Tuhinga 21: 147–159

A review of ectoparasites of *Apteryx* spp. (kiwi) in New Zealand, with new host records, and the biology of *Ixodes anatis* (Acari: Ixodidae)

Allen C.G. Heath

AgResearch Wallaceville, National Centre for Biosecurity and Infectious Disease,
PO Box 40 063, Upper Hutt, New Zealand (allen.heath@agresearch.co.nz)

ABSTRACT: The ectoparasite fauna of kiwi is reviewed, and new host records given for ticks and fleas. New locality records for the tick *Ixodes anatis* Chilton, 1904 are provided, together with geographical distribution, seasonal data for each tick stage, and a discussion on the biology of the tick as far as could be ascertained from the available material and observational data. The effects of the parasites on the hosts, and the extent to which host phylogeny is only dimly illuminated by host–parasite relationships, are presented. The availability of a good series of the trombiculid *Guntheria* (*Derrickiella*) *apteryxi* Loomis & Goff, 1983 suggests that this mite is likely to be more specific to the kiwi than the mammalian links with other species in this genus would otherwise indicate. Some suggestions are made for further research, especially into tick biology.

KEYWORDS: kiwi, chewing lice, fleas, mites, ticks, *Ixodes anatis*, new host and locality records, biology, seasonality, effects on hosts.

Introduction

New Zealand kiwi (Apterygidae) are endemic, flightless, ratite birds, classified as threatened, with the North Island brown kiwi, *Apteryx mantelli* (arguably the most numerous species), rated as 'seriously declining' (Sales 2005). This is because kiwi are under continuous population pressure, principally for reasons of predation (McLennan *et al.*1996).

A considerable number of these birds have now been examined, both for scientific and conservation purposes, and it has become apparent that they carry a diverse and specific ectoparasite fauna, comprising a tick, chewing lice, feather mites and a trombiculid mite, in addition to a number of internal parasites (McKenna 1998). There is also recent evidence of at least two haematozoan parasites associated with kiwi (Peirce *et al.* 2003), one of which may be transmitted by the kiwi tick, *Ixodes anatis* Chilton, 1904 (Jefferies *et al.* 2008).

In addition, there are adventitious, haematophagous ectoparasites (an exotic tick and fleas, for example) that potentially expose the birds to vector-borne disease or pathology, following blood removal or injection of allergens. There are no published records of the extent to which kiwi are fed upon by Simuliidae (sand flies, black flies) and Culicidae (mosquitoes), possibly the most numerous and widespread haematophagous Diptera in New Zealand, and both groups of which feed on other birds.

This report summarises hitherto unpublished and previously published records, and brings together current knowledge of the ectoparasites of kiwi. It is important to recognise the risks posed to this unusual endemic bird group, with its fragile, generally declining population, and to identify research needs.

History

The first published records of arthropod parasites of kiwi were by Maskell (1897), who described the tick *Ixodes apteridis* from *Apteryx mantelli* in Taranaki, and *Ixodes* *aptericola* from *Apteryx australis* in Dusky Sound. The types of those species could not be located by Dumbleton (1953) and, although he thought it highly probable that both of these records referred to *Ixodes anatis*, he concluded correctly that this could not be proved. In the unlikely event that these types become available and all prove to be conspecific, *I. apteridis* would have priority over *I. aptericola* and *I. anatis*, with the latter two names becoming junior synonyms (Dumbleton 1953).

Ixodes anatis was described by Chilton (1904), who erroneously (but understandably) ascribed it as a parasite of the grey duck, *Anas superciliosa superciliosa*, the nominate type host, from Ashburton. Since then, there have been only five records of *I. anatis* from Anatidae: two more from the grey duck (Nuttall 1916; Dumbleton 1953); two from mallard ducks, *Anas platyrhynchos* (see below under 'material examined'); and one from a Canada goose, *Branta canadensis* (Dumbleton 1953). The remaining records, which are considerably greater in number were all for kiwi (this paper).

Other specific ectoparasites of kiwi were relatively slow in coming to scientific notice, with the first chewing louse described by Harrison (1915), the next by Clay (1953), and the remainder between then and 2004 (Table 1). The first mites from a kiwi were described only in 1970 (Gaud & Atyeo 1970). There is a total of eight species of chewing lice in two genera, five species of feather mites in two genera, five species of fleas in five genera, two species of ticks in two genera, and one species of trombiculid mite. The latter is arguably kiwi-specific, because the genus to which it belongs primarily infests mammals in Papua New Guinea (Goff 1980), with only a small number collected from birds (Brennan 1965; Brennan & Amerson 1971; Domrow 1974).

Material and methods

A literature search provided published records, and additional material in ethanol or on microscope slides was made available through collections or written records from Dallas Bishop, Richard Bowman, Isabel Castro, Garry Clark, Richard Jakob-Hoff, Ricardo Palma and the late Robert Pilgrim, or submitted to the author for identification. The material is located in the collections of the Museum of New Zealand Te Papa Tongarewa, Wellington, and in AgResearch, Wallaceville. Records of genera and species of chewing lice were taken from Pilgrim & Palma (1982), Palma (1991) and Palma & Price (2004). Records for feather mites are from Gaud & Atyeo (1970) and Bishop (1985). Records for ticks and the trombiculid mite are cited in the text where appropriate. In a survey of 32 North Island brown kiwi from Ponui Island in the Hauraki Gulf, the birds were treated with pyrethrum powder for 10 minutes, the feathers ruffled, and all ectoparasites collected onto a tray (Isabel Castro, pers. comm. 30 March 2005). Abbreviations for tick, trombiculid mite and flea material are: ♀, female; ♂ male; N, nymph; L, larva.

Material examined

Ticks

***Ixodes anatis* Chilton, 1904**

NEW RECORDS:

Ex *Apteryx mantelli* – North Island: 1♀, 6N, 6L, Kaeo, North Auckland, 16 Aug. 1959; 1N, Hukatere, Kaipara, 21 Sep. 1967; 4L, Bay of Islands, 11 Oct. 1967; 2♀, 5♂, 4N, 1L, no locality, Apr. 1973; 6N, Waiohau, Whakatane, Jul. 1973; 3♀, 10N, on road between Hamilton and Tokoroa, 25 Feb. 1975; 4♀, 35N, 34L, Dargaville, Jun. 1975; 11N, 3L, near Whangarei, Jul. 1978; 6♀, Tangiteroria, 2 Dec. 1978; 9♀, 2N, Tangiteroria, 14 Dec. 1978; 7♀, 7♂, 15N, 3L, Tangiteroria, 18 Dec. 1978; 1♀, 2N, Tangiteroria, 13 Jun. 1979; 2♀, 3♂, 15N, 11L, Little Barrier I., Jun. 1980; 17N, Little Barrier I., Jun. 1980; 5♀, 15N, 11L, Little Barrier I., 9 Jun. 1980; 5N, Little Barrier I., Jun. 1980; 7N, 22L, near Whangarei, 23 Feb. 1981; 1♀, Waipoua Forest, 3 Oct. 1982; 3♀, 5♂, Little Barrier I., 14 Feb. 1992; 3♂, 1N, Rarewarewa, Northland, May 1994; 2♂, Purua, Northland, Feb. 2000; 1♀, Hodges Bush, Northland, 13 Feb. 2000; 1♂, Hodges Bush, Northland, 3 Jun. 2000; 3♂, 2N, 3L, Rarewarewa, Northland, 19 Jun. 2000; 1♂, 31N, Rarewarewa, Northland, 21 Jul. 2000; 4♀, Purua, Northland, 12 Mar. 2001; 414♀, 466♂, 1044N, 1253L, Ponui I., Hauraki Gulf, Mar. 2004 (32 birds); 2♀, 2♂, 35N, 99L, Ponui I., Hauraki Gulf, 21 Mar. 2004; 2♀, 5♂, 7N, Ponui I., Hauraki Gulf, 25 Mar. 2004; 1N, Purua, Northland, 13 May 2004; 11♀, 11♂, 4N, Trounson Kauri Park, Northland, 15 Jun. 2004; 1♀, 2♂, Colville, Coromandel Peninsula, 16 May 2008; 1♀, 6N, 10L, Tiritiri Matangi I., Hauraki Gulf, 14 Feb. 2009; 1♀, Waimana, Bay of Plenty, no date; 14N, 5L, Taranaki, no date.

