ISOLATION OF DERMATOPHYTES FROM DOGS AND CATS IN THE SOUTH OF ENGLAND FROM 1991-2017.

Sarah M. Long[1], Hope E. L. Carveth[1]*, Yu-Mei Chang[2], Dan G. O'Neill[3] and Ross Bond[1]

[1]Department of Clinical Sciences and Services, Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Herts AL9 7TA, U.K.

[2]Research Support Office, Royal Veterinary College, Royal College Street, London NW1 0TU, U.K.

[3]Department of Pathobiology and Population Sciences, Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Herts AL9 7TA, U.K.

*Present address: Cheshirepet, Manor Lane, Holmes Chapel, Cheshire CW4 8AB, U.K.

Corresponding author: Professor Ross Bond, Department of Clinical Sciences and Services, Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Herts AL9 7TA, U.K. rbond@rvc.ac.uk; 01707 666333.

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STRUCTURED ABSTRACT

Background Since the epidemiology of canine and feline dermatophytosis might evolve in response to chronological, sociological and ecological factors, we studied the occurrence of dermatophyte pathogens over 27 years subsequent to the last major UK survey.

Methods Dermatophyte culture submission records from dogs and cats to the Royal Veterinary College Diagnostic Laboratory in England between 1991 and 2017 were reviewed. Samples were routinely cultured aerobically at 26^{o}C for up to 4 weeks on Sabouraud's dextrose agar containing cycloheximide and chloramphenicol; dermatophytes were identified using conventional phenotypic methods.

Results Proportional isolation from cats (15.9 per cent of 1389) exceeded that of dogs (8.1 per cent of 2193) ($P<0.001$). Together, *Microsporum canis* and *Trichophyton mentagrophytes* accounted for 91.9 per cent (n=203) and 80.2 per cent (n=142) of isolations from cats and dogs, respectively. *M. canis* was more frequently ($P<0.001$) isolated from cats and dogs under 2 years of age. Dermatophytes were more frequent ($P\leq0.001$) in samples from first-opinion rather than referral practice, and from Jack Russell and Yorkshire terriers, and Persian and Chinchilla cats ($P\leq0.002$).

Conclusions *M. canis* and *T. mentagrophytes* remain the most common agents of canine and feline dermatophytosis in the south of England; continued clinical vigilance is required.

INTRODUCTION

Dermatophytosis (tinea, 'ringworm') is an infection of the hair, nail / claw or stratum corneum by keratinophilic fungi of the family *Arthrodermataceae* [1, 2] Traditionally, three genera of causal agents are identified by phenotypic characteristics (*Microsporum*, *Trichophyton, Epidermophyton*) but recent phylogenetic analyses have recognised four additional clades (*Lophophyton, Paraphyton, Nannizzia, Arthroderma*).[2] Reports indicate that superficial mycotic skin disease affects more than 20 per cent of the world's human population. [3] Many of the individual dermatophyte species are adapted to humans ('anthropophilic' species; for example, *M. audouinii*, *T. rubrum*, *T. tonsurans*) or other specific animal hosts ('zoophilic' species; for example, *M. canis* in cats, *T. verrucosum* in cattle) but these zoophilic species occasionally cause zoonotic disease in owners of companion animals and in livestock workers.[4, 5] Transfer of 'anthropophilic' dermatophytes from humans to companion animals is considered much less frequent.[6]

Whilst it is clear that the dermatophyte pathogens encountered will vary with the species of the mammalian host, there is also marked geographical variation, particularly in human medicine.[4, 7] For example, scalp dermatophytosis (tinea capitis) in humans is most often caused by *M. canis* in most parts of Asia and Europe, whereas *T. tonsurans* predominates in the Americas and UK.[7] In dogs, *M. gypseum* (syn. *N. gypsea* [2]) accounted for 44 per cent of 70 canine isolates over a ten year period in Louisiana, USA.[8] Sparkes et al. presented contrasting data in a compelling account of the epidemiological and diagnostic features of dermatophytosis in dogs and cats in the UK from 1956 to 1991.[9] Amongst 8349 samples submitted to the Mycology Diagnostic Service of the School of Veterinary Science, University of Bristol, *M. gypseum* accounted for only 3 out of 475 dog isolations.[9] In that U.K. study, *M. canis* accounted for 92 and 65 per cent of cat and dog isolates, respectively, whereas *T. mentagrophytes* accounted for 6 and 24 per cent of cat and dog isolates, respectively.[9]

In addition to the geographical factors mentioned above, a notable epidemiological feature of human dermatophytosis is the shift in the spectrum of dermatophyte species isolated over time due to population mobility and migration, socio-economic factors such as popularisation of footwear, and improvements in human hygiene.[7, 10] We reviewed dermatophyte culture submissions from dogs and cats in the south of England to the

Royal Veterinary College's Diagnostic Laboratory over the 27 years (1991-2017) subsequent to the study period of Sparkes *et al.*,[9] to determine whether the epidemiological features of dermatophytosis in these hosts were evolving. We speculated that the occurrence of dermatophyte pathogens in dogs and cats in recent years would be similar to those previously reported by Sparkes *et al.*[9] in view of geographical proximity of the two study centres and because dog and cat populations are likely to be less affected by the socio-economic and migratory factors that influence human health.

