THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

A survey of the level of horse owner uptake of evidence-based anthelmintic treatment protocols for equine helminth control in the UK

Citation for published version:

Tzelos, T, Morgan, ER, Easton, S, Hodgkinson, JE & Matthews, JB 2019, 'A survey of the level of horse owner uptake of evidence-based anthelmintic treatment protocols for equine helminth control in the UK', *Veterinary Parasitology*, vol. 274, pp. 108926. <https://doi.org/10.1016/j.vetpar.2019.108926>

Digital Object Identifier (DOI):

[10.1016/j.vetpar.2019.108926](https://doi.org/10.1016/j.vetpar.2019.108926)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Veterinary Parasitology

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

1 **A survey of the level of horse owner uptake of**
2 **evidence-based anthelmintic treatment**
3 **protocols for equine helminth control in the**
4 **UK**

5 Thomas Tzelos^{a, b, *}, Eric R. Morgan^c, Stephanie Easton^a, Jane
6 E. Hodgkinson^d, Jacqueline B. Matthews^a

7 *^a Moredun Research Institute, Pentlands Science Park,*
8 *Edinburgh, EH26 0PZ, UK*

9 *^b The Roslin Institute, University of Edinburgh, Edinburgh,*
10 *EH25 9RG, UK*

11 *^c School of Biological sciences, Queen's University, Belfast, BT9*
12 *7BL, UK*

13 *^d Institute of Infection and Global Health, University of*
14 *Liverpool, Liverpool, L69 7ZJ, UK*

15

16 * Corresponding author at The Roslin Institute, University of
17 Edinburgh, Easter Bush, Edinburgh, EH25 9RG, UK. Email
18 address: thomas.tzelos@roslin.ed.ac.uk; Tel: +44 (0) 131 651
19 9100

20

21 **Abstract**

22 Interval treatment control programmes used widely in equine
23 helminth control have favoured the development of anthelmintic
24 resistance worldwide. Best practice guidelines have been
25 designed to address resistance and include the requirement for
26 improved pasture hygiene to break helminth transmission cycles,
27 along with anthelmintic application informed by the results of
28 diagnostic tests to reduce selection pressure for resistance. Using
29 an online questionnaire, this study examined uptake of measures
30 recommended in these guidelines by UK horse owners. The
31 survey comprised 58 questions spanning grazing management,
32 anthelmintic use and use of faecal egg count (FEC) testing to
33 inform treatment decisions. Analysis was carried out using a
34 combination of Chi-square and Mann-Whitney tests. In total,
35 705 owners responded and, following specific exclusion criteria,
36 the responses of 652 individuals were analysed. The majority of
37 the respondents owned <20 horses on private premises or livery
38 yards in England. The main outputs of the survey were as
39 follows. Overall, 60.9% of respondents used FEC tests to inform
40 the requirement to administer anthelmintics, with macrocyclic
41 lactones the most frequently-used anthelmintics. Of the
42 respondents, 38% obtained advice on anthelmintic choice from
43 their veterinarians; however, many respondents (43.8%)
44 purchased anthelmintics via the internet. Encouragingly, 74.4%
45 of respondents stated that they practiced good pasture hygiene

46 by removing dung from pasture. Generally, there were
47 differences between the responses of participants who based
48 anthelmintic treatments on FEC testing (targeted treatments; TT)
49 and those who practiced calendar-based anthelmintic treatments
50 (interval treatments; IT). Briefly, the “key” findings from the
51 Chi-square analysis included higher levels of satisfaction with
52 the level of knowledge about equine parasites/parasitic diseases
53 and higher levels of concern about anthelmintic resistance from
54 TT-respondents compared to IT-participants. Confusion on the
55 interpretation of quarantine recommendations was identified in
56 this study group and there was poor uptake of testing for
57 anthelmintic effectiveness. Overall, compared to previous
58 reports, this study indicated improved engagement of UK horse
59 owners with some helminth control practices recommended to
60 reduce the spread of anthelmintic resistance. However, a
61 proportion of respondents did not utilise these practices and there
62 were still important gaps in the use of appropriate quarantine and
63 efficacy testing. These identified gaps must be taken into
64 consideration in knowledge dissemination activities in the
65 future.

66

67 **Keywords:** helminths; equine; questionnaire; anthelmintics;
68 anthelmintic resistance; faecal egg count tests.

69

70 **1. Introduction**

71 Broad spectrum anthelmintics have been used for over 50
72 years for controlling equine helminth infections. A popular
73 approach has been to administer anthelmintics to all animals
74 within a group using interval treatment protocols, introduced in
75 the 1960s following studies which sought to control the
76 pathogenic nematode, *Strongylus vulgaris* (Drudge and Lyons,
77 1966). Over the years, the widespread use of interval treatment
78 protocols has led to substantial reductions in *S. vulgaris*-
79 associated disease; however, it has promoted development of
80 anthelmintic resistance, particularly in the highly prevalent
81 cyathostomin group of nematodes [reviewed by (Kaplan, 2002;
82 Kaplan and Nielsen, 2010; von Samson-Himmelstjerna, 2012;
83 Matthews, 2014; Peregrine et al., 2014; Tzelos and Matthews,
84 2016)]. Resistance to benzimidazoles and
85 tetrahydropyrimidines, as measured by faecal egg count
86 reduction test (FECRT), is widespread in cyathostomin
87 populations worldwide (Matthews, 2014; Peregrine et al., 2014).
88 Apart from one study in Brazil (Canevar et al., 2013) and one in
89 UK donkeys (McArthur et al., 2015), published reports of
90 macrocyclic lactone effectiveness assessed by FECRT have
91 indicated acceptable efficacy against cyathostomins at two
92 weeks after treatment (Traversa et al., 2009; Relf et al., 2014).
93 However, shortened strongyle egg reappearance periods (ERP)
94 after ivermectin and moxidectin treatments has been reported in

95 several countries (von Samson-Himmelstjerna et al., 2007;
96 Rossano et al., 2010; Lyons et al., 2011; Geurden et al., 2014;
97 Relf et al., 2014; van Doorn et al., 2014; Tzelos et al., 2017). A
98 shortened ERP is considered as an early indicator of resistance
99 (Sangster, 2001). Although ivermectin and moxidectin appear
100 effective in terms of reducing egg shedding two weeks after
101 treatment, these compounds may be less effective against larval
102 and early-adult stages, which mature and produce eggs before
103 the standard ERP (Lyons et al., 2009; Lyons et al., 2010; Lyons
104 and Tolliver, 2013). Ivermectin resistance is also reported as
105 widespread in *Parascaris equorum* (Reinemeyer, 2009).

