier (*Circus approximans*) from the grassland matrix (Baker-Gabb, 1981; Gardner, 1998).

Statistical analyses

The presence of mites was treated as a categorical variable for all analyses (presence/absence). A Student's *t*-test examined the relationship between mite presence and time of breeding season. An analysis of covariance (ANCOVA) with clutch identity as the covariate assessed the significance of both territory micro-climate and local population density on the likelihood of mite-infestation in nests. Clutch identity was used as the covariate in ANCOVAs to avoid pseudoreplication when using measurements of siblings from the same nest. An ANCOVA with clutch identity and time of breeding season as covariates assessed the significance of each of the following on mite presence: clutch size, time between clutches, chick age at fledging, fledgling body size and fledgling survival to one month of age. When using an ANCOVA to examine the relationship between presence of mites on chick body size, an additional covariate of age of chick when measured, was added to the analyses.

Sample sizes varied among tests as data could not be obtained for all individuals. Data were tested for normality with a Shapiro Wilks W test and if not normally distributed, were cube root transformed (Legendre and Legendre, 1983). Data variances were not significantly different and means are presented ± 1 SE. All analyses were carried out using JMP (1995).

Results

Twenty of 188 nests with chicks at banding age (16.9%) had detectable levels of *O. bursa* (Fig. 1), and 41 of 177 chicks (23.2%) suffered from mite infestation in these nests (Table 1). Clutches with mites were generally laid later in the season (85.3 ± 0.5 days after first hatched clutch) than clutches without mites (57.4 ± 2.9 days after first hatched clutch) ($t = -4.53$, $n = 176$, $P <$

Figure 1. Dorsal view of the blood-sucking mite *Ornithonyssus bursa*. The background grid is 1×1 mm.

Table 1. The number of North Island robin nests and chicks with mites (*Ornithonyssus bursa*) during the three year study.

	Nests with mites		Chicks with mites	
Year 1 2000/2001	Brood 1	0/8	Brood 1	0/15
	Brood 2	1/4	Brood 2	2/8
	Total	1/12		2/23
Year 2 2001/2002	Brood 1	3/22	Brood 1	5/40
	Brood 2	4/13	Brood 2	10/29
	Brood 3	3/3	Brood 3	5/5
	Total	10/38		20/74
Year 3 2002/2003	Brood 1	2/21	Brood 1	4/37
	Brood 2	7/16	Brood 2	15/34
	Brood 3	0/4	Brood 3	0/9
	Total	9/41		19/80
All years	20/91	41/177		

0.0001). There was a non-significant trend between the occurrence of mites in a nest, and the time between nesting attempts; second clutches laid closer to the previous clutch had a higher likelihood of mites (ANCOVA $F = 2.91$, $n = 52$, $P = 0.094$). There was no correlation with number of chicks in the clutch and the presence of mites ($F = 2.02$, $n = 176$, $P = 0.16$), but mites were more likely found on older chicks (12.3 ± 0.5 versus 10.1 ± 0.2 days: $F = 6.82$, $n = 169$, $P = 0.0098$). There was a non-significant trend between the presence of mites on chicks and local population density, with mites being more frequent in low-density
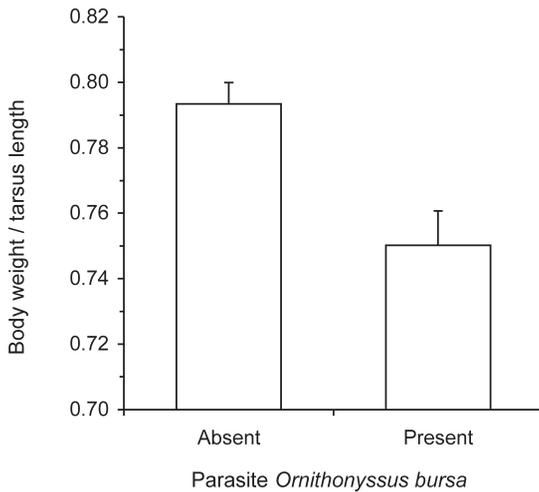
Figure 2. Index of body size (weight / tarsus length; mean ± 1 SE) of North Island robin chicks in nests free from mites or infested with mites.
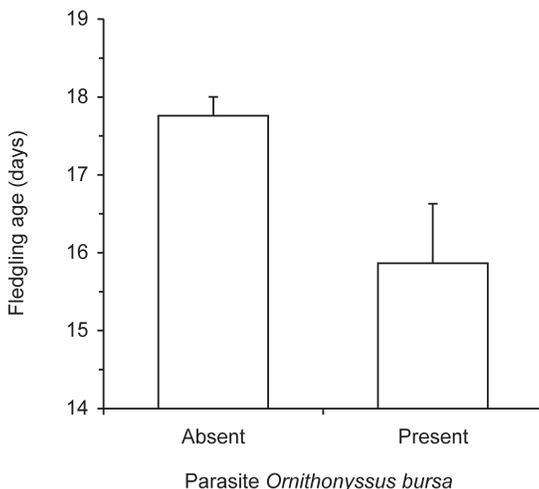