Ex *Apteryx australis australis* – South Island: 4♀, Clinton Valley, Fiordland, 4 Mar. 2003.

Ex *Apteryx australis lawryi* – Stewart Island: 2♂, Mason Bay, Stewart I., Feb. 1988; 2N, 1L, Mason Bay, Stewart I., Oct. 1990; 5N, Mason Bay, Stewart I., 31 Jan. 1991; 1♀, Mason Bay, Stewart I., 31 Jan. 1991; 1♀, Stewart I., 28 Jan. 2003; 1N, Mason Bay, Stewart I., 4 Feb. 2003; 4♀, Mason Bay, Stewart I., 6 Feb. 2003.

Ex *Anas platyrhynchos* – South Island: 1♀, Mosgiel, 12 Oct. 1999, G. Clark; 3♀, Southland, Mar. 2006, R. Bowman. **New host record**.

LITERATURE RECORDS:

Ex *Apteryx mantelli* – North Island: 1♀, 1♂ (as *Ixodes apteridis*), Taranaki, 1896 (Maskell 1897); 2♀, North Island, Mar. 1914 (Nuttall 1916); 'females', 1♂, 1N, Aponga, North Auckland, Jul. 1921; 'females', 1♂, 1N, 'larvae', Orowhana Range, North Auckland, Sep. 1923; 1♀, 1N, 'larvae', Tangihua Range, North Auckland, 1949 (all Dumbleton (1953)); no stage given, Little Barrier I., no date (Dumbleton 1961).

Ex *Apteryx australis australis* – South Island: 1♀ (as *Ixodes aptericola*), Dusky Sound, 1896 (Maskell 1897).

Ex *Apteryx australis lawryi* – Stewart Island: no collection details given (Morgan 2008).

Ex *Anas superciliosa* – South Island: stages not given, Ashburton, Mar. 1903 (Dumbleton 1953); 1♀, 1♂, Ashburton, May 1903 (Chilton 1904); 2♀, 1N, Ashburton, 1904 (Nuttall 1916).

Ex *Branta canadensis* – North Island: no stages given, New Plymouth, 1927 (Dumbleton 1953).

***Haemaphysalis longicornis* Neumann, 1901**

NEW RECORDS:

Ex *Apteryx mantelli* – North Island: 'nymphs', Mt Moehau, Coromandel, Sep. 2002; 19L, Ponui I., Hauraki Gulf, Mar. 2004 (3 birds); 2L, Moehau, Coromandel, 11 Mar. 2008; 4L, Point Jackson, Coromandel, 7 Apr. 2008.

LITERATURE RECORDS:

Ex *Apteryx mantelli* – North Island: 2L, on road between Hamilton and Tokoroa, 25 Feb. 1975; 1L, Dargaville, Jun. 1975; 2N, Rainbow Springs, Rotorua, 20 Sep. 1976; 1N, Tangiteroria, 2 Dec. 1978; 1N, Tangiteroria, 18 Dec. 1978 (all from Heath *et al.* 1988).

Feather mites

NEW RECORDS:

Nil.

LITERATURE RECORDS:

See Table 1.

Trombiculid mite

***Guntheria* (*Derrickiella*) *apteryxi* Loomis & Goff, 1983**

NEW RECORDS:

Ex *Apteryx mantelli* – North Island: 38L, Ponui I., Hauraki Gulf, Mar. 2004 (6 birds).

Ex *Apteryx haastii* – South Island: 6L, Aorere River, Golden Bay, 28 Jun. 1986.

LITERATURE RECORD:

Ex *Apteryx mantelli* – North Island: 5L, Tangarakau, Taranaki, 27 Nov. 1955 (Loomis & Goff 1983).

Fleas

***Pygiopsylla phiola* Smit, 1979**

NEW RECORDS:

Ex *Apteryx mantelli* – North Island: 1♀, Little Barrier I., Jun. 1980; 1♀, Rotorua, no date; 74♀, 57♂, Ponui I., Mar. 2004 (6 birds); 1♀, Hodges Bush, Northland, 22 Nov. 2004.

LITERATURE RECORDS:

Nil.

***Ctenocephalides felis felis* (Bouché, 1835)**

NEW RECORD:

Ex *Apteryx haastii* – South Island: 1♂, Tekua, Westport, 24 Feb. 1977.

LITERATURE RECORDS:

Nil.

***Nosopsyllus fasciatus* (Bosc, 1880)**

NEW RECORD:

Ex *Apteryx mantelli* – North Island: 4♀, Mt Bruce (bird ex Raetihi), 3 Aug. 1972.

LITERATURE RECORDS:

Nil.

***Pulex irritans* Linnaeus, 1758**

NEW RECORD:

Ex *Apteryx mantelli* – North Island: 1♀, Parakao, Northland, 7 Feb. 1977.

LITERATURE RECORDS:

Nil.

***Parapsyllus nestoris nestoris* Smit, 1965**

NEW RECORDS:

Ex occupied nests of *Apteryx australis lawryi* – Stewart Island: 3♂, 2♀, Mason Bay, Stewart I., Feb. 1990; 3♂, 3♀, Mason Bay, Stewart I., 31 Jan. 1991.

LITERATURE RECORD:
Ex *Apteryx australis lawryi* – Stewart Island: 1♂, 27 Feb. 1968, Masons (*sic*) Bay, Stewart I. (Smit 1979).

***Parapsyllus longicornis* (Enderlein, 1901)**
NEW RECORD:
Ex burrow of *Apteryx owenii* – North Island: 1♂, 1♀, Kapiti I., 24 Aug. 1990.
LITERATURE RECORDS:
Nil.

Chewing lice

NEW RECORDS:
Nil.
LITERATURE RECORDS:
See Table 1.

Results

All known species of ectoparasites collected to date from kiwi in New Zealand are summarised in Table 1.