106 Anthelmintic resistance is a major welfare threat,
107 particularly to young animals which are more susceptible to life-
108 threatening burdens of these parasites (Reid et al., 1995). It is
109 therefore essential that anthelmintic potency is protected and that
110 treatment applications be informed by diagnostic tests (Herd,
111 1993; Proudman and Matthews, 2000; Lester and Matthews,
112 2014; Nielsen et al., 2014a) and integrated with improved
113 pasture hygiene practices such as dung removal to reduce
114 infection levels in the environment (Herd, 1986; Corbett et al.,
115 2014; Tzelos et al., 2017). Despite this approach being advocated
116 for >20 years, surveys across different countries have indicated
117 relatively low horse-owner uptake of the principals behind
118 sustainable methods of helminth control (O'Meara and Mulcahy,
119 2002; Lind et al., 2007; Fritzen et al., 2010; Relf et al., 2012;

120 Nielsen et al., 2014b; Stratford et al., 2014; Bolwell et al., 2015;
121 Robert et al., 2015; Salle and Cabaret, 2015; Rosanowski et al.,
122 2016). In particular, the common finding in the aforementioned
123 studies from 2002 to 2015 was the respondents' high levels of
124 concern about anthelmintic resistance and the relatively low
125 percentage of FEC testing before anthelmintic treatment (range
126 among studies 0-50.6%).

127 There are nil survey-related studies in equine-
128 parasitology in the UK published since 2014. The objective,
129 here, was to assess if there was continued improvement in the
130 uptake of evidence-based helminth control practices by horse
131 owners, since there have been several industry-led initiatives
132 promoting diagnostic-led treatment protocols to horse owners
133 over the last decade; for example the Smart Worming
134 Programme (<http://www.smartworming.co.uk>) and updated
135 guidelines by the British Horse Society
136 ([www.bhs.org.uk/~media/bhs/files/pdf-documents/worm-](http://www.bhs.org.uk/~media/bhs/files/pdf-documents/worm-control.ashx)
137 [control.ashx](http://www.bhs.org.uk/~media/bhs/files/pdf-documents/worm-control.ashx)). Furthermore, it is imperative to assess which
138 practices still lack any uptake; for example, field assessment of
139 anthelmintic efficacy, identified previously as not being
140 implemented (Easton et al., 2016).

141

142 **2. Materials and methods**

143 **2.1. Questionnaire format**

144 A questionnaire was designed using previously
145 published formats to assess equine helminth control measures
146 (Relf et al., 2012; Stratford et al., 2014; Easton et al., 2016), in
147 this case, utilizing the web-based software tool, (SurveyMonkey,
148 <https://www.surveymonkey.com/>). The questionnaire comprised
149 58 questions divided into a ‘Welcome’ page with details about
150 the project and requesting consent (n=1); ‘General Information’
151 (n=5) exploring demographic details of each respondent;
152 ‘Worms and Deworming’ (n=29) assessing helminth control
153 methods used and attitudes to parasites, treatment, advice and
154 anthelmintic purchasing; ‘Faecal Egg Counts’ (n=6), which
155 focused on respondent experience regarding FEC tests and
156 anthelmintic efficacy testing; ‘Worm Control in Foals’ (n=2) and
157 ‘General Management’ (n=12) which investigated additional
158 approaches to helminth control such as the removal of faeces
159 from pasture, stocking density levels and approaches to
160 quarantine. A ‘Future Studies’ section (n=3) asked whether
161 respondents would be willing to participate in future
162 parasitological studies to assess helminth prevalence and
163 anthelmintic efficacy. The ‘Question Logic’ function in
164 SurveyMonkey was employed in some questions flows and
165 respondents were directed in specific routes depending on their
166 preceding answer. Most questions were of the closed multiple
167 choice type. There were also open-ended questions and, in some
168 cases, an opportunity for respondents to include additional

169 comments. The questionnaire is included in Supplementary file
170 1. The survey was piloted using a small group of horse owners
171 prior to distribution. These pilot survey results were not included
172 in the analyses described below. Ethical approval was granted by
173 the Senior Management Group of Moredun Research Institute
174 when the project was approved for submission. All data were
175 stored on a secure server at Moredun Research Institute, and
176 backed up daily at an external site, with access limited to
177 research project staff. Informed consent was obtained by
178 respondents, and responses were anonymised prior to analysis.

179

180 2.2. Questionnaire distribution

181 The target population was UK individuals who manage
182 and/or own equids. Responses were sought from stud farm and
183 livery yard managers, riding school managers and owners who
184 used livery yards or private premises. The questionnaire was
185 available online for 13 weeks (13 April - 6 July 2015), and was
186 primarily promoted via social media (mainly through posts on
187 Facebook, <https://www.facebook.com/>). The questionnaire
188 hyperlink was posted to equid-oriented groups on Facebook
189 (n=10) with a short description of the project. A reminder was
190 posted every 2 weeks. In addition, 384 equine practice email
191 addresses were obtained from the British Equine Veterinary
192 Association website (www.beva.org.uk). An email, detailing

193 study background and an online link to the questionnaire was
194 distributed to practices inviting them to promote the survey to
195 clients via websites, social media and/or newsletters. A direct
196 email was also sent to 518 equine premises, including riding
197 schools and livery yards listed on the British Horse Society
198 website ([http://www.bhs.org.uk/professionals/become-bhs-](http://www.bhs.org.uk/professionals/become-bhs-approved/approved-livery-yards)
199 [approved/approved-livery-yards](http://www.bhs.org.uk/professionals/become-bhs-approved/approved-livery-yards)). The Horse Trust also
200 promoted the survey on their website
201 (<http://www.horsetrust.org.uk/>) and Facebook page.