MATERIALS AND METHODS:

Ethics:

This retrospective study of archived data was approved by the Royal Veterinary College's Social Science Research Ethical Review Board (URN SR2017-1039).

Methods:

Results from canine and feline dermatophyte culture submissions (samples of scales, hairs or claws) to the Royal Veterinary College Diagnostic Laboratory in the south of England between 1991 and 2017 were extracted by retrospective review of laboratory records. Paper records in the form of laboratory notebooks were scrutinised for the period 1991 to 1996, whereas subsequent data were retrieved from an electronic laboratory information management system (LabVantage LVL 5.4, LabVantage Solutions Inc., New Jersey, U.S.A.). The species, breed, age, sex, date of submission, and whether the sample was from a first opinion or referral dermatology practice (Royal Veterinary College Queen Mother Hospital for Animals or dermatology specialists in private practice) were recorded, along with the final result of the dermatophyte culture. Samples were routinely cultured aerobically at 26^{o}C for up to 4 weeks on Sabouraud's dextrose agar (CM0041, Oxoid, Basingstoke, U. K.) containing 0.4 g/L cycloheximide and 0.05 g/L chloramphenicol (Dermasel selective supplement, Oxoid SR0075E, Basingstoke, U. K.). Dermatophytes were identified using conventional phenotypic methods, based on gross colonial and microscopical features, and requirements for growth.[11]

Statistical analyses

Frequencies of pathogens isolated and their proportions in dog and cat submissions and in association with signalment, type of practice, season and trends during the study period were compared using chi-squared tests using the Unistat v3.0 statistical software programme. Association with breed was determined by comparing the proportional isolation from dogs of a particular breed with isolation from all dogs that were known to be of another breed using the chi-squared test. Seasons were defined according to the meteorological calendar as winter (December-February); spring (March-May); summer (June-August); and autumn, (September-November) (https://www.metoffice.gov.uk). Statistical significance was set at $P < 0.05$.

RESULTS:

Dermatophyte isolation

During the study period, there were 2193 canine and 1389 feline submissions (Tables 1 and 2). Proportional dermatophyte isolation from feline submissions (221 of 1389, 15.9 per cent) exceeded ($P<0.001$) that of canine submissions (177 of 2193, 8.1 per cent).

Table 1. The number of dermatophyte culture submissions from dogs in first opinion and referral dermatology practices in the south of England, and the proportions from which *Microsporum canis* and *Trichophyton mentagrophytes* were isolated, for the period 1991 to 2017.

Years	**Submissions (first opinion / referral)**	**Dermatophyte isolations (% of submissions)**	***M. canis* isolations (% of submissions)**			***T. mentagrophytes* Isolations (% of submissions)**		
			Overall	First opinion	Referral	Overall	First opinion	Referral
1991-93	293 (38/255)	28 (9.6)	6 (2.0)	2 (5.3)	4 (1.6)	6 (2.0)	1 (2.6)	5 (2.0)
1994-96	351 (44/307)	36 (10.3)	12 (3.4)	3 (6.8)	9 (2.9)	16 (4.6)	3 (6.8)	13 (4.2)
1997-99	317 (79/238)	13 (4.1)	4 (1.3)	2 (2.5)	2 (0.8)	8 (2.5)	1 (1.3)	7 (2.9)
2000-02	194 (117/77)	22 (11.3)	16 (8.2)	11 (9.4)	5 (6.5)	3 (1.5)	2 (1.7)	1 (1.3)

2003-05	221 (174/47)	20 (9.1)	13 (5.9)	12 (6.9)	1 (2.1)	7 (3.2)	5 (2.9)	2 (4.3)
2006-08	309 (230/79)	30 (9.7)	9 (2.9)	8 (3.5)	1 (1.3)	20 (6.5)	16 (7.0)	4 (5.1)
2009-11	251 (130/121)	18 (7.2)	11 (4.4)	11 (8.5)	0 (0)	4 (1.6)	3 (2.3)	1 (0.8)
2012-14	160 (67/93)	5 (3.1)	1 (0.6)	1 (1.5)	0 (0)	2 (1.3)	2 (3.0)	0 (0)
2015-17	97 (31/66)	5 (5.1)	2 (2.1)	2 (6.5)	0 (0)	2 (2.1)	1 (3.2)	1 (1.5)
Total	**2193 (910/1283)**	**177 (8.1)**	**74 (3.4)**	**52 (5.7)**	**22 (1.7)**	**68 (3.1)**	**34 (3.7)**	**34 (2.7)**

Table 2. The number of dermatophyte culture submissions from cats in first opinion and referral dermatology practices in the south of England, and the proportions from which *Microsporum canis* and *Trichophyton mentagrophytes* were isolated, for the period 1991 to 2017.