Figure 3. Age in days (mean ± 1 SE) of North Island robin chicks when fledging in relation to mite infestation of the nest.

areas (density 1, 42.86%; density 2, 2.86%; density 3, 22.0%. $F = 3.51$, $n = 176$, $P = 0.062$). The micro-climate of the territory affected the presence of mites in the nests, with nests in damper areas having a higher frequency of mites (28.17%) than nests in drier areas (20.0%) ($F = 5.05$, $n = 175$, $P = 0.026$).

Chicks from mite-infested nests were significantly smaller in body size than chicks from mite-free nests ($F = 29.09$, $n = 147$, $P < 0.0001$) (Fig. 2). The chicks from nests with mites fledged at an earlier age than chicks without mites (16.29 ± 0.76 versus 17.76 ± 0.24 days: $F = 7.87$, $n = 118$, $P = 0.0059$) (Fig. 3). However, these effects did not carry over once the chicks left the nest, with there being no difference in body size or survival of juveniles from nests with or without mites one month post-fledging ($F = 0.258$, $n = 47$, $P = 0.61$ and $F = 0.67$, $n = 151$, $P = 0.41$ respectively).

Discussion

Distribution of mites

The likelihood of finding mites in a robin's nest increased as the breeding season progressed; a result also found for saddlebacks on the same island (Stamp *et al.,* 2002). However, unlike Stamp *et al.* (2002), I also found mites in nests where chicks were yet to hatch, and in one instance, this appeared to be the cause of the female abandoning the nest. When ectoparasites are present in a nest they often occur in high numbers (i.e. in the hundreds or thousands of individuals) (Powlesland, 1977; Møller, 1990; pers. obs). Because of this, a detectable mite presence can indicate an infestation level high enough to affect the chicks during their nesting period.

The usual time for completion of a mite's life cycle is approximately two weeks (Powlesland, 1977). The generation time of mites is also correlated with climatic conditions (Walter and Proctor 1999); this would explain the increased likelihood of a nest infestation as the season progressed into the summer, and in areas of higher local humidity. The latter might be especially important for the development of mites in open nest cups, like those of North Island robins, when compared to cavity nesting species. In contrast to studies showing a positive relationship between mite infestation and local bird density (Poiani, 1992), the trend in this study was for infestations of mites to be lower in areas with more robins. This may be because *O. bursa* is a generalist species (parasitising saddleback, stitchbird, red-crowned kakariki (*Cyanoramphus novaezelandiae*), morepork and North Island robin on the island), so other factors such as the density of other bird species and congregation points, such as water sources, may be important.

Mites are expected to maximise their reproduction when there is an abundant food source, such as chicks in the nest. Studies show that the number of *O. bursa* mites in nests is positively correlated with the number of mites on the adults when they arrived to the breeding grounds (Møller, 1990). An indication that this might also be the case in the North Island robin is that clutches laid closer in time to the previous clutch were more likely to develop mites. With less time between clutches it is reasonable to assume that parents carried more mites in their plumage from their previous clutch when establishing their new nest, thus, infecting their new nest with a larger founding mite population and leading to a higher likelihood of the second nest being infested. Chick age was positively correlated with the occurrence of mites, as was expected from the mite's developmental cycle resulting in emerging nymphs and adult mites when the chicks are about 12 days old.

Effects of mites on body size, fledging age and survival of young

Mites have been negatively correlated with chick weight gains in many avian species including house sparrow (*Passer domesticus*) (Weddle, 2000), barn swallow (*Hirundo rustica*) (Møller, 1993), European starling (*S. vulgaris*) (Fauth *et al.*, 1991), purple martin (*Progne subis*) (Moss and Camin, 1970), European storm-petrel (*Hydrobates pelagicus*) (Merino *et al.*, 1999), and rock dove (*Columba livia*) (Clayton and Tompkins, 1995). However, this finding is not universal, with no effect of mites being found in studies of house sparrows (Szabó *et al.*, 2002), European starlings (Powlesland, 1977), and North Island saddlebacks (Stamp *et al.*, 2002). This study demonstrates that the North Island robins on Tiritiri Matangi Island belong in the former category, with a significant negative correlation between mite parasitism and chick weight. However, this effect was limited to their time in the nest, with fledglings quickly compensating for their lower nestling weight by one month post-fledging.