Effects on the host

Obligate ectoparasites
Chewing lice and feather mites
Chewing lice (Insecta: Phthiraptera) and feather mites (Acari: Analgidae) are permanent, host-specific (some are species-specific), obligate parasites of kiwi, and would not leave the host for any purpose other than to transfer to another host through direct contact. Most of the chewing lice found on kiwi are sufficiently host-specific (monoxenous) as to be diagnostic for particular hosts, but the feather mites, with one exception, are polyxenous.

Clayton *et al.* (2008) reviewed the impact of chewing lice on wild bird hosts, noting that hosts may suffer from a variety of effects, ranging from a reduction in food consumption and body mass, and a reduction in egg production, possibly due to irritation at the level of the skin by louse activity, to death of chicks. Birds may also suffer severe plumage damage, leading in some cases to an increase in thermal conductance and, eventually, an elevated metabolic rate and a decline in body mass, which can significantly affect winter survival. Lice can also act as intermediate hosts or vectors for viruses, bacteria and filarioid nematodes that may cause host disease. There are no reports of the impact of lice on kiwi, but feather damage is a possibility. In addition, birds taking time to groom more frequently than would otherwise be the case spend proportionately less time eating, or may be distracted when they should be alert for predators (Clayton *et al.* 2008).

The capacity for feather mites to be parasites and, by definition, to cause harm is less convincing than for lice. For instance, Proctor (2003) reported that there is only slight correlative evidence for negative effects of feather mites in wild birds, and in domestic species feather damage and some skin lesions are the worst effects. Some birds may undertake feather-pulling and others lose condition, but unusual densities of mites are frequently a prerequisite (Proctor 2003). Feather mites have been noted to reach high levels in kiwi, but this has been established *post mortem* and the consequences for the living bird are only speculative.

Temporary/facultative ectoparasites
Trombiculid mites
The trombiculid mite *Guntheria* (*Derrickiella*) *apteryxi*, found on *Apteryx mantelli*, is the larval stage of a free-living mite, the adult and other post-larval stages of which are unknown. These larval mites feed on host blood; such trophic behaviour can be harmful (Kettle 1990), particularly if large numbers of mites are present simultaneously. The consequences are blood loss, irritation and dermatitis, which affect the feeding behaviour of the host as well as its general well-being. Many trombiculid mites are implicated in disease transmission (Kettle 1990). The mite *Ornithonyssus bursa*, a common ornithophilic species, together with a blood-feeding hemipteran (Cimicidae), were found to have an effect on the reproductive success of swallow hosts, although more specifically on the number of broods reared in a season as opposed to clutch and brood sizes (de Lope and Møller 1993).

Species of *Guntheria* are usually found on small mammals, especially rodents (including the Pacific rat, *Rattus exulans*), although *Guntheria domrowi* (Brennan, 1965) has been collected regularly from various waders (rails) in the central Pacific (Domrow 1978), while other species have been collected from birds in Australia (Domrow 1974). Examination of ectoparasites collected by I. Castro from 32 kiwi (*Apteryx mantelli*) yielded six birds with *Guntheria* (*Derrickiella*) *apteryxi*, one with 27 mites and the others each with 1–5 mites. This trombiculid has also been taken from a South Island kiwi (Table 1). Thus, kiwi are possibly regular hosts for this mite and are not necessarily infested when they come within the range of *R. exulans* or

Table 1 Ectoparasites collected from kiwi in New Zealand. Data taken from new records listed in this paper, in addition to records in: Gaud & Atyeo (1970) and Bishop (1985) for feather mites; Pilgrim & Palma (1982), Palma (1991) and Palma & Price (2004) for chewing lice; Smit (1979) for fleas.

Host	Parasite
Apteryx australis Brown kiwi[1]	*Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwilichus delosikyus* Gaud & Atyeo, 1970 (feather mite)
Apteryx australis australis South Island brown kiwi	*Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwilichus cryptosikyus* Gaud & Atyeo, 1970 (feather mite) *Ixodes anatis* Chilton, 1904 (tick) *Apterygon dumosum* Tandan, 1972 (chewing louse) *Rallicola* (*Aptericola*) *gadowi* Harrison, 1915 (chewing louse)
Apteryx australis lawryi Stewart Island brown kiwi	*Kiwialges palametrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwilichus cryptosikyus* Gaud & Atyeo, 1970 (feather mite) *Ixodes anatis* Chilton, 1904 (tick) *Apterygon dumosum* Tandan, 1972 (chewing louse) *Rallicola* (*Aptericola*) *gadowi* Harrison, 1915 (chewing louse) *Parapsyllus nestoris nestoris* Smit, 1965 (flea)[2]
Apteryx rowi Okarito brown kiwi	*Apterygon okarito* Palma & Price, 2004 (chewing louse) *Rallicola* (*Aptericola*) *gadowi* Harrison, 1915 (chewing louse)
Apteryx mantelli North Island brown kiwi	*Kiwialges palametrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Guntheria* (*Derrickiella*) *apteryxi* Loomis & Goff, 1983 (trombiculid mite) *Haemaphysalis longicornis* Neumann, 1901 (tick) *Ixodes anatis* Chilton, 1904 (tick) *Apterygon mirum* Clay, 1961 (chewing louse) *Rallicola* (*Aptericola*) *rodericki* Palma, 1991 (chewing louse) *Pygiopsylla phiola* Smit, 1979 (flea) *Nosopsyllus fasciatus* (Bosc, 1800) (flea) *Pulex irritans* Linnaeus, 1758 (flea)
Apteryx haastii Great spotted kiwi	*Kiwialges haastii* Bishop, 1985 (feather mite) *Kiwialges palametrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwilichus cryptosikyus* Gaud & Atyeo, 1970 (feather mite)[3] *Guntheria* (*Derrickiella*) *apteryxi* Loomis & Goff, 1983 (trombiculid mite) *Apterygon hintoni* Clay, 1966 (chewing louse) *Rallicola* (*Aptericola*) *gracilentus* Clay, 1953 (chewing louse) *Ctenocephalides felis felis* (Bouché, 1835) (flea)
Apteryx owenii Little spotted kiwi	*Kiwialges palametrichus* Gaud & Atyeo, 1970 (feather mite) *Kiwialges phalagotrichus* Gaud & Atyeo, 1970 (feather mite) *Apterygon dumosum* Tandan, 1972 (chewing louse) *Rallicola* (*Aptericola*) *gadowi* Harrison, 1915 (chewing louse) *Rallicola* (*Aptericola*) *pilgrimi* Clay, 1972 (chewing louse) *Parapsyllus longicornis* (Enderlein, 1901) (flea)[4]

1 Gaud & Atyeo (1970) recorded one sample of *Kiwialges phalogotrichus* from Stewart Island but no locality is given for the *Kiwilichus delosikyus* material, so no subspecies name can be given to the host.
2 Found in *Apteryx australis lawryi* nest.
3 Sales (2005) incorrectly gave the genus as *Kiwialges*, and also omitted *Kiwilichus delosikyus*.
4 Found in *Apteryx owenii* nest.