Years	**Submissions (first opinion / referral)**	**Dermatophyte isolations (% of submissions)**	***M. canis* isolations (% of submissions)**			***T. mentagrophytes* Isolations (% of submissions)**		
			Overall	First opinion	Referral	Overall	First opinion	Referral
1991-93	132 (34/98)	31 (23.5)	26 (19.7)	10 (29.4)	16 (16.3)	3 (2.3)	3 (8.8)	0 (0)
1994-96	303 (116/187)	48 (15.8)	39 (12.9)	14 (12.1)	25 (13.4)	4 (1.3)	3 (2.6)	1 (0.5)
1997-99	332 (231/101)	41 (12.4)	23 (6.9)	15 (6.5)	8 (7.9)	11 (3.3)	9 (3.9)	2 (2.0)
2000-02	101 (62/39)	15 (14.9)	15 (14.9)	11 (17.7)	4 (10.3)	0 (0)	0 (0)	0 (0)
2003-05	118 (85/33)	24 (20.3)	22 (18.6)	19 (22.4)	3 (9.1)	2 (1.7)	2 (2.4)	0 (0)
2006-08	131 (106/25)	29 (22.1)	21 (16.0)	19 (17.9)	2 (8.0)	6 (4.6)	6 (5.7)	0 (0)
2009-11	115 (62/35)	17 (14.8)	15 (13.0)	13 (21.0)	2 (3.8)	1 (0.9)	1 (1.6)	0 (0)
2012-14	95 (50/45)	11 (11.6)	8 (8.4)	5 (10.0)	3 (6.7)	3 (3.2)	2 (4.0)	1 (2.2)
2015-17	62 (22/40)	5 (8.1)	3 (4.8)	3 (13.6)	0 (0)	1 (1.6)	0 (0)	1 (2.5)
Total	**1389 (768/621)**	**221 (15.9)**	**172 (12.4)**	**109 (14.2)**	**63 (10.1)**	**31 (2.2)**	**26 (3.4)**	**5 (0.8)**

Dermatophyte species

M. canis was the most frequently isolated species from both cats (172 of 221 positive cultures, 77.8 per cent) and dogs (74 of 177, 41.8 per cent) (Table 3). *T. mentagrophytes* was the second most frequently isolated species from both cats (31 of 221 positive cultures, 14.0 per cent) and dogs (68 of 177, 38.4 per cent) (Table 3). Thus, *M. canis* and *T. mentagrophytes* accounted for 91.9 per cent (203 of 221) and 80.2 per cent (142 of 177) of isolations from cats and dogs, respectively, and 86.7 per cent (345 of 398) of dermatophyte isolations in the study.

'Sylvatic dermatophytosis' refers to skin disease caused by acquisition of zoophilic species associated with wildlife, [9] namely *T. mentagrophytes* (whose zoophilic form is commonly associated with rodents [12]), *T. erinacei* (commonly from hedgehogs[13, 14]) and *M. persicolor* (syn. *N. persicolor*, [2] commonly from field and bank voles and mice[15-17].). These sylvatic species were more frequent in submissions from dogs (86 of 2193, 3.9 per cent) than cats (31 of 1389, 2.2 per cent) (P=0.007). Two of the sylvatic species, *T. erinacei* and *M. persicolor*, were infrequently isolated from dogs (11 isolations, 6.2 per cent of positive cultures; and 7 isolations, 4.0 per cent of positive cultures, respectively) but never from cats (Table 3).

The only other zoophilic dermatophyte isolated was *T. verrucosum* which was isolated from two dogs (1.1 per cent of positive cultures). The isolation of geophilic dermatophytes comprised infrequent recovery of *M. gypseum* (3 from cats [1.4 per cent of positive cultures], 8 from dogs [4.5 per cent of positive cultures]) and the closely related *M. fulvum* (syn. *N. fulva*, single isolate from a dog); *T. terrestre* was isolated from 7 cats (3.2 per cent of positive cultures) and 3 dogs (1.7 per cent of positive cultures). Mixed cultures were obtained from two dogs (*M. persicolor* and *T. terrestre*) and one cat (*M. canis* and *M. gypseum*).

Table 3. Species of dermatophytes isolated in samples obtained in first-opinion and referral dermatology practice from dogs and cats in the south of England between 1991 and 2017.