Mites also increased the likelihood of a chick fledging at a younger age, potentially affecting its survival. Once chicks leave the nest they continue to be fed by both parents, but they are more exposed to adverse weather conditions and predators. Early-fledging chicks are poor flyers and remain on the ground or lower tree limbs for several days (Å. Berggren, unpubl. data), thus increasing the risk of predation from ground-dwelling predators. Chicks may jump from a mite-infested nest for several reasons; they may be irritated or their parents may reduce their feeding visits to avoid the mites themselves. Shorter nestling periods in mite-infested nests have also been reported in the barn swallow (Møller, 1990), but not in the North Island saddleback (Stamp *et al.*, 2002).

The effect of blood-sucking mites on chick survival varies between species. Nestlings of the colonial sand martins (*Riparia riparia*) whose nests were treated with pyrethrum were twice as likely to survive than the control group (Szép and Møller, 2000), post-fledging survival was negatively correlated with mites in rock doves (Clayton and Tompkins, 1995), and mites reduced chick survival in the barn swallow (Barclay, 1988; Møller, 1990). However, mites did not affect chick survival in the European starling (Powlesland, 1977; Fauth *et al.*, 1991), the North Island saddleback (Stamp *et al.*, 2002), or the house sparrow (Szabó *et al.*, 2002). A lack of effect on survival of fledglings was also observed in this study. Despite mite-infested fledglings being both smaller and fledging earlier, there was no effect on fledgling survival at one month after leaving the nest. However, the effects of mites on survival may become significant in areas where ground-dwelling predators are higher. A chick that fledges early as a result of mites, and is effectively flightless for several days, may run a higher risk during this period of being preyed upon.

In high density bird populations, such as communal breeders, it is thought that exposure to relatively high levels of parasites in the nest acts to select for increased resistance in the host to the parasites' negative effects (Møller *et al.,* 2001). One prediction from this is that such an investment in increased immune function may be costly and associated with a longer development time in the nest: with chicks being exposed to parasites for a longer time period. The North Island robin is sedentary and the prevalence of the mites is not very high in the population (half of the pairs in the population did not suffer from mites in any of their clutches during the study); thus any possible differences in individual resistance are difficult to test because of confounding habitat variables. However, there was no evidence that infested chicks stayed longer in the nest. One possibility not explored in my study is that heavily parasitised nestlings trade-off growth in body size for feather development, to allow them to escape from the nest at an earlier age (see Saino *et al.*, 1998). Future studies of parasitism in this species should test this hypothesis by measuring feather development in parasitised and non-parasitised chicks, and relate it to fledging age.

Parasite virulence is partly related to landscape variables; thus, isolated bird populations may coevolve with their parasites, leading to lower parasite virulence. Small or distant islands tend to be occupied with species showing the least defence against parasites while also having the least virulent parasites (Hochberg and Møller, 2001). However, the birds on Tiritiri Matangi Island have only been introduced relatively recently (11 species introduced during the past 5-20 years), many from mainland sites with low population density. Thus, the expected relationship between host

resistance and parasite virulence on the island is difficult to estimate. One possibility is that with the rapid increase in bird density (both intra- and inter-specific) in the past 10 years, combined with a small number of bird generations in that time, parasites were able to spread more easily and this may have favoured the evolution of increased virulence in generalist parasites such as *O. bursa*. However, this is expected to invoke a strong selection pressure on host resistance. Islands like Tiritiri Matangi may be valuable 'experimental areas' for research into the evolution of host resistance and parasite virulence; they may show immunological parameters in a state of flux between mainland populations and isolated island populations. This would not only provide increased knowledge on the current parasite-host situation in bird populations today, but would also be valuable for future conservation work where translocations and wildlife health issues are an important tool.