Table 2 Numbers of ticks (*Ixodes anatis*) on 32 specimens of A*pteryx mantelli*, Ponui Island.

	Females	Males	Nymphs	Larvae
Total	414	466	1044	1253
Range	0–52	0–36	1–111	3–104
Prevalence	31/32	31/32	32/32	32/32
Mean intensity ± SD	13.4 ±13.8	15.03 ±10.01	32.3 ±28.9	39.2 ±32.5

other rodents. Nevertheless, rodents may use kiwi dens and burrows opportunistically and bring the mites into close proximity with kiwi.

Fleas

Parapsyllus nestoris nestoris has been collected only in the southern half of the South Island and is the only member of the genus that occurs on landbirds. There was only one record of one male from a Stewart Island brown kiwi (Smit 1979), but 11 further *P. n. nestoris* were collected from two occupied nests (see above, under 'Material examined'). All other fleas reported here represent new host records. Two adults of *Parapsyllus longicornis* were found in a nest of a little spotted kiwi, *Apteryx owenii*; this flea is very common and occurs on a large number of different seabird hosts (with one record from a rodent) throughout the North and South Islands (Smit 1979).

Rodents are the principal hosts of *Pygiopsylla phiola*, with Norway rat (*Rattus norvegicus*) represented most frequently in collections of the flea; there are fewer records from *Rattus exulans*, and records from the black (or ship) rat (*Rattus rattus*) are rare (Smit 1979). *Pygiopsylla phiola* was introduced from Australia and occurs only in the northern half of New Zealand and in the Chatham Islands, and has also been taken from humans (Smit 1979). Among the 32 kiwi examined by I. Castro, nine had one or two fleas, but one female bird had 120 fleas (68 females, 52 males) on its body, an extraordinary number. This host–parasite association may reflect either the use of kiwi burrows by the regular hosts of the fleas, or the use by the kiwi of burrows previously occupied by other species.

The cat flea (*Ctenocephalides felis felis*) and the rat flea (*Nosopsyllus fasciatus*) are cosmopolitan species with a wide host range. While also cosmopolitan, *Pulex irritans* (usually designated as the human flea) has a much narrower host range in New Zealand – principally humans and the domestic pig, with the dog and Norway and ship rats as occasional hosts (Smit 1979). The record of *P. irritans* on a kiwi is difficult to explain as the host is not normally peridomestic.

The role of fleas as vectors of bacteria or as intermediate hosts for tapeworms is well known (Lewis 1993). In New Zealand, the cat flea is an established vector of *Rickettsia felis* (Kelly *et al.* 2004), implying that kiwi are encountering potential dangers to their well-being. Further, fleas cannot be discounted as intermediate hosts of blood-borne protozoa, because at least one species, *Xenopsylla trispinis* Waterston, 1911, is strongly suspected to function as such in conjunction with an argasid tick for the blood parasite *Hepatozoon atticorae* in South African cliff swallows (Bennett *et al.* 1992).

Blood-feeding Diptera

There are no records of mosquitoes feeding on kiwi (A.E. Snell, pers. comm. October 2009), nor have Simuliidae or other blood-feeding Diptera been observed taking a meal from kiwi. It would, however, be very surprising if this was not the case, given the wide distribution and diurnal, crepuscular or nocturnal activity of such flies (Crosskey 1990; Service 1993), and the fact that many species in New Zealand are ornithophilic (Allison *et al.* 1978; Derraik & Snell 2004; Massey *et al.* 2007).

Ticks

Despite a small number of aberrant host records on Anatidae, *Ixodes anatis* is a kiwi-specific tick, and can occur in large numbers on some birds. Nuttall (1916) reported the comments of a collector who found the ticks 'on young kiwis about the ears and top of the head' and on 'the base of the rudimentary wings in old birds'. Morgan (2008) also frequently found ticks around the head of birds, 'including the ear canals'.

Myers (1924) reported that specimens of kiwi were 'repeatedly caught by dogs in the North Auckland Peninsula and [were] frequently found to carry a heavy infestation of ticks', but he provided no quantitative data. The overall mean number (±SD) of ticks per bird from 32 kiwi (*Apteryx mantelli*: 17 males, 8 females and 7 juveniles) collected in March 2004 on Ponui Island in the Hauraki Gulf, with all stages considered, was 97.8 ±56.8 (range 17–231) (Table 2).

The effects of tick infestations on kiwi have not been characterised, and Morgan (2008) did not identify any deleterious effects. Ticks can affect hosts in many ways, including blood loss and subsequent anaemia, as well as toxicoses and paralysis, together with transmission of a range of viral, bacterial and protozoan pathogens. These combined effects are immensely costly to the livestock industry, but also impinge on wildlife and human health (Sonenshine 1993).

Many ticks were found on kiwi infected with *Babesia kiwiensis* (Peirce *et al.* 2003), and it was surmised that the tick may be a vector. Later, *B. kiwiensis* DNA was found in a tick taken from an infected bird (Jefferies *et al.* 2008), but this was interpreted with caution as it did not necessarily imply a life-cycle contribution on the part of the tick. Peirce *et al.* (2003) noted that kiwi chicks carry large burdens of ticks soon after hatching, and blood-borne parasites remain in circulation for many months, thus making them available to feeding ticks. Furthermore, female birds in particular are sedentary during breeding, thus providing greater opportunity for ticks to acquire and later pass on haematozoa.

It is possible that tick burdens of the size shown in Table 2 could have deleterious effects on kiwi, at the very least affecting health and influencing growth rate or, at worst, causing death in young birds. A mean intensity of around 28 adult *Haemaphysalis longicornis* was sufficient to cause deleterious effects in sheep (Heath *et al.* 1977). The presence of external and internal parasites, and the chance of acquisition of blood-borne pathogens, indicate that there are numerous factors threatening kiwi populations in addition to predation. Dumbleton (1961) found a specimen of *Ixodes anatis* in the faeces of a domestic cat on Little Barrier Island. There are no records of *I. anatis* on cats (or any other mammals for that matter), although they do commonly acquire other ticks, such as *H. longicornis*. Dumbleton's finding is most likely evidence of predation rather than grooming on the part of a tick-infested cat, as that mammal and others are causing a serious decline in kiwi numbers (McLennan *et al.* 1996).

Kiwi tick: *Ixodes anatis*

Ixodes anatis has been included in the subgenus *Sternalixodes* by Clifford *et al.* (1973), a taxon that is confined to the Australian (also known as the Australasian) zoogeographic region and comprises nine species shared between New Zealand, Australia and New Guinea (Homsher *et al.* 1988). These species share some structural features, a relatively narrow geographic range and some male behavioural similarities, although *I. anatis* stands alone in that respect. It is noteworthy that the primary (and sometimes only) hosts of all but *I. anatis* are various species of mammal, adding further to the kiwi's 'honorary mammal' status (see below).

Distribution

The kiwi tick occurs throughout New Zealand (Fig. 1), although collection records possibly reflect the intensity with which some kiwi populations are monitored and the birds handled. Not every northern locality has been marked on the map so as to reduce overlapping of points.