Dermatophyte isolated	**Isolations from dogs**			**Isolations from cats**			**Total (%)**
	Total (%)	**First opinion (%)**	**Referral (%)**	**Total (%)**	**First opinion (%)**	**Referral (%)**	

M. canis	74 (41.8)	52 (53.6)	22 (27.5)	172 (77.8)	109 (75.2)	63 (82.9)	246 (61.8)
T. mentagrophytes	68 (38.4)	34 (35)	34 (42.5)	31 (14.0)	26 (17.9)	5 (6.6)	99 (24.9)
T. erinacei	11 (6.2)	1 (1.0)	10 (12.5)	0	0	0	11 (2.8)
M. gypseum	8 (4.5)	4 (4.1)	4 (5.0)	3 (1.4)	1 (0.7)	2 (2.6)	11 (2.8)
M. persicolor	7 (4)	2 (2.1)	5 (6.3)	0	0	0	7 (1.8)
T. terrestre	3 (1.7)	2 (2.1)	1 (1.3)	7 (3.2)	6 (4.0)	1 (1.3)	10 (2.5)
T. verrucosum	2 (1.1)	0	2 (2.5)	0	0	0	2 (0.5)
M. fulvum	1 (0.6)	0	1 (1.3)	0	0	0	1 (0.3)
Microsporum not fully identified	1 (0.6)	0	1 (1.3)	1 (0.5)	1 (0.7)	0	2 (0.5)
Mixed cultures	2 (1.1) *	2 (2.1)	0	1 (0.5) *	1 (0.7)	0	3 (0.8)
Trichophyton not fully identified	0	0	0	6 (2.7)	1 (0.7)	5 (6.6)	6 (1.5)
Total:	**177**	**97**	**80**	**221**	**145**	**76**	**398**

*Mixed cultures in canine submissions were *T. terrestre* and *M. persicolor* . The feline submission yielded *M. canis* and *M. gypseum*.

Breed

Breed information was recorded in 2096 of 2193 canine submissions; 129 different dog breeds, including cross breeds, were represented (Table 4). The Jack Russell terrier [JRT] and Yorkshire terrier [YT] appeared over-represented amongst submissions that yielded a positive culture, when compared to all dogs known to be of another breed. Dermatophytes were isolated from 37 out of 154 (24.0 per cent) submissions from JRT (7 per cent of sample population, $P < 0.001$), and from 11 out of 54 (20.4 per cent) submissions from YT (2.3 per cent of sample population, $P=0.002$)(Table 4). JRT most often yielded sylvatic dermatophytes (*T. mentagrophytes*, n=20; *M. persicolor*, n=5; *T. erinacei*, n=4) rather than other species (*M. canis*, n=5; *M. gypseum*, n=3), whereas *M. canis* and *T. mentagrophytes* were evenly represented amongst isolates from YT (both n=5; *T. verrucosum*, n=1). German shepherd dogs and Labrador retrievers appeared under-represented amongst submissions that yielded

a positive culture; dermatophytes were isolated from 1 out of 96 (1.0 per cent) submissions from German shepherd dogs (4.4 per cent of sample population, P=0.020), and from 5 out of 179 (3.9 per cent) submissions from Labrador retrievers (8.2 per cent of sample population, P=0.036).

Table 4. Dermatophyte isolation from dog breeds with ≥20 submissions from first-opinion and referral dermatology practice in the south of England between 1991 and 2017.

Breed	**Number of submissions (% of total submissions)**	**Dermatophyte isolations from first opinion submissions (%)**	**Dermatophyte isolations from referral submissions (%)**	**Number of dermatophyte isolations (% of submissions positive)**	**Statistical comparison***
Cross breed	238 (10.9)	8 / 127 (6.3)	12 / 111 (10.8)	20 (8.4)	NS: P=0.89
Labrador retriever	179 (8.2)	2 / 84 (2.4)	5 / 95 (5.3)	7 (3.9)	**P=0.036, UR**
Jack Russell Terrier	154 (7.0)	15 / 71 (21.1)	22 / 83 (26.5)	37 (24.0)	**P<0.001, OR**
Staffordshire Bull Terrier	105 (4.7)	7 / 68 (10.3)	1 / 37 (2.7)	8 (7.6)	NS: P=0.96
German Shepherd Dog	96 (4.4)	1 / 31 (3.2)	0 / 65	1 (1.0)	**P=0.02, UR**
Boxer	67 (3.1)	0 / 19	5 / 48 (10.4)	5 (7.5)	NS: P=0.94
West Highland white terrier	67 (3.1)	5 / 19 (26.3)	2 / 48 (4.2)	7 (9.2)	NS: P=0.59
Golden Retriever	63 (2.9)	2 / 23 (8.7)	1 / 40 (2.5)	3 (4.8)	NS: P=0.47
Cocker Spaniel	60 (2.7)	6 / 29 (20.7)	0 / 31	6 (10.0)	NS: P=0.73