202

203 2.3. Data analysis

204 In terms of selecting respondents to be included in the
205 analysis, data were included when a respondent provided
206 consent to participate (Question 1), had completed the ‘General
207 Information’ section and provided a response to at least one
208 question in ‘Worms and Deworming’ section. Respondent
209 answers were then exported to Microsoft Excel (Microsoft Excel
210 for Windows, 2010) and basic descriptive analysis performed in
211 Microsoft Excel. Statistical analyses were carried out using
212 Minitab 17 (Minitab® 17.1.0). Chi-square tests were performed
213 for each question to determine whether the frequency of owners
214 expressing agreement or disagreement with specific statements
215 differed between those respondents that practiced ‘interval
216 treatment’ (IT; i.e. calendar-based anthelmintic treatments of all

217 animals in a group not informed by diagnostic [i.e. FEC] testing)
218 *versus* ‘targeted treatment’ (TT; i.e. anthelmintic treatment of
219 animals based on the results of diagnostic [i.e. FEC] tests)
220 protocols. In particular, chi square tests examined whether
221 respondents who followed targeted treatment (TT) protocols
222 (n=397) answered specific questions differently to those that
223 followed interval treatment (IT) protocols (n=161). Those
224 respondents who stated that they followed a different type of
225 protocol to the two stated above (94/652) were not included in
226 this analysis. Due to testing of multiple comparisons (n=53),
227 following correction via Šidák’s formula (Sidak, 1967), values
228 of $P \leq 0.0015$ were considered significant. For responses on a
229 ranked (Likert) scale, significant chi-square results on a
230 compressed scale (agree/disagree) were followed by Mann-
231 Whitney tests across the full Likert scale.

232

233 **3. Results**

234 **3.1. Demographic features of the study respondents**

235 A total of 705 respondents clicked on the hyperlink, 652
236 of which were then included in the analysis. Of the latter, 519
237 respondents completed the survey, and 133 incomplete
238 questionnaires fulfilled the inclusion requirements. Respondent
239 distribution across the UK and general information on the
240 respondents are presented in Table 1. Briefly, respondents were

distributed as follows: England (73.5%; 479/652), Scotland (17.9%; 117/652), Wales (7.7%; 50/652) and N. Ireland (0.9%; 6/652). The largest proportion of respondents had accessed the survey after learning about it on social media (75.9%; 495/652), followed by direct email (13.5%; 88/652), ‘friend/colleague’ (8.3%; 54/652) and the Horse Trust website (2.3%; 15/652). A total of 92% respondents (600/652) stated that they were horse owners, 13.8% (90/652) were yard managers and 3.4% (22/652) were stud farm owners/managers (please note that respondents could chose more than one option here). A total of 8.7% (57/652) of respondents owned / managed ≥ 20 horses, 90.4% (589/652) managed/owned < 20 horses and 0.9% (6/652) did not provide horse numbers. A total of 639 respondents stated they owned/managed at least one adult horse (> 3 years-old), 120 respondents owned/managed at least one “youngster” (1-3 years-old) and 43 respondents stated they owned/managed at least one foal (< 1 year-old). The majority of horses were kept on private premises (50.6%; 330/652), followed by livery yards (37.3%; 243/652), riding schools (3.4%; 18/652); livestock farms (2.9%; 19/652), multi-purpose stables (2.7%; 18/652), stud farms (2%; 13/652) and colleges/rescue centres (1.1%; 7/652).

3.2. Descriptive analysis of responses

264 An outline of the descriptive results is presented here and
265 summary details for all survey questions are presented in
266 Supplementary file 2. A FEC-directed TT regimens were
267 followed by 60.9% respondents (397/652), whilst 24.7%
268 (161/652) respondents stated that they used calendar-based IT
269 regimens. A further 14.4% (94/652) respondents stated that they
270 followed a “different type” of helminth control protocol,
271 including “strategic” treatments (1-4 times/year) or “irregular”
272 treatments (when they suspected worm infection). One
273 respondent stated that they did not treat their horses with
274 anthelmintics. Of the 395 respondents who stated that they
275 followed a TT helminth control protocol, 54.9% (217/395) had
276 moved from an IT protocol or “strategic deworming”
277 programme in the previous 1-5 years, 24.6% (97/395)
278 respondents had changed their type of helminth control to a TT
279 one in the previous 5-10 years, 13.7% (54/395) in the previous
280 year, 1.5% (3/395) stated that they did not know when they had
281 made this change and 5.3% (21/395) stated they had always
282 followed a TT programme. When asked who influenced them in
283 changing their helminth control practice to a TT approach,
284 30.4% (120/395) of the respondents indicated that it was their
285 veterinarian who had done so and 32.4% (128/395) stated that
286 they were influenced by ‘Other’ factors, with the majority
287 (26.3%; 104/395) stating that it was personal research via the
288 internet, academic literature or magazines.

289 With regard to respondent opinions on their own level of
290 knowledge of parasites/parasitic diseases, 37.5% (191/509) were
291 ‘neither satisfied nor dissatisfied’, 27.1% (138/509) and 11.8%
292 (60/509) were ‘satisfied’ and ‘very satisfied’ with their
293 knowledge levels, respectively. The remaining 16.3% (83/509)
294 and 7.3% (37/509) were ‘dissatisfied’ and ‘very dissatisfied’
295 with their knowledge of parasites and parasitic diseases,
296 respectively. There was a high level of respondent recognition of
297 worm species names listed in the survey. In order of importance,
298 the helminths considered as key targets to treat were: small
299 strongyles (38.7%; 197/509), *Anoplocephala perfoliata* (25.3%;
300 129/509), large strongyles (21%; 107/509), *Parascaris equorum*
301 (5.1%; 26/509), *Fasciola hepatica* (1.6%; 8/509), *Oxyuris equi*
302 (1.4%; 7/509) and *Gasterophilus intestinalis* (1%; 5/509).
303 Regarding anthelmintic resistance, 32.2% (161/500) and 37.2%
304 (186/500) of respondents were ‘concerned’ and ‘very concerned’
305 about this issue, respectively. Despite these levels of concern of
306 anthelmintic resistance, 75.2% (376/500) respondents stated
307 they were not aware of the anthelmintic sensitivity status of the
308 worm populations on the premises where their horse(s) grazed.