Most collections of ticks in the North Island were from north of Auckland, and include Whangarei, Tangiteroria,

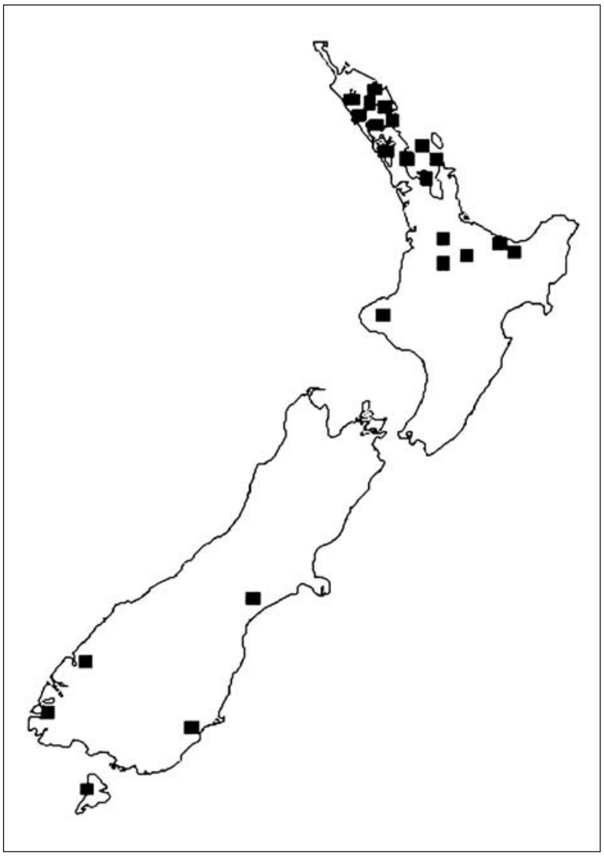

Fig. 1 Locality records for *Ixodes anatis*.

Table 3 Frequency of occurrence of *Ixodes anatis* for each month and each stage, independent of absolute numbers of ticks. Records include data from Chilton (1904) for the grey duck, and from Nuttall (1916) and Dumbleton (1953) for kiwi, as well as new records listed in this paper. Some literature records are excluded because the month of collection was not given. The number of times kiwi have been examined in a particular month are also given.

Stage/sex	J	F	M	A	M	J	J	A	S	O	N	D
Female	1	5	7	1	2	5	1	1	2	1	0	3
Male	0	3	3	1	3	4	2	0	1	0	0	1
Nymph	1	4	3	1	2	8	4	1	3	1	0	3
Larva	0	2	3	2	0	4	1	1	1	2	0	1
Number of records each month	3	9	8	1	4	10	3	1	2	4	0	3

Dargaville, Rarewarewa, Purua, Kaeo, Kaipara, Waipoua, Bay of Islands, Tiritiri Matangi Island, Little Barrier Island and Ponui Island, as well as Coromandel, with multiple records from many of these localities. There are also records from around Hamilton and Otorohanga, in addition to Rotorua, Whakatane and Waimana in the Bay of Plenty, and Taranaki. In the South Island, ticks have been collected from ducks in Ashburton and Mosgiel, and from kiwi in Dusky Sound and Clinton Valley in Fiordland; there are further records from kiwi in Mason Bay, Stewart Island.

Seasonal activity

There have been neither long-term studies of tick infestation of kiwi, nor regular sampling of a defined host population. Neither have nesting burrows or other hiding places been systematically searched for resting ticks. For these reasons, seasonal activity patterns can only be assumed by analysis of the frequency with which each life-cycle stage appears in the available preserved material. Such material suffers from being irregularly collected and fragmented, and is possibly incomplete in that rarely are all ticks present on a host removed, especially small, inconspicuous larvae (with the exception of the data shown in Table 2). Table 3 has been constructed from published records and preserved material without using actual counts, as these could be biased in favour of more readily seen stages. In addition, as there are no records of the number of non-infested kiwi that have been examined, it is impossible to know how many birds were examined in each time period. The absence of a stage in a given month, e.g. November, indicates that there are no records of kiwi with ticks in that month. For most months of the year there are fewer than five records, so the data in Table 3 should be interpreted with caution.

Biology

Despite the lack of direct evidence, there is no reason to suspect that *Ixodes anatis* is anything other than a three-host tick. In other words, each feeding stage spends a period off the host (once engorged with blood), during which it moults (larva into nymph, and nymph into adult) or lays eggs (adult female). Newly hatched larvae and newly moulted, unfed stages locate a host, attach to it and feed. With a presumed endophilous nidicolous species (Sonenshine 1993) such as *I. anatis*, it is possible, but not always likely, that the same bird acts as host for each individual feeding stage, whereas in non-nidicolous species (such as *Haemaphysalis longicornis*) that are widespread in the field, different individual animals of the same host species or hosts of different species may be fed upon.

Endophilous nidicolous ticks live in the nest, burrow or other habitation of their hosts, rather than on the open ground nearby (Sonenshine 1993). Kiwi often share burrows and use a large number of dens scattered throughout their home range. Generally, they move to a different burrow each day and often return to dens they have used before (McLennan *et al.* 1987). Birds thereby maintain regular contact with the ticks and give ticks the opportunity to feed, moult, mate and lay eggs in dens without the risk of undue periods of starvation or reduced reproductive success.

No kiwi ticks have been observed in copulation on their hosts. This is not surprising, as a general defining characteristic of the genus *Ixodes* is that copulation always takes place off the host (Varma 1993). However, Moorhouse (1966) observed *Ixodes holocyclus* Neumann, 1899, a species in the same subgenus (*Sternalixodes*) as *Ixodes anatis*, in copulation on the host. Furthermore, Moorhouse (1966) and Moorhouse & Heath (1975) recorded male *Ixodes* apparently attempting to feed on engorged females while on the host and leaving scars on the female integument as evidence of this. Among the eight species of female ticks observed by Moorhouse & Heath (1975) to bear feeding/probing scars from males, six were Australian and belong in the subgenus *Sternalixodes*. The 414 females of *I. anatis* collected from Ponui Island kiwi were examined for possible evidence of male probing, and three fully engorged specimens were found to bear one scar each that was similar, but not identical, to those described by Moorhouse (1966) and Moorhouse & Heath (1975). The scars were not around the genital aperture, but more distal, and even though scars from mechanical injury are rare in ticks (Moorhouse & Heath 1975), there is a possibility that this was their origin.

In the absence of any compelling evidence to the contrary, an intriguing question is: why are male and female ticks found in approximately equal numbers on kiwi (Table 2) when they mate off the host? The answer could be that sexual activity between ticks takes place in daylight hours, when kiwi rest in hollow logs or other natural dens. Male ticks may seek teneral females within the den at this time, and these (and other unfed stages) can then readily attach to a host. Two of the 466 male ticks collected from kiwi on Ponui Island, as well as two from a Northland site, had what could be remnants of a spermatophore in the genital aperture, but the structures could not be confirmed. No female ticks examined had any evidence of spermatophores in the genital aperture. Collectively, these observations suggest that *Ixodes anatis* follows the general *Ixodes* pattern in mating off the host and that it does not exhibit *Sternalixodes* on-host mating behaviour as described by Moorhouse & Heath (1975).