Cavalier King Charles Spaniel	59 (2.7)	1 / 25 (4.0)	2 / 34 (5.9)	3 (5.1)	NS: P=0.56
Yorkshire Terrier	54 (2.5)	6 / 24 (25.0)	5 / 30 (16.7)	11 (20.4)	**P=0.002, OR**
Doberman	44 (2)	1 / 3 (33.3)	2 / 41 (4.9)	3 (6.8)	NS: P=0.99
Bulldog	42 (1.9)	1 / 19 (5.3)	0 / 23	1 (2.4)	NS: P=0.29
Springer Spaniel	36 (1.6)	0 / 10	3 / 26 (11.5)	3 (8.3)	NS: P=0.82
Dachshund	30 (1.4)	2 / 17 (11.8)	0 / 13	2 (6.7)	NS: P=0.94
Border Collie	29 (1.3)	2 / 13 (15.4)	0 / 16	2 (6.9)	NS: P=0.90
Rottweiler	27 (1.2)	0 / 5	2 / 22 (9.1)	2 (7.4)	NS: P=0.80
Irish Water Spaniel	26 (1.2)	0 / 0	2 / 26 (7.7)	2 (7.7)	NS: P=0.75
English Bull Terrier	22 (1)	0 / 8	0 / 14	0 (0.0)	NS: P=0.32
Beagle	21 (1)	0 / 1	2 / 20 (10.0)	2 (9.5)	NS: P=0.89
Border Terrier	21 (1)	2 / 10 (20.0)	0 / 11	2 (9.5)	NS: P=0.89
Great Dane	20 (0.9)	0 / 6	1 / 14 (7.2)	1 (5.0)	NS: P=0.94
All dogs	2193			177 (8.1)	

Comparison of the proportional isolation from dogs of a particular breed with isolation from all dogs that were known to be of another breed (chi-squared tests). NS, P>0.05; OR, over-represented; UR, under-represented.

Breed information was recorded in 1075 of 1389 feline submissions; 18 short-haired (n=753) and 11 long-haired breeds (n=322) were represented, including most commonly domestic short-haired cats (DSH, n=612), Persians (n=183), domestic long-haired cats (DLH, n=71) and Burmese (n=36) (Table 5). The proportion of long-haired cats yielding a positive culture (97 of 322, 30.1 per cent) significantly exceeded the

proportion (73 of 753, 9.7 per cent) in short haired cats (P<0.001). Two long-haired breeds, Persian and Chinchilla, appeared over-represented amongst submissions that yielded a positive culture, when compared to all cats known to be of another breed (Table 5). Dermatophytes were isolated from 60 out of 183 (32.8 per cent) submissions from Persians (17.0 per cent of sample population, P < 0.001), and from 10 out of 25 (40.0 per cent) submissions from Chinchillas (2.3 per cent of sample population, P<0.001). *M. canis* accounted for 88.3 per cent (53 out of 60) and 90 per cent (9 out of 10) of isolates obtained from Persians and Chinchillas, respectively. DSH cats appeared under-represented amongst submissions that yielded a positive culture; dermatophytes were isolated from 67 out of 612 (10.9 per cent) submissions, but from 104 out of 463 (22.5 per cent) submissions from cats of another breed , P<0.001) (Table 5).

Table 5. Dermatophyte isolation from samples obtained in first-opinion and referral dermatology practice from cat breeds with ≥20 submissions in the south of England between 1991 and 2017.

Breed	**Number of submissions (% of total submissions)**	**Dermatophyte isolations from first opinion submissions**	**Dermatophyte isolations from referral submissions**	**Number of dermatophyte isolations (% of submissions positive)**	**Statistical comparison***
Short haired cats					
DSH	612 (56.9)	56 / 372 (15.1)	11 / 240 (4.6)	67 (10.9)	**P<0.001, UR**
Burmese	36 (3.3)	4 / 20 (20.0)	0 / 16	4 (12.5)	NS: P=0.42
Long-haired cats					
Persian	183 (17.0)	27 / 73 (37.0)	33 / 110 (30)	60 (32.8)	**P<0.001, OR**
DLH	71 (6.6)	14 / 51 (27.5)	2 / 20 (10.0)	16 (22.5)	NS: P=0.11
Chinchilla	25 (2.3)	2 / 5 (40.0)	8 / 20 (40.0)	10 (40)	**P<0.001, OR**
Total	1075			171 (15.9)	

Comparison of the proportional isolation from cats of a particular breed with isolation from all cats that were known to be of another breed (chi-squared tests). NS, P>0.05; OR, over-represented; UR, under-represented.

Age

There were 157 dermatophyte isolations from 2012 dogs with a recorded age, and 182 dermatophyte isolations from 1112 cats with a recorded age (Table 6). Proportional *M. canis* isolation from dogs under 2 years old (26 of 413 submissions, 6.3 per cent) significantly exceeded isolation from dogs aged 2 or more years (42 of 1599 submissions, 2.6 per cent) (P<0.001) (Table 6). By contrast, proportional *T. mentagrophytes* isolation from dogs under 2 years (2 of 413 submissions, 0.5 per cent) was significantly lower than from dogs aged 2 years or more (59 of 1599 submissions, 3.7 per cent) (P<0.001).