309 Macrocyclic lactones were the most frequently used
310 anthelmintics [ivermectin (42.5%; 197/463),
311 moxidectin/praziquantel (35.6%; 165/463),
312 ivermectin/praziquantel (35%; 162/463) and moxidectin (32%;
313 148/463)]. Use of other classes of anthelmintics was as follows:

314 fenbendazole as a single dose 5.2% (24/463) or a 5-day course
315 15.8% (73/463), pyrantel 17.7% (82/463) and praziquantel
316 22.5% (104/463) of respondents. A small proportion of
317 respondents stated that they used “herbal products” (4.8%;
318 22/463). A total of 16% (74/463) of respondents were not
319 familiar with the chemical names of anthelmintics specified in
320 the survey. The majority of respondents stated that they
321 “specifically targeted” tapeworm infections (77.3%; 358/463),
322 with almost all respondents stating that they had used a product
323 that contained praziquantel for tapeworm control. Over 60%
324 (61.8%; 286/463) of respondents stated that they “specifically
325 targeted” encysted stage cyathostomin infections with
326 anthelmintic treatment. For small strongyles, 70.3% (201/286)
327 respondents stated they targeted encysted larvae with a product
328 containing moxidectin, 5.6% (16/286) five-day fenbendazole,
329 1.7% (5/286) ivermectin and 22.4% (64/286) stated that they did
330 not know or followed their prescriber’s advice for this type of
331 treatment.

332 When selecting an anthelmintic, 38% (176/463) of
333 respondents stated that they sought advice from a veterinarian,
334 19.2% (89/463) from a suitably qualified person (SQP), 16.8%
335 (78/463) from a FEC service company, 4.8% (22/463) from an
336 internet retailer, 1.5% (7/463) from a pharmacist, whilst 8.2%
337 (38/463) of the respondents did not seek advice before
338 purchasing an anthelmintic. When considering where thy

339 purchased anthelmintics from, 20.7% (96/463) of respondents
340 stated that they bought anthelmintics from same source from
341 which they sought advice on anthelmintic selection. The highest
342 proportion (43.8%; 203/463) of respondents stated they used an
343 internet retailer for the purchase of anthelmintics. The remainder
344 stated that they used a veterinarian (3.2%; 15/463), SQP (14.7%;
345 68/463) or pharmacist (3%; 14/463) for their anthelmintics
346 purchase.

347 In the section pertaining to ‘Worm control in foals’,
348 76.2% (337/442) of respondents stated that they did not have
349 foals at their premises. From the remaining 105 participants that
350 answered this question, 66.7% (70/105) of respondents stated
351 that they anthelmintic treated the foals at their premises. The
352 remaining participants stated that they did not treat foals (21.9%;
353 23/105) or they did not know (11.4%; 12/105). On the question,
354 “How does the deworming of foals compare to that of adult
355 equines at your premises?”, the respondents who anthelmintic
356 treated foals stated: ‘Same anthelmintic(s) are used, but different
357 dosing regimen’ (37.1%; 26/70); ‘Different anthelmintic(s) are
358 used’ (22.9%; 16/70); ‘Same protocol as in adults’ (17.1%;
359 12/70); ‘Other’ (14.3%; 10/70); and, ‘I do not know’ (8.6%;
360 6/70).

361 With regards to general management (Supplementary
362 file 2), 74.4% (392/527) of respondents stated that they practiced
363 dung removal from pasture, 25% (132/527) did not remove dung

364 and 0.6% (3/527) did not know whether this was applied at their
365 premises. Additionally, 53.6% (210/392) of respondents that
366 practiced dung removal from pasture stated that dung was
367 removed daily and 31.4% (123/392) stated that it was removed
368 every 2-7 days. The remainder stated that the frequency of dung
369 removal was as follows: every 8-14 days (6.6%; 26/392), 15-28
370 days (4.1%; 16/392), less often (3.8%; 15/392) or do not know
371 (0.5%; 2/392).

372 When asked whether new arrivals to the premises were
373 treated with anthelmintics, 25.6% (137/535) of respondents
374 stated that their premise was a closed yard, 9.5% (51/535) of
375 respondents did not anthelmintic treat new arrivals and 6.5%
376 (35/535) did not know what new arrivals were treated with. A
377 total of 58.3% (312/535) of respondents stated they administered
378 anthelmintic(s) to new arrivals with the preference for
379 “quarantine treatment” as follows; moxidectin/praziquantel
380 (25.9%; 81/312), ivermectin/praziquantel (20.1%; 63/312), a 5-
381 day course fenbendazole (10.5%; 33/312), ivermectin (8.9%;
382 28/312), moxidectin (6.4%; 20/312), praziquantel (2.6%; 8/312),
383 pyrantel (1.9%; 6/312), a single-dose of fenbendazole (1.9%;
384 6/312) and a “herbal product” (0.3%; 1/312). A total of 18.8%
385 (59/312) of respondents did not know the anthelmintic used, 7%
386 (22/312) did not recognize the chemical terms and 19.5%
387 (61/312) selected “other”, the majority stating that treatment

388 depended on 'FEC testing', 'advice from a prescriber', 'time of
389 year' and 'last anthelmintic used'.