While *O. bursa* is an obvious and potentially important parasite affecting the health of birds, it is only one of many blood-sucking parasites. Blowflies can lower chick survival (Szabó *et al.*, 2002) and blood-sucking fleas have been seen to reduce chick weight (Richner *et al.*, 1993; Christe *et al.*, 1996; Merino *et al.*, 1999; Nilsson, 2003) and survival (Richner *et al.*, 1993). The New Zealand native blood-sucking louse fly *Ornithoica* sp. parasitises both juvenile and adult North Island robin (Å Berggren, unpublished data). Louse flies are also common in many other New Zealand bird species and spend most of their life in the plumage of birds (Lee and Clayton, 1995). This parasite is another potential negative addition to the parasite load of the robin as they are of a substantial size (approximate 6 mm long) and can occur in high numbers on a single individual (Å Berggren, unpublished data). Though endoparasites in New Zealand birds have been investigated (McFarland *et al.,* 2003), and taxonomy studies on ectoparasites have been done (Palma, 2000; Palma and Price 2005), little is known about host-parasite interactions in endemic bird species. In light of this, and the results from this study, I conclude that further research is urgently needed on the prevalence and effect of parasites on endemic New Zealand fauna.

Acknowledgements

References

Armstrong, D.P.; Ewen, J.G. 2002. Dynamics and viability of a New Zealand robin population reintroduced to regenerating fragmented habitat. *Conservation Biology 16:* 1074-1085.

Armstrong, D.P.; Ewen, J.G.; Dimond, W.J.; Lovegrove, T.G.; Bergström, A.; Walter, B. 2000. Breeding biology of North Island robins (*Petroica australis longipes*) on Tiritiri Matangi Island, Hauraki Gulf, New Zealand. *Notornis 47:* 106-118.

Baker-Gabb, D.J. 1981. The diet of the Australasian harrier (*Circus approximans*) in the Manawatu-Rangitikei sand country, New Zealand. *Notornis 28:* 241-254.

Barclay, R.M.R. 1988. Variation in the costs, benefits, and frequency of nest use by barn swallows (*Hirundo rustica*). *The Auk 105:* 53-60.

Brown, K.P.; Moller, H.; Innes, J.; Jansen, P. 1998. Identifying predators at nests of small birds in a New Zealand forest. *Ibis 140:* 274-279.

Burtt Jr, E.H.; Chow, W.; Babbitt, G.A. 1991. Occurrence and demography of mites of tree swallow, house wren, and eastern bluebird nests. *In:* Loye, J.E.; Zuk, M. (Editors), *Bird-parasite interactions*, pp 104-122. Oxford University Press, Oxford.

Christe, P.; Richner, H.; Oppliger, A. 1996. Begging, food provisioning, and nestling competition in great tit broods infested with ectoparasites. *Behavioral Ecology 7:* 127-131.

Clayton, D.H.; Tompkins, D.M. 1995. Comparative effects of mites and lice on the reproductive success of rock doves (*Columba livia*). *Parasitology 110:* 195-206.

Darolová, A.; Hoi, H.; Schleicher, B. 1997. The effect

of ectoparasite nest load on the breeding biology of the penduline tit *Remiz pendulinus*. *Ibis 139:* 115-120.

Fauth, P.T.; Krementz, D.G.; Hines, J.E. 1991. Ectoparasitism and the role of green nesting material in the European starling. *Oecologia 88:* 22-29.

Gardner, J.L. 1998. Experimental evidence for edge-related predation in a fragmented agricultural landscape. *Australian Journal of Ecology 23:* 311-321.

Higgins, P.J.; Peter, J.M. 2002. *Handbook of Australian, New Zealand and Antarctic birds*. Oxford University Press, Melbourne, Australia.

Hochberg, M.E; Møller, A.P. 2001. Insularity and adaptation in coupled victim-enemy associations. *Journal of Evolutionary Biology 14:* 539-551.

JMP, version 3. 1995. SAS Institute Inc, Cary, NC, USA.

Kinsky, F. 1957. North Island robin "anting". *Notornis 7:* 112.

Lee, P.L.; Clayton, D.H. 1995. Population biology of swift (*Apus apus*) ectoparasites in relation to host reproductive success. *Ecological Entomology 20:* 43-50.

Legendre, L.; Legendre, P. 1983. *Numerical Modelling*. Elsevier, Amsterdam.

Loye, J.E.; Zuk, M. 1991. *Bird-parasite interactions.* Oxford University Press, Oxford.

McFarland, L.H.; Mouritsen, K.N.; Poulin, R. 2003. From first to second and back to first intermediate host: the unusual transmission route of *Curtuteria australis* (Digenea: Echinostomatidae). *The Journal of Parasitology 89:* 625-628.