Proportional *M. canis* isolation from cats aged under 2 years (67 of 286 submissions, 23.4 per cent) significantly exceeded isolation from cats aged 2 or more years (74 of 826 submissions, 9.0 per cent) (P<0.001) (Table 6). The higher proportional *T. mentagrophytes* isolation from cats aged under 2 years (11 of 286 submissions, 3.8 per cent) was on the margin of statistical significance when compared with cats aged 2 years or more (15 of 826 submissions, 1.8 per cent) (P=0.050).

Table 6. Isolation of dermatophytes in samples obtained in first-opinion and referral dermatology practice from dogs and cats of different ages in the south of England between 1991 and 2017.

	Dog				Cat			
Age (years)	Number of submissions	Number positive (%)	Number of *M. canis*	Number of *T. mentagrophytes*	Number of submissions	Number positive (%)	Number of *M. canis*	Number of *T. mentagrophytes*
<1	187	17 (9.1)	15	1	141	53 (37.6)	45	7
1	226	12 (5.3)	11	1	145	27 (18.6)	22	4
2	196	11 (5.6)	3	8	128	19 (14.8)	12	3
3	188	9 (4.8)	4	4	104	18 (17.3)	14	3
4	169	15 (8.9)	5	7	76	12 (15.8)	9	2
5	190	17 (8.9)	5	8	66	6 (9.1)	4	1

6	178	8 (4.5)	5	1	67	1 (1.5)	1	0
7	148	7 (4.7)	3	3	42	3 (7.1)	1	0
8	126	13 (10.3)	4	7	63	5 (7.8)	3	0
9	121	10 (8.3)	3	2	51	6 (11.8)	4	1
10	106	15 (14.2)	6	4	57	10 (17.5)	9	1
11	58	7 (12.1)	2	3	42	3 (7.1)	3	0
12	44	1 (2.3)	0	1	43	4 (9.3)	2	2
13-19	75	15 (20)	2	11	87	15 (14.1)	12	2
NR	181	20	6	7	277	39	31	5
Total	2193	177 (8.1)	74	68	1389	221 (15.9)	172	31

NR; not recorded.

Sex

In dogs, proportional dermatophyte isolation from males (70 out of 1078, 6.5 per cent) was similar to females (80 out of 926, 8.6 per cent) (P=0.069). Similarly, in cats, proportional dermatophyte isolation from males (101 out of 611, 16.5 per cent) was similar to females (79 out of 567, 13.9 per cent) (P=0.216).

Season

Proportional dermatophyte isolation from canine submissions varied with season (P=0.029); the isolation rate was highest in the summer and lowest in the spring (Table 7). No variation in proportional dermatophyte isolation was identified between seasons for feline submissions (P=0.47).

Table 7. Dermatophyte isolation in each of the four seasons from samples obtained in first-opinion and referral dermatology practice from dogs and cats in the south of England between 1991 and 2017.

	Number of submissions	Number of dermatophyte isolations	% of submissions positive
Dog*			
Spring	525	29	5.5
Summer	467	50	10.7
Autumn	637	53	8.3
Winter	564	45	8.0
Overall	2193	177	
Cat			
Spring	348	51	14.7
Summer	281	53	18.9
Autumn	365	58	15.9
Winter	395	59	14.9
Overall	1389	221	

*Comparison between seasons, P=0.029, Chi-squared test.

First opinion versus referral submissions

Proportional dermatophyte isolation from dogs sampled in first opinion practice (97 of 910, 10.7 per cent) was higher than in referral submissions (80 of 1283, 6.2 per cent) ($P < 0.001$). Similarly, the proportion of dermatophyte isolation from cats sampled in first opinion practice (145 of 768, 18.9 per cent) was higher than in referral submissions (76 of 621,12.2 per cent) ($P = 0.001$).

In cats, there was a higher isolation rate of *M. canis* in first opinion samples (109 of 768, 14.2 per cent) than in referral samples (63 of 621, 10.1 per cent) ($P=0.023$) (Table 2). Similarly, in dogs, there was a higher proportion of isolation of *M. canis* in first opinion samples (52 of 910, 5.7 per cent) than in referral submissions (22 of 1283, 1.7 per cent) ($P<0.001$) (Table 1).

Isolation of *T. mentagrophytes* was also more frequent from first opinion samples from cats (first opinion 26 of 768 [3.4 per cent]) than in referral samples (5 of 621 [0.8 per cent]) (P=0.002)(Table 2), whereas isolation rates were comparable in canine samples (first opinion 34 of 910, 3.7 per cent versus referral 34 of 1283, 2.7 per cent) (P=0.190) (Table 1). Small numbers preclude reliable statistical analyses of the remaining dermatophyte species but it is notable that 10 of 11 isolations of *T. erinacei* and 5 of 7 isolations of *M. persicolor* were from canine referral submissions.