390

391 3.3. Chi-square and Mann-Whitney analyses of survey answers
392 by respondents who reported using targeted treatment (TT)
393 *versus* interval treatment (IT) protocols

394 In order to determine whether the frequency of owners
395 expressing agreement or disagreement on specific aspects/views
396 of helminth control differed between the groups categorized as
397 respondents who followed a TT protocol and respondents who
398 followed an IT protocol, Chi-square and Mann-Whitney tests
399 were performed (see Supplementary files 3 and 4 for Chi-square
400 and Mann-Whitney test results, respectively). In particular, for
401 responses on a ranked or Likert scale, significant chi-square
402 results were followed up with a Mann-Whitney test, and only
403 those results that produced significant values using both tests are
404 reported here. The P-values presented below are from the Chi-
405 square tests, whilst the P-values from the Mann-Whitney tests
406 can be found in Supplementary file 4.

407 Respondents who followed TT protocols were more
408 likely to state that they were more 'satisfied' with their level of
409 knowledge about equine parasites/parasitic diseases than those
410 that used IT protocols (TT: 29.62%, 109/368; IT: 20%, 28/140;
411 $P=0.0002$). Likewise, the TT group respondents were more

412 likely to state that they were ‘very concerned’ about anthelmintic
413 resistance than those who implemented an IT protocol (TT:
414 41.32%, 150/363; IT: 26.28%, 36/137; $P=0.0006$).

415 The TT group of respondents were more likely to
416 ‘strongly agree’ with the following statements: “I believe that
417 wormers are bad for my horse and want to minimise their use as
418 far as possible” (TT: 21.32%, 71/333; IT: 5.6%, 7/125;
419 $P<0.0001$); “I am aware of the emergence of wormer resistance
420 in horses and this concerns me” (TT: 59.46%, 198/333; IT:
421 34.4%, 43/125; $P<0.0001$); and, “Knowing how many eggs are
422 being shed by horses helps me to manage grazing so that horses
423 do not encounter heavily contaminated pastures” (TT: 25.31%,
424 81/320; IT: 7.38%, 9/122; $P<0.0001$). Those respondents who
425 followed TT protocols were significantly more likely to
426 ‘strongly disagree’ with the statements “FEC are too expensive
427 and provide no advantage over administering wormer regardless
428 of results” (TT: 52.5%, 168/320; IT: 4.1%, 5/122; $P<0.0001$) and
429 “Not enough advice on what to do arrives with FWEC for them
430 to be useful to me” (TT: 36.56%, 117/320; IT: 6.56%, 8/122;
431 $P<0.0001$).

432 Those respondents who followed an IT protocol were
433 more likely to ‘strongly agree’ with the statement “If FEC were
434 quicker and cheaper I would use them more” (TT: 9.69%,
435 31/320; IT: 25.41%, 31/122; $P<0.0001$). On the other hand, the
436 IT group were more likely to ‘disagree’ with the statement

437 “Worms are something our horses have to live with and are not
438 always bad for them” (TT: 29.43%, 98/333; IT: 48%, 60/125;
439 $P<0.0001$).

440 In terms of reported anthelmintic treatment practices, the
441 respondents in the TT group were more likely to select ‘yes’
442 when asked if they treated for tapeworm (TT: 81.9%, 276/337;
443 IT: 65%, 82/126; $P<0.0001$) or encysted cyathostomin larvae
444 (TT: 66.77%, 225/337; IT: 48.41%, 61/126; $P<0.0001$). Finally,
445 the IT group of respondents were more likely to seek advice from
446 an internet retailer compared to TT participants (TT: 2.97%,
447 10/337; IT: 9.52%, 12/126; $P<0.0001$).

448

449 **4. Discussion**

450 This study examined helminth control approaches of
451 horse owners in the UK. Participation was similar to a recent
452 survey in the UK (Easton et al., 2016) and relatively higher than
453 previous UK studies that focused on particular regions or sectors,
454 i.e. 193 responses in a study focused on horse establishments in
455 Scotland and 61 responses in a study focused on UK
456 thoroughbred establishments (Relf et al., 2012; Stratford et al.,
457 2014). An important finding was that 60.9% of respondents
458 stated that they followed a TT regimen based on FEC testing, the
459 majority of whom switched from IT protocols in the preceding
460 1-5 years before this survey. The percentage of owners following

461 a TT strategy based on FEC test results reported here is the
462 highest reported to date. For example, a study conducted in
463 Scotland in 2010 (Stratford et al., 2014), indicated that 40% of
464 respondents followed TT regimens. The last UK-wide survey,
465 conducted in 2009-2010, targeted Thoroughbred breeding farms
466 and in that case, 100% of respondents followed an IT regimen
467 (Relf et al., 2012). Studies based outside of the UK also
468 demonstrated a lower uptake of TT protocols; for example, 25%
469 in France (Salle and Cabaret, 2015); 20% in New Zealand
470 (Bolwell et al., 2015); 30% in the USA (Robert et al., 2015);
471 50.6% in Denmark (Nielsen et al., 2014b); 0% in Germany
472 (Fritzen et al., 2010); 1% in Sweden (Lind et al., 2007) and 16%
473 in the Republic of Ireland (O'Meara and Mulcahy, 2002).

474 The results presented here should be interpreted in
475 consideration of inevitable bias. The sample size, although
476 higher than similar UK studies (Relf et al., 2012; Stratford et al.,
477 2014), is approximately 0.15% of the estimated 446,000 horse-
478 owning premises quoted in The National Equestrian Survey
479 2015 (BETA, 2015). The distribution/promotion of the current
480 survey was online, which might lead to non-response bias by
481 only reaching those individuals with access to the internet.
482 Nevertheless, a recent study has demonstrated that online
483 questionnaires could potentially replace hard-copy
484 questionnaires without compromising response rates (Hohwu et
485 al., 2013). This questionnaire was partly distributed via equine

486 veterinarian practices to their clients, which could also have
487 skewed the results towards approaches that those practices
488 promote. It is also possible that horse owners who participated
489 here were more in favour of using FEC tests and the currently-
490 recommended approaches. Finally, there could also be a social
491 desirability bias. This type of response bias is the increased
492 likelihood that survey participants select answers in such a
493 manner that will be viewed favourably by others. This type of
494 bias was recently described in a horse owner survey as a factor
495 influencing the use of FEC tests before treatment (Rose Vineer
496 et al., 2017).