Tick activity in relation to kiwi reproductive biology

Sales (2005) summarised knowledge of kiwi reproductive biology, noting that egg-laying occurred between midwinter and mid-spring, followed by an average 80-day incubation period (range 75–85 days). Through the application of some arbitrary values, it is possible to examine where tick seasonality and kiwi reproductive biology overlap. By using the solar year to define the seasons, the mid-point of the winter solstice in the southern hemisphere can be calculated to fall on or about 7 August, and the mid-point of the spring equinox on or about 7 November. Thus, for an 80-day incubation period, an egg laid in midwinter would hatch around 26 October, and one in mid-spring around 26 January. Young kiwi are still considered as juvenile up to 50 or 60 days after hatching, remaining in the nest or returning every day during this period (Sales 2005). This means that the seasonal activity of ticks as shown in Table 3 has a reasonable approximation to the timing of the reproductive biology and early development of kiwi, with ticks occurring more frequently in months when chicks are likely to be in close contact with the nest. Dens or nests would provide a relatively stable microclimate for tick development. There appear to have been no systematic examinations of nest material from kiwi burrows to determine whether or not ticks are present and, if so, the size and composition of tick populations therein.

Cattle tick: *Haemaphysalis longicornis*

New Zealand has only one exotic livestock tick, *Haemaphysalis longicornis*, which has been present for over a century, infesting a wide range of mammal and bird hosts throughout most of the North Island, and a restricted part (Takaka, Golden Bay) of the South Island (Myers 1924; Heath 1985; Heath *et al.* 1988). As kiwi regularly move between forest remnants (Potter 1990), crossing adjacent pasture in the process, it is perhaps not surprising that they should encounter *H. longicornis.* This is of concern because of the wide range of other bird hosts on which the tick also feeds, as these could be a source of tick-borne pathogens to kiwi.

Myers (1924) discussed the possibility of *Haemaphysalis longicornis* (as *Haemaphysalis bispinosa*) occurring on kiwi, and reported that he had examined large numbers of ticks from the birds and that they were, without exception, *Ixodes anatis*. He concluded that, 'None of these bird-infesting … ticks have so far, to my knowledge, been found on farm-animals … nor has *H. bispinosa* occurred on the kiwi'.

Of 78 published and new records of ticks taken from *Apteryx mantelli* and presented here, 11 were for *Haemaphysalis longicornis*, with nymphs (4 records) and larvae (7 records) unevenly represented. All records were from localities north of 38° 00'S where the tick is common and widespread.

Haemaphysalis longicornis has actual and potential competence to be a vector for a number of important pathogens of livestock, companion animals and humans (Heath 2002), including *Babesia* spp. It is noteworthy that no link between kiwi haematozoa and *H. longicornis* has hitherto been suggested.

Seabird tick: *Ixodes eudyptidis*

Bishop & Heath (1998) listed a record of *Ixodes eudyptidis* from a kiwi (from Whangarei), but on later examination the specimens were found to be those of *Ixodes anatis*. It would perhaps not be unusual for *I. eudyptidis* to feed on kiwi, as it is found on a large number of seabird hosts (Bishop & Heath 1998) and can also feed on mammals (Heath 2006), but there are no confirmed records on kiwi.

Significance of the parasites as indicators of evolutionary relationships

Gaud & Atyeo (1970) concluded that the four new species of feather mites they described from kiwi, while also necessitating the erection of two new genera, did not project much light on the real affinities of the Apterygidae, because species of the subfamily Analginae are found on many orders of birds. The only fact of note was that no species of Analginae had been found on other ratites (Gaud & Atyeo 1970). The description of *Kiwialges haastii* from *Apteryx haastii* by Bishop (1985) was notable for providing the only monoxenous species of feather mite on kiwi, but additional host records for the other species of Analgidae provided by Bishop (1985) added nothing to the view held by Gaud & Atyeo (1970).

Regarding chewing lice, Harrison (1915) pointed out that the genus *Rallicola* is confined to the rails (Rallidae). He also concluded that kiwi had no affinities with other ratites such as the ostrich, emu and rhea, but were more closely related to the rails. Clay (1953) discussed this point and did not reject it, confining herself principally to an examination of the possible phylogenetic origins of the genus *Rallicola*. Clay (1972) examined the host–parasite relationships of the three *Rallicola* species from kiwi. Palma (1991) described a fourth species of *Rallicola* confined to the North Island brown kiwi. The description by Palma & Price (2004) of a new species of the only endemic New Zealand chewing louse genus, *Apterygon*, brought the number of species to four and also showed that among the five species of kiwi (one with two subspecies), three had species of *Apterygon* that were confined to them alone (Palma & Price 2004). These records demonstrate endemicity, but offer few clues to kiwi phylogeny, apart from showing a close relationship between the North Island brown kiwi and the Okarito brown kiwi (Palma & Price 2004). Recent cladistic studies have not completely resolved the phylogeny of modern birds. Depending upon whether morphological or molecular analyses are used, the Apterygidae are either sister to all other living ratites or are grouped with the emu and cassowaries (Bourdon 2007). The ectoparasite fauna of kiwi does not provide supporting evidence for either of these views.

Kiwi have been termed ‘honorary mammals’ for a number of physiological reasons (Calder 1978), but also for some of the parasites they carry. Of these, the roundworm *Toxocara cati* (Zeder, 1800) is the most notable (McKenna 1998), but both the flea *Pygiopsylla phiola* and the trombiculid mite *Guntheria* (*Derrickiella*) *apteryxi* could be used in support of the same contention. The flea is almost exclusively a rodent parasite, and species of *Guntheria* are most commonly found on mammals, including rodents and *Rattus* spp., with two species from *Rattus exulans*, the Pacific rat (Goff 1980). Martin *et al.* (2007) found that kiwi are more reliant on olfactory and tactile information than visual information, and that this state is also found in nocturnal mammals such as rodents, adding further confirmation to the ‘honorary mammal’ status. This is further reinforced by the taxonomic relationship between *Ixodes anatis* and eight other tick species that infest only mammals in Australia and New Guinea (Homsher *et al.* 1988), although this relationship seems to have little evolutionary or phylogenetic relevance except what might otherwise be elucidated through molecular genetics.

It could be argued that these examples of host–parasite relationship merely show that the parasites are adaptable, but perusal of checklists of external and internal parasites of birds and mammals in New Zealand (McKenna 1997, 1998; Bishop & Heath 1998; Tenquist & Charleston 2001) reveals very little evidence of ‘host switching’. Among mammalian nematodes, only *Toxocara cati* has been found in a bird (a kiwi; McKenna 1997, 1998), and among the Siphonaptera there are rare records of mammal fleas on birds (*Ctenocephalides canis*, *Pulex irritans*, *Pygiopsylla hoplia*, *Xenopsylla cheopis*) and bird fleas on mammals – mostly humans (*Pagipsylla galliralli*, *Parapsyllus magellanicus*, *Parapsyllus nestoris antichthones*, *Parapsyllus longicornis*) (Bishop & Heath 1998; Tenquist & Charleston 2001).