Trends in the dermatophyte isolation rate over the study period.

The number of submissions from both dogs and cats reduced during each successive three-year period from 2009 onwards (Tables 1 and 2). The proportion of samples yielding a dermatophyte was below the study mean (8.1 per cent in dog samples, 15.9 per cent in cat samples) in both dogs and cats from 2009 to 2017. No clear overall trend in the proportion of samples yielding a particular dermatophyte species could be observed during the study period. However, the proportion of samples yielding *M. canis* was below the study mean for dog samples (3.4 per cent) and cat samples (12.4 per cent) during 1997-1999, and from 2012 onwards. The proportion of samples yielding *T. mentagrophytes* was above the study mean for dog samples (3.1 per cent) during 1994-1996 and 2003-2008, and for cat samples (2.2 per cent) during 1991-1993, 1997-1999, 2006-2008 and 2012 to 2014.

DISCUSSION.

There are a number of similarities between the results of the present study and that of Sparkes *et al.*; this is not surprising since the same host species were sampled from a similar geographical region.[9] One notable difference regarding the sample population in the present study was the relatively high percentage of submissions from referral practice (1904 of 3582 submissions, 53.1 per cent). By contrast, Sparkes *et al.* evaluated specimens primarily from first opinion practitioners that dated back to 1956 and thus encompassed a period when referral dermatology practice was much less developed. The more frequent isolation of *M. canis* and of dermatophytes overall in our first-opinion samples indicates that the

type of practice (referral versus first-opinion) can influence isolation rates and thus comparative analyses. Nevertheless, our isolation rate of *M. canis* from first-opinion feline samples (109 of 768, 14.2 per cent) and overall (172 of 1389, 12.4 per cent) was substantially lower than that of Sparkes *et al.* (827 of 3407, 24.3 per cent).[9] It is not clear whether this difference reflects a subtle geographical effect (laboratories based in south east versus south west England), a decrease in the frequency of infection over time, perhaps due to improved infection control processes within infected catteries, or reduced outdoor access for cats. Alternatively, it might reflect altered clinical practice with proportionally more frequent sampling in an attempt to confirm the presence or absence of this contagious and zoonotic disease[18] or increased in-house testing by practitioners. Data from the Mycology Reference Laboratory in Bristol, U. K., indicated a 90 per cent reduction in the relative isolation of *M. canis* from humans between 1980 and 2005, [4] which is notable since pets have been implicated as the source of *M. canis* in humans. [19] However, the more comparable first-opinion isolation rates of *M. canis* from dogs in the present (52 of 910, 5.7 per cent) and the previous study of Sparkes *et al.*(309 of 4942, 6.3 per cent)[9] indicates that *M. canis* continues to circulate in this region.

T. mentagrophytes remains the second most commonly isolated dermatophyte species in England[9] from both cats and dogs and this, along with the occasional isolation of *T. erinacei* and *M. persicolor*, suggests a continued role for wildlife as vectors of dermatophytosis in companion animals.[20], and in turn to their owners.[21] It therefore remains important to question owners about their pet's lifestyle and access to rodents when they present animals with clinical signs compatible with dermatophytosis. Our proportional isolation rates of *T. mentagrophytes* from first-opinion canine (34 of 910, 3.7 per cent) and feline samples (26 of 768, 3.4 per cent) were both higher than those Sparkes *et al.* (canine 114 of 4942, 2.3 per cent; feline 50 of 3407, 1.5 per cent).[9] Similarly, Bourdeau et al. observed increased isolation of *T. mentagrophytes* from dogs and cats in France over the eight year period between 2010 and 2018. [22] It is not clear whether this reflects altered risk-factors for susceptible pets or the gradual emergence of a particular zoophilic *T. mentagrophytes* genotype(s) that is better adapted to dogs and cats.

It was notable that *T. erinacei* and *M. persicolor* were almost exclusively isolated in submissions from referral practices. *M. persicolor* is an unusual dermatophyte that is unable to perforate hair; invasion of the inter-follicular stratum corneum results in a localised or generalised scaling response that differs clinically from the alopecia and folliculitis seen with more conventional dermatophyte pathogens. [1, 17, 23] Cases observed in

the authors' institution have typically had a chronic course which might reflect reduced clinical suspicion of dermatophytosis prior to referral, as well as reduced tendency for recovery associated with relatively low-grade inflammatory responses. [17, 23] By contrast, *T. erinacei* typically generates a severely inflammatory folliculitis and furunculosis that often affects the dorsum of the muzzle in hunting dogs; this presentation is sometimes mis-diagnosed as an autoimmune disease, commonly pemphigus foliaceus. [23-26] These diverse clinical presentations seen in dermatophytosis highlight the need for veterinary practitioners to maintain a high index of suspicion so that relevant samples are systematically collected.