497 Here, respondents had a good general knowledge of
498 parasites/parasitic disease. When asked to identify the most
499 important parasites to target, many responses matched the
500 reports in scientific articles; namely cyathostomins as the most
501 important parasite to target, followed by tapeworm and large
502 strongyles (Kaplan and Nielsen, 2010). Respondents using TT
503 protocols were more satisfied with their level of parasitology
504 knowledge compared to IT-participants. This is similar to a
505 previous UK survey study that also showed that horse owners
506 who were less satisfied with their level of knowledge were 57%
507 less likely to follow TT strategies (Allison et al., 2011).
508 Nevertheless, in the current study, just under a quarter of
509 respondents were still not satisfied with their knowledge levels,

510 highlighting a requirement for improving knowledge transfer to
511 horse owners in the UK.

512 The most commonly used anthelmintic class reported in
513 previous studies in the UK and elsewhere was the macrocyclic
514 lactones (Fritzen et al., 2010; Hinney et al., 2011; Relf et al.,
515 2012; Stratford et al., 2014; Robert et al., 2015; Salle and
516 Cabaret, 2015) and this was the case for the current study. Note
517 that treatment frequency was not recorded here because it was
518 difficult to assimilate information in the TT group as, at certain
519 times, treatment was linked to egg shedding levels in individuals.
520 The high reliance on macrocyclic lactones needs to be addressed,
521 especially in IT programmes, because of the strong selection
522 pressure for resistance caused by regular treatments using the
523 same type of compound (Matthews, 2008; Tzelos and Matthews,
524 2016). A total of 74 (out of 463) respondents stated that; “I do
525 not know what these chemical terms are”. This is of concern and
526 indicates sub-standard information transfer at the point of sale or
527 in the advice given before purchase.

528 Anthelmintic resistance was the topic that most
529 respondents were concerned about, with those using TT
530 protocols significantly more concerned about this issue
531 compared to the IT group as indicated by the Chi-square analysis
532 here. Nevertheless, approximately 75% of the overall study
533 population were not aware of the status of anthelmintic
534 resistance in worm populations at their premises. This particular

535 discrepancy has also been reported in the past in a questionnaire
536 study examining the interaction of horse owners with
537 anthelmintic prescribers (Easton et al., 2016). Potential reasons
538 associated with the lack of efficacy testing include the perception
539 of additional labour in collecting the samples and the additional
540 economic cost. Another potential reason might be the lack of
541 promotion or emphasis of efficacy testing by prescribers to horse
542 owners. Current recommendations are that a FECRT be
543 performed each year to avoid using ineffective anthelmintics
544 (Tzelos and Matthews, 2016). Going forward, considering the
545 levels of anthelmintic resistance reported in cyathostomins and
546 in *P. equorum* (Raza et al., 2019), improved knowledge transfer
547 from prescribers to horse owners needs to highlight the benefit
548 of efficacy testing.

549 Although the majority of respondents sought advice on
550 anthelmintic selection from a veterinarian or SQP, only a small
551 proportion bought anthelmintics from these sources, with the
552 main route of purchase being internet retailers. A recent analysis
553 of UK horse owner anthelmintic purchasing behaviours similarly
554 demonstrated that most respondents received advice from
555 veterinarians before purchasing dewormers online (Easton et al.,
556 2016). In the current study, it was more likely that respondents
557 would follow an IT protocol when advice was sought from an
558 internet retailer. Getting information from an internet retailer is
559 not ideal; one study showed that horse owners who purchased

560 anthelmintics online most often stated they received little/no
561 specific advice at the point of purchase (Easton et al., 2016).
562 Face-to-face interactions with veterinarians or other qualified
563 prescribers (in the UK, SQPs or veterinary pharmacists) should
564 be encouraged as it has been shown that horse owners who
565 purchased anthelmintics from veterinarians (and other
566 prescribers, SQPs or veterinary pharmacists) were more likely to
567 be recommended FEC test analysis in their interaction than
568 online retailers (Easton et al., 2016).

569 It was more likely for IT-participants to treat *all* new
570 acquisitions with anthelmintics than those following a TT
571 protocol. Approximately 12% of TT-participants performed
572 FEC analysis on new arrivals and applied a treatment based on
573 the test results. The latter approach would not inform on the
574 presence of immature helminth stages and standard FEC analysis
575 is unlikely to provide information on the presence of
576 *Anoplocephala perfoliata* infection. Thus, it is recommended
577 that new acquisitions be treated with a product containing
578 moxidectin to target strongyle larvae and adult stages and that
579 these horses be kept off pasture for at least 3 days after treatment
580 (Tzelos and Matthews, 2016). Testing for *A. perfoliata* infection
581 using an ELISA-based test (in the UK) or treatment with
582 praziquantel is also recommended (Tzelos and Matthews, 2016).
583 Here, a product containing moxidectin was used by only 32.3%
584 of respondents when treating new arrivals. Best practice

585 quarantine recommendations need to be disseminated more
586 widely.

587 Foal treatment was another aspect that a knowledge gap
588 was identified. Current suggestions for foal treatment include
589 specific treatments at specific time due to the relatively long
590 prepatent period of ascarid infections, which should be the main
591 focus for foals (Tzelos and Matthews, 2016). Most participants
592 that replied to this question (37.1%; 26/70) stated that they used
593 the same anthelmintics with adult horses, but with different
594 dosing regimen. It is worth mentioning here that a total of 39/70
595 respondents that replied to the previous question stated that they
596 had nil foals. This discrepancy could be because they might not
597 had foals at their premises at the time the survey took place, but
598 they did in the past and felt like they should answer the question.
599 Generally, more emphasis should be given in advice on helminth
600 control practices in foals in the future.