Similarly, ornithophilic *Ornithonyssus* mites are occasionally found on humans and other mammals (Tenquist & Charleston 2001), but in neither these nor the earlier mentioned instances is the level of infestation, or number of hosts affected, of the magnitude described here for *Pygiopsylla phiola* and *Guntheria apteryxi* on kiwi.

Conclusions

Ectoparasites confined to kiwi and occasionally encountered by those hosts have been reviewed. Although some biological data are available or can be inferred for *Ixodes anatis*, there is still much that can be learned about this tick species. Even less is known about prevalence and distribution of the other ectoparasites.

Kiwi should be systematically surveyed for ectoparasites throughout their range and throughout the year, and closer attention given to dens and nests. Experimental work on the vector competency of *Ixodes anatis* and *Haemaphysalis longicornis*, with respect at least to haematozoa, along with some consideration of other potential tick- or flea-borne pathogens, would be valuable. Studies of *I. anatis* under laboratory conditions would provide more accurate data on the duration of life-history stages and provide an opportunity for the study of tick physiology and reproduction, while molecular genetics may clarify phylogenetic associations with other tick species.

Acknowledgements

The following colleagues are gratefully thanked for their help in providing material or information for this paper: Dallas Bishop (AsureQuality, Upper Hutt, New Zealand); Richard Bowman (Environment Southland, Invercargill, New Zealand); Isabel Castro (Massey University, Palmerston North, New Zealand), who was especially generous with her data; Gary Clark (Labnet, Invermay, New Zealand); Richard Jakob-Hoff (Auckland Zoological Gardens, Auckland, New Zealand); Ricardo Palma (Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand); and the late R.L.C. Pilgrim (University of Canterbury, Christchurch, New Zealand). Ricardo Palma is especially thanked for additional help throughout. An anonymous referee provided useful comments that improved the text. This study was funded by the New Zealand Foundation for Research, Science and Technology (FRST) as part of the wildlife biodiversity component of the Better Border Biosecurity (B3) programme.

References

Allison, F.R., Desser, S.S. and Whitten, L.K. (1978). Further observations on the life cycle and vectors of the haemosporidian *Leucocytozoon tawaki* and its transmission to the Fiordland crested penguin. *New Zealand Journal of Zoology* 5: 371–374.

Bennett, G.F., Earlé, R.A. and Penzorn, B.L. (1992). *Ornithodoros peringueyi* (Argasidae) and *Xenopsylla trispinis* (Siphonaptera), probable intermediate hosts of *Hepatozoon atticorae* of the South African cliff swallow, *Hirundo spilodera*. *Canadian Journal of Zoology* 70: 188–190.

Bishop, D.M. (1985). *Kiwialges haastii* n.sp., a feather mite (Acari: Analgesidae) from the great spotted kiwi, *Apteryx haastii* Potts, 1872 (Aves: Apterygidae); with a key to species of *Kiwialges*, and new host records. *New Zealand Journal of Zoology* 11: 233–237.

Bishop, D.M. and Heath, A.C.G. (1998). Checklist of ectoparasites of birds in New Zealand. *Surveillance* 25 (Special Issue): 13–31.

Bourdon, E. (2007). A new phylogeny of extant ratite birds. *Journal of Morphology* 268: 152 (Abstract).

Brennan, J.M. (1965). A small collection of chiggers (Acarina: Trombiculidae) from the north central Pacific. *Journal of Parasitology* 51: 888–892.

Brennan, J.M. and Amerson, A.B. (1971). Six new species and additional records of chiggers from the central Pacific (Acarina: Trombiculidae). *Journal of Parasitology* 57: 1311–1317.

Calder III, W.A. (1978). The kiwi. *Scientific American* 238: 132–142.

Chilton, C. (1904). A species of *Ixodes* parasitic on the grey duck. *Transactions and Proceedings of the New Zealand Institute* 36: 201–202.

Clay, T. (1953). Revisions of the genera of Mallophaga. – I. The *Rallicola*-complex. *Proceedings of the Zoological Society of London* 123: 563–587.

Clay, T. (1972). The species of *Rallicola* (Insecta: Phthiraptera: Ischnocera) parasitic on kiwis (*Apteryx*). *New Zealand Journal of Science* 15: 70–76.

Clayton, D.H., Adams, R.J. and Bush, S.E. (2008). Phthiraptera, the chewing lice. Pp. 515–526. *In*: Atkinson, C.T., Thomas, N.J. and Hunter, D.B. (*eds*) *Parasitic diseases of wild birds*. Ames, IA: Wiley-Blackwell. xii + 595 pp.

Clifford, C.M., Sonenshine, D.E., Keirans, J.E. and Kohls, G.M. (1973). Systematics of the subfamily Ixodinae (Acarina: Ixodidae). 1. The subgenera of *Ixodes*. *Annals of the Entomological Society of America* 66: 489–500.

Crosskey, R.W. (1990). *The natural history of blackflies*. Chichester: John Wiley & Sons. ix + 711 pp.

de Lope, F. and Møller, A.P. (1993). Effects of ectoparasites on reproduction of their swallow hosts: a cost of being multi-brooded. *Oikos* 67: 557–562.

Derraik, J.G.B. and Snell, A.E. (2004). Notes on daytime biting catches of mosquitoes (Diptera: Culicidae) in native forest sites in the Auckland region. *The Weta* 28: 24–29.

Domrow, R. (1974). Miscellaneous mites from Australian vertebrates. 1–48. *Proceedings of the Linnean Society of New South Wales* 99: 15–35.

Domrow, R. (1978). New records and species of chiggers from Australasia (Acari: Trombiculidae). *Journal of the Australian Entomological Society* 17: 75–90.

Dumbleton, L.J. (1953). The ticks (Ixodoidea) of the New Zealand sub-region. *Cape Expedition Series, Bulletin* 14: 1–35.

Dumbleton, L.J. (1961). The ticks (Acarina: Ixodoidea) of sea birds in New Zealand waters. *New Zealand Journal of Science* 4: 760–769.

Gaud, J. and Atyeo, W.T. (1970). Acariens Sarcoptiformes plumicoles (Analgoidea) parasites des Apterygiformes. *Acarologia* 12: 402–414.

Goff, M.L. (1980). The genera *Guntheria* and *Ornithogastia* (Acari: Trombiculidae) in Papua New Guinea. *Pacific Insects* 22: 35–77.

Harrison, L. (1915). Mallophaga from *Apteryx*, and their significance; with a note on the genus *Rallicola*. *Parasitology* 8(1): 88–100.

Heath, A.C.G. (1985). Ticks (*Haemaphysalis longicornis*). Pp. 23–29. *In*: Charleston, W.A.G. (*ed.*) *Ectoparasites of sheep in New Zealand and their control.* Palmerston North: Sheep and Beef Cattle Society of the New Zealand Veterinary Association. vii + 79 pp.

Heath, A.C.G. (2002). Vector competence of *Haemaphysalis longicornis* with particular reference to blood parasites. *Surveillance* 29(4): 12–14.