Merino, S.; Minguez, E.; Belliure, B. 1999. Ectoparasite effects on nestling European storm-petrels. *Waterbirds 22:* 297-301.

Moss, W.W.; Camin, J.H. 1970. Nest parasitism, productivity, and clutch size in purple martins. *Science 168:* 1000-1003.

Møller, A.P. 1990. Effects of parasitism by a haematophagous mite on reproduction in the barn swallow. *Ecology 71:* 2345-2357.

Møller, A.P. 1993. Ectoparasites increase the cost of reproduction in their hosts. *Journal of Animal Ecology 62:* 309-322.

Møller, A.P; Merino, S; Brown, C.R; Robertson, R.J. 2001. Immune defense and host sociality: a comparative study of swallows and martins. *The American Naturalist 158:* 136-145.

Nilsson, J.-Å. 2003. Ectoparasitism in marsh tits: costs and functional explanations. *Behavioral Ecology 14:* 175-181.

Norris, K.R. 1991. General Biology. *In:* Naumann, I.D.; Carne, P.B.; Lawrence, J.F.; Nielsen, E.S.; Spradbery, J.P.; Taylor, R.W.; Whitten, M.J.;

Littlejohn, M.J. (editors) *The insects of Australia: a textbook for students and research workers*, pp 68-108. Melbourne University Press, Melbourne, Australia.

Oppliger, A.; Richner, H.; Christe, P. 1994. Effect of an ectoparasite on lay date, nest-site choice, desertion, and hatching success in the great tit (*Parus major*). *Behavioral Ecology 5:* 130-134.

Palma, R.L. 2000. The species of *Saemundssonia* (Insecta: Phthiraptera: Philopteridae) from skuas (Aves: Stercorariidae). *New Zealand Journal of Zoology 27*: 121-128.

Palma, R.L.; Price, R.D. 2005. *Menacanthus rhipidurae*, a new species of chewing louse (Insects: Phthiraptera: Menoponidae) from South Island fantails, *Rhipidura fuliginosa fuliginosa* (Aves: Passeriformes: Dicruridae). *New Zealand Journal of Zoology 32:* 111-115.

Poiani, A. 1992. Ectoparasitism as a possible cost of social life: a comparative analysis using Australian passerines (Passeriformes). *Oecologia 92:* 429-441.

Powlesland, R.G. 1977. Effects of the haematophagous mite *Ornithonyssus bursa* on nestling starlings in New Zealand. *New Zealand Journal of Zoology 4:* 85-94.

Richner, H.; Oppliger, A.; Christe, P. 1993. Effect of an ectoparasite on reproduction in great tits. *Journal of Animal Ecology 62:* 703-710.

Saino, N; Calza, S; Møller, A.P. 1998. Effects of a dipteran ectoparasite on immune response and growth trade-offs in barn swallow, *Hirundo rustica*, nestlings. *Oikos 81:* 217-228.

Sánchez-Guzmán, J.M; Villegas, A; Corbacho, C; Morán, R; Marzal, A; Real, R. 2004. Response of the haematocrit to body condition changes in northern bald ibis *Geronticus eremita*. *Comparative Biochemistry and Physiology, Part A 139:* 41-47.

Stamp, R.K.; Brunton, D.H.; Walter, B. 2002. Artificial nest box use by the North Island saddleback: effects of nest box design and mite infestations on nest site selection and reproductive success. *New Zealand Journal of Zoology 29:* 285-292.

Szabó, K.; Szalmás, A.; Liker, A.; Barta, Z. 2002. Effects of haematophagous mites on nestling house sparrows (*Passer domesticus*). *Acta Parasitologica 47:* 318-322.

Szép, T.; Møller, A.P. 2000. Exposure to ectoparasites increases within-brood variability in size and body mass in the sand martin. *Oecologia 125:* 201-207.

Taylor, S.; Castro, I. 2000. *Hihi Standard Operating Procedures*. Department of Conservation, Wellington.

Walter, D.E.; Proctor, H.C. 1999. *Mites: ecology, evolution and behaviour*. University of New South

Wales Ltd, Sydney.

Weddle, C.B. 2000. Effects of ectoparasites on nestling body mass in the house sparrow. *The Condor 102:* 684-687.

Wikel, S.K; Alarcon-Chaidez, F.J. 2001. Progress toward molecular characterization of ectoparasite modulation of host immunity. *Veterinary Parasitology 101:* 275-287.

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