601 Dung removal from pasture plays a crucial role in
602 reducing infection pressure in the environment (Herd, 1986).
603 Here, 74.4% respondents stated that they removed dung, similar
604 to levels in a recent UK survey where ~80% of respondents
605 stated that they did this (Easton et al., 2016). These levels of
606 uptake are the highest reported to date and are higher than
607 reported in other countries (O'Meara and Mulcahy, 2002; Lind
608 et al., 2007; Fritzen et al., 2010; Bolwell et al., 2015) and offer
609 hope that some messages on sustainable helminth control are

610 reaching the target audience in the UK. Potential reasons
611 associated with the unwillingness of horse owners/managers to
612 engage with this activity include land gradient, increased horse
613 numbers, labour associated, limited staff resources and/or lack
614 of knowledge.

615

616 **5. Conclusion**

617 Overall and despite the aforementioned limitations, the
618 results of this study highlight; 1) a recent shift from IT to TT
619 strategies on many yards in the UK, 2) some confusion in the
620 interpretation of current quarantine treatment guidelines, 3) a
621 lack of anthelmintic efficacy testing overall and 4) high
622 proportions of the horse owners purchasing anthelmintics online.
623 The areas in which knowledge gaps were identified should be
624 considered to enhance knowledge dissemination in the future.
625 Improving knowledge in horse owners, especially in those who
626 do not use a face-to-face interaction for advice on helminth
627 control, could be facilitated by developing accurate knowledge-
628 transfer tools such as free guidelines or decision support tools.
629 Alternatively, these issues could be addressed by altering
630 prescribing legislation to promote better quality face-to-face
631 interactions when anthelmintics are sold and minimise the
632 amount of anthelmintics purchased online.

633

634 **Acknowledgements**

635 This work was supported by funding from The Horse Trust
636 (Project Grant Reference: G4014). The authors would like to
637 thank the respondents for completing the survey and the equine
638 veterinary practices for promoting the survey.

639

640 **References**

- 641 Allison, K., Taylor, N.M., Wilsmore, A.J., Garforth, C., 2011. Equine
642 anthelmintics: survey of the patterns of use, beliefs and
643 attitudes among horse owners in the UK. *Vet. Rec.* 168, 483.
- 644 BETA, 2015. The National Equestrian Survey: Overview Report,
645 British Equestrian Trade Association, UK.
- 646 Bolwell, C.F., Rosanowski, S.M., Scott, I., Sells, P.D., Rogers, C.W.,
647 2015. Questionnaire study on parasite control practices on
648 Thoroughbred and Standardbred breeding farms in New
649 Zealand. *Vet. Parasitol.* 209, 62-69.
- 650 Canever, R.J., Braga, P.R., Boeckh, A., Grycajuck, M., Bier, D.,
651 Molento, M.B., 2013. Lack of *Cyathostomin* sp. reduction
652 after anthelmintic treatment in horses in Brazil. *Veterinary*
653 *parasitology* 194, 35-39.
- 654 Corbett, C.J., Love, S., Moore, A., Burden, F.A., Matthews, J.B.,
655 Denwood, M.J., 2014. The effectiveness of faecal removal
656 methods of pasture management to control the
657 cyathostomin burden of donkeys. *Parasit. Vectors* 7, 1-7.
- 658 Drudge, J.H., Lyons, E.T., 1966. Control of internal parasites of the
659 horse. *Journal of the American Veterinary Medical*
660 *Association* 148, 378-383.
- 661 Easton, S., Pinchbeck, G.L., Tzelos, T., Bartley, D.J., Hotchkiss, E.,
662 Hodgkinson, J.E., Matthews, J.B., 2016. Investigating
663 interactions between UK horse owners and prescribers of
664 anthelmintics. *Prev. Vet. Med.* 135, 17-27.
- 665 Fritzen, B., Rohn, K., Schnieder, T., von Samson-Himmelstjerna, G.,
666 2010. Endoparasite control management on horse farms--
667 lessons from worm prevalence and questionnaire data.
668 *Equine Vet. J.* 42, 79-83.
- 669 Geurden, T., van Doorn, D., Claerebout, E., Kooyman, F., De
670 Keersmaecker, S., Vercruysse, J., Besognet, B., Vanimisetti,
671 B., di Regalbono, A.F., Beraldo, P., Di Cesare, A., Traversa, D.,
672 2014. Decreased strongyle egg re-appearance period after
673 treatment with ivermectin and moxidectin in horses in
674 Belgium, Italy and The Netherlands. *Vet. Parasitol.* 204, 291-
675 296.
- 676 Herd, R.P., 1986. Epidemiology and control of equine strongylosis at
677 Newmarket. *Equine veterinary journal* 18, 447-452.
- 678 Herd, R.P., 1993. Control strategies for ruminant and equine
679 parasites to counter resistance, encystment, and ecotoxicity
680 in the USA. *Vet. Parasitol.* 48, 327-336.
- 681 Hinney, B., Wirtherle, N.C., Kyule, M., Miethe, N., Zessin, K.H.,
682 Clausen, P.H., 2011. A questionnaire survey on helminth
683 control on horse farms in Brandenburg, Germany and the
684 assessment of risks caused by different kinds of
685 management. *Parasitol. Res.* 109, 1625-1635.
- 686 Hohwu, L., Lyshol, H., Gissler, M., Jonsson, S.H., Petzold, M., Obel,
687 C., 2013. Web-based versus traditional paper
688 questionnaires: a mixed-mode survey with a Nordic
689 perspective. *J. Med. Internet Res.* 15, e173.

690 Kaplan, R.M., 2002. Anthelmintic resistance in nematodes of horses.
691 Vet. Res. 33, 491-507.

692 Kaplan, R.M., Nielsen, M.K., 2010. An evidence-based approach to
693 equine parasite control: It ain't the 60s anymore. Equine
694 Vet. Educ. 22, 306-316.

695 Lester, H.E., Matthews, J.B., 2014. Faecal worm egg count analysis
696 for targeting anthelmintic treatment in horses: points to
697 consider. Equine Vet. J. 46, 139-145.