Heath, A.C.G. (2006). Observations on *Ixodes eudyptidis* Maskell (Acari: Ixodidae), *Ornithodoros capensis* Neumann (Acari: Argasidae), and other tick parasites of sea birds in New Zealand. *Systematic and Applied Acarology* 11: 131–140.

Heath, A.C.G., Pearce, D.M., Tenquist, J.D. and Cole, D.J.W. (1977). Some effects of a tick infestation (*Haemaphysalis longicornis*) on sheep. *New Zealand Journal of Agricultural Research* 20: 19–22.

Heath, A.C.G., Tenquist, J.D. and Bishop, D.M. (1988). Bird hosts of the New Zealand cattle tick, *Haemaphysalis longicornis*. *New Zealand Journal of Zoology* 15: 585–586.

Homsher, P.J., Keirans, J.E., Robbins, R.G., Irwin-Pinkley, L. and Sonenshine, D.E. (1988). Scanning electron microscopy of ticks for systematic studies: structure of Haller's organ in eight species of the subgenus *Sternalixodes* of the genus *Ixodes* (Acari: Ixodidae). *Journal of Medical Entomology* 25: 348–353.

Jefferies, R., Down, J., McInnes, L., Ryan, U., Robertson, H., Jakob-Hoff, R. and Irwin, P. (2008). Molecular characterisation of *Babesia kiwiensis* from the Brown kiwi (*Apteryx mantelli*). *Journal of Parasitology* 94(2): 557–560.

Kelly, P.J., Meads, N., Theobald, A., Fournier, P.E. and Raoult, D. (2004). *Rickettsia felis*, *Bartonella henselae*, and *B. clarridgeiae*, New Zealand. *Emerging Infectious Diseases* 10: 967–968.

Kettle, D.S. (1990). *Medical and veterinary entomology.* Wallingford: CAB International. 658 pp.

Lewis, R.E. (1993). Fleas (Siphonaptera). Pp. 529–573. *In*: Lane, R.P. and Crosskey, R.W. (*eds*) *Medical insects and arachnids.* London: Chapman & Hall. xv + 723 pp.

Loomis, R.B. and Goff, M.L. (1983). A new species of *Guntheria* (Acari: Trombiculidae) from New Zealand. *Journal of Medical Entomology* 20: 87–89.

McKenna, P.B. (1997). Checklist of helminth parasites of terrestrial mammals in New Zealand. *New Zealand Journal of Zoology* 24: 277–290.

McKenna, P.B. (1998). Checklist of helminth and protozoan parasites of birds in New Zealand. *Surveillance* 25 (Special Issue): 3–12.

McLennan, J.A., Potter, M.A., Robertson, H.A., Wake, G.C., Colbourne, R., Dew, L., Joyce, L., McCann, A.J., Miles, J., Miller, P.J. and Reid, J. (1996). Role of predation in the decline of the kiwi, *Apteryx* spp., in New Zealand. *New Zealand Journal of Ecology* 20: 27–35.

McLennan, J.A., Rudge, M.R. and Potter, M.A. (1987). Range size and denning behaviour of brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay. *New Zealand Journal of Ecology* 10: 97–107.

Martin, G.R., Wilson, K.-J., Wild, J.M., Parsons, S., Kubke, M.F. and Corfield, J. (2007). Kiwi forego vision in the guidance of their nocturnal activities. *Plos ONE* [online journal] 2(2), (published 7 February 2007), www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0000198#s1. Accessed March 2010.

Maskell, W.M. (1897). On some tick-parasites of the kiwi. *Transactions and Proceedings of the New Zealand Institute* 29: 290–293.

Massey, B., Gleeson, D.M., Slaney, D. and Tompkins, D.M. (2007). PCR detection of *Plasmodium* and blood meal identification in a native New Zealand mosquito. *Journal of Vector Ecology* 32: 154–156.

Moorhouse, D.E. (1966). Observations on copulation in *Ixodes holocyclus* Neumann and the feeding of the male. *Journal of Medical Entomology* 3: 168–171.

Moorhouse, D.E. and Heath, A.C.G. (1975). Parasitism of female ticks by males of the genus *Ixodes*. *Journal of Medical Entomology* 12: 571–572.

Morgan, K.J. (2008). *Kiwi first aid and veterinary care.* Wellington: Science & Technical Publishing, Department of Conservation. 103 pp.

Myers, J.G. (1924). The cattle tick (*Haemaphysalis bispinosa*). Investigations during 1923–24. *New Zealand Department of Agriculture Bulletin* 116: 1–105.

Nuttall, G.H.F. (1916). Notes on ticks. IV. Relating to the genus *Ixodes* and including descriptions of three new species and two new varieties. *Parasitology* 8: 294–337.

Palma, R.L. (1991). A new species of *Rallicola* (Insecta: Phthiraptera: Philopteridae) from the North Island brown kiwi. *Journal of the Royal Society of New Zealand* 21: 313–322.

Palma, R.L. and Price, R.D. (2004). *Apterygon okarito*, a new species of chewing louse (Insecta: Phthiraptera: Menoponidae) from the Okarito brown kiwi (Aves: Apterygiformes: Apterygidae). *New Zealand Journal of Zoology* 31: 67–73.

Peirce, M.A., Jakob-Hoff, R.M. and Twentyman, C. (2003). New species of haematozoa from Apterygidae in New Zealand. *Journal of Natural History* 37: 1797–1804.

Pilgrim, R.L.C. and Palma, R.L. (1982). A list of the chewing lice (Insecta: Mallophaga) from birds in New Zealand. *National Museum of New Zealand, Miscellaneous Series* 6: 1–32.

Potter, M.A. (1990). Movement of North Island and brown kiwi (*Apteryx australis mantelli*) between forest remnants. *New Zealand Journal of Ecology* 14: 17–24.

Proctor, H.C. (2003). Feather mites (Acari: Astigmata): ecology, behavior, and evolution. *Annual Review of Entomology* 48: 185–209.

Sales, J. (2005). The endangered kiwi: a review. *Folia Zoologica* 54(1–2): 1–20.

Service, M.W. (1993). Mosquitoes (Culicidae). Pp. 120–240. *In*: Lane, R.P. and Crosskey, R.W. (*eds*) *Medical insects and arachnids*. London: Chapman & Hall. xv + 723 pp.

Smit, F.G.A.M. (1979). The fleas of New Zealand. *Journal of the Royal Society of New Zealand* 9(2): 143–232.

Sonenshine, D.E. (1993). *Biology of ticks. Vol. 2*. New York: Oxford University Press. xvii + 465 pp.

Tenquist, J.D. and Charleston, W.A.G. (2001). A revision of the annotated checklist of ectoparasites of terrestrial mammals in New Zealand. *Journal of the Royal Society of New Zealand* 31: 481–542.

Varma, M.R.G. (1993). Ticks and mites (Acari). Pp. 597–658. *In*: Lane, R.P. and Crosskey, R.W. (*eds*) *Medical insects and arachnids*. London: Chapman & Hall. xv + 723 pp.