The failure to isolate *T. erinacei* from cats in the present study is in accordance with previous reports from countries where hedgehogs are endemic [9, 27, 28]; indeed, the authors are unaware of any reports of infection with this dermatophyte in cats. This might reflect either enhanced innate immunity, lack of expression by *T. erinacei* of adhesins or other virulence factors relevant for invasion of feline skin, or a more circumspect approach by cats encountering hedgehogs when compared with dogs [20]. A previous U.K. survey showed that cats were also very infrequently infested by the hedgehog flea, *Archaeopsylla erinacei* whereas this flea was the second-most abundant species (after *Ctenocephalides felis*) recovered from dogs [29]

The low numbers of geophilic dermatophytes isolated (*M. gypseum, M. fulvum* and *T. terrestre*) mirrors that found previously by Sparkes *et al.*[9] in the U. K. and is in contrast to data from warmer regions such as Azerbaijan,[30] France,[22] India,[31] Italy [27, 32] and southern USA. [8] where *M. gypseum* in particular is much more common, especially in dogs. The clinical significance of the isolation of *T. terrestre* is questionable as this species is traditionally viewed as being non-pathogenic. [33, 34]

The lower proportional dermatophyte isolation rate seen in dogs compared to cats is in accordance with previous studies. [9, 35] This might reflect either reduced susceptibility of the canine host, potential for genotypic variation in endemic stains that confers enhanced virulence in different host species, [36] or sampling of a higher proportion of dogs with skin disease as veterinary surgeons seek to differentiate suspected

dermatophytosis from other common infectious folliculitides such as pyoderma and demodicosis. [1, 20] The lack of a sex bias in the present study is in accordance with previous reports. [9, 18]

The over representation of JRT and YT amongst affected dogs is in agreement with the previous publication by Sparkes *et al.* [9] The frequent isolation of sylvatic dermatophytes from JRT likely reflects their tendency to hunt. Whilst YT dermatophytosis has been previously associated with primarily *M. canis*,[9, 27] our study indicates that *T. mentagrophytes* may also be important, although larger studies are needed to confirm this. The over-representation of Persians amongst the affected cats was also in accordance with previous studies, whereas Chinchilla cats do not appear to feature in previous reports (reviewed by [18]). This may reflect the fact that some organisations regard Chinchilla cats to be a colour ('silver') variant within the Persian breed (https://icatcare.org). Ineffective grooming associated with brachycephaly, or health disorders such as respiratory disease or osteoarthritis, might play a role in dermatophyte susceptibility in Persian cats.[37, 38]

The slight seasonal trend for a higher proportion of positive samples seen in dogs in the summer might reflect a climatic effect on outdoor fungal reservoirs, increased wildlife activity and scope for dog contact, or increased roaming or hunting behaviour by dogs during the warmer months. Dermatophytosis is generally considered to be more frequent in countries with a warmer climate.[18] Seasonality of dermatophyte isolation appears to vary inconsistently and with dermatophyte species and geographic location; for example, *M. gypseum* was more commonly isolated during the summer in Italy[32], and *M. gypseum* in the summer and *M. canis* in the autumn the southern USA.[8] A significant seasonal trend in dermatophyte isolation in the UK was not found by Sparkes *et al.* [9]

The more frequent isolation of *M. canis* from younger dogs and cats was in accordance with previous reports. [8, 9, 38]. However, this relationship did not apply to dogs with *T. mentagrophytes* dermatophytosis, where dogs of less than 2 years of age were less often affected. We speculate that this reflects an acquired and enhanced wildlife-hunting prowess amongst more adult dogs, thus increasing direct exposure to the reservoir hosts.

In this study, we are unaware of the underlying population size from which the samples came and therefore cannot estimate the prevalence of dermatophytosis in the wider cat and dog populations. Furthermore, isolation of a dermatophyte from a skin specimen does not differentiate between mechanical carriage and active infection; this may be particularly relevant for *M. canis* in cats.[39] It is clear, however, that dermatophytosis, particularly caused by *M. canis* and *T. mentagrophytes*, continues to be a significant problem. The index of clinical suspicion for this contagious and zoonotic disease should remain high in a variety of dermatological presentations, particularly in young animals, dogs and cats of certain breeds, and in animals exposed to wildlife and other reservoirs of infection.

A. CONTRIBUTORSHIP STATEMENT SL and HC collated the data, which was analysed by SL, HC and RB. SL and RB wrote the paper with input and revision from HC, DON and YC; in particular, DON and YC contributed to the epidemiological and statistical aspects of the manuscript, respectively. RB conceived, supervised and co-ordinated each step of the project, and submitted the manuscript.

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DATA AVAILABILITY STATEMENT All data relevant to the study are included in the article.

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