698 Lind, E.O., Rautalinko, E., Ugglä, A., Waller, P.J., Morrison, D.A.,
699 Høglund, J., 2007. Parasite control practices on Swedish
700 horse farms. Acta Vet. Scand. 49, 25.

701 Lyons, E.T., Tolliver, S.C., 2013. Further indication of lowered activity
702 of ivermectin on immature small strongyles in the intestinal
703 lumen of horses on a farm in Central Kentucky. Parasitol.
704 Res. 112, 889-891.

705 Lyons, E.T., Tolliver, S.C., Collins, S.S., 2009. Probable reason why
706 small strongyle EPG counts are returning "early" after
707 ivermectin treatment of horses on a farm in Central
708 Kentucky. Parasitol. Res. 104, 569-574.

709 Lyons, E.T., Tolliver, S.C., Collins, S.S., Ionita, M., Kuzmina, T.A.,
710 Rossano, M., 2011. Field tests demonstrating reduced
711 activity of ivermectin and moxidectin against small
712 strongyles in horses on 14 farms in Central Kentucky in
713 2007–2009. Parasitol. Res. 108, 355-360.

714 Lyons, E.T., Tolliver, S.C., Kuzmina, T.A., Collins, S.S., 2010. Critical
715 tests evaluating efficacy of moxidectin against small
716 strongyles in horses from a herd for which reduced activity
717 had been found in field tests in Central Kentucky. Parasitol.
718 Res. 107, 1495-1498.

719 Matthews, J.B., 2008. An update on cyathostomins: Anthelmintic
720 resistance and worm control. Equine Vet. Educ. 20, 552-560.

721 Matthews, J.B., 2014. Anthelmintic resistance in equine nematodes.
722 Int. J. Parasitol. Drugs Drug Resist. 4, 310-315.

723 McArthur, C.L., Handel, I.G., Robinson, A., Hodgkinson, J.E.,
724 Bronsvoort, B.M., Burden, F., Kaplan, R.M., Matthews, J.B.,
725 2015. Development of the larval migration inhibition test for
726 comparative analysis of ivermectin sensitivity in
727 cyathostomin populations. Veterinary parasitology 212, 292-
728 298.

729 Nielsen, M.K., Pfister, K., von Samson-Himmelstjerna, G., 2014a.
730 Selective therapy in equine parasite control--application and
731 limitations. Vet. Parasitol. 202, 95-103.

732 Nielsen, M.K., Reist, M., Kaplan, R.M., Pfister, K., van Doorn, D.C.,
733 Becher, A., 2014b. Equine parasite control under
734 prescription-only conditions in Denmark--awareness,
735 knowledge, perception, and strategies applied. Vet.
736 Parasitol. 204, 64-72.

737 O'Meara, B., Mulcahy, G., 2002. A survey of helminth control
738 practices in equine establishments in Ireland. Vet. Parasitol.
739 109, 101-110.

740 Peregrine, A.S., Molento, M.B., Kaplan, R.M., Nielsen, M.K., 2014.
 741 Anthelmintic resistance in important parasites of horses:
 742 does it really matter? *Vet. Parasitol.* 201, 1-8.
 743 Proudman, C., Matthews, J., 2000. Control of intestinal parasites in
 744 horses. *In Pract.* 22, 90-97.
 745 Raza, A., Qamar, A.G., Hayat, K., Ashraf, S., Williams, A.R., 2019.
 746 Anthelmintic resistance and novel control options in equine
 747 gastrointestinal nematodes. *Parasitology* 146, 425-437.
 748 Reid, S.W., Mair, T.S., Hillyer, M.H., Love, S., 1995. Epidemiological
 749 risk factors associated with a diagnosis of clinical
 750 cyathostomiasis in the horse. *Equine veterinary journal* 27,
 751 127-130.
 752 Reinemeyer, C.R., 2009. Diagnosis and control of anthelmintic-
 753 resistant *Parascaris equorum*. *Parasit. Vectors* 2 Suppl 2, S8.
 754 Relf, V.E., Lester, H.E., Morgan, E.R., Hodgkinson, J.E., Matthews,
 755 J.B., 2014. Anthelmintic efficacy on UK Thoroughbred stud
 756 farms. *Int. J. Parasitol.* 44, 507-514.
 757 Relf, V.E., Morgan, E.R., Hodgkinson, J.E., Matthews, J.B., 2012. A
 758 questionnaire study on parasite control practices on UK
 759 breeding Thoroughbred studs. *Equine Vet. J.* 44, 466-471.
 760 Robert, M., Hu, W., Nielsen, M.K., Stowe, C.J., 2015. Attitudes
 761 towards implementation of surveillance-based parasite
 762 control on Kentucky Thoroughbred farms - Current
 763 strategies, awareness and willingness-to-pay. *Equine Vet. J.*
 764 47, 694-700.
 765 Rosanowski, S.M., Scott, I., Sells, P.D., Rogers, C.W., Bolwell, C.F.,
 766 2016. Cross-sectional survey of parasite control practices on
 767 Thoroughbred and Standardbred training yards in New
 768 Zealand. *Equine Vet. J.* 48, 387-393.
 769 Rose Vineer, H., Vande Velde, F., Bull, K., Claerebout, E., Morgan,
 770 E.R., 2017. Attitudes towards worm egg counts and targeted
 771 selective treatment against equine cyathostomins. *Prev.*
 772 *Vet. Med.* 144, 66-74.
 773 Rossano, M.G., Smith, A.R., Lyons, E.T., 2010. Shortened strongyle-
 774 type egg reappearance periods in naturally infected horses
 775 treated with moxidectin and failure of a larvicidal dose of
 776 fenbendazole to reduce fecal egg counts. *Vet. Parasitol.* 173,
 777 349-352.
 778 Salle, G., Cabaret, J., 2015. A survey on parasite management by
 779 equine veterinarians highlights the need for a regulation
 780 change. *Vet. Rec. Open* 2, e000104.
 781 Sangster, N.C., 2001. Managing parasiticide resistance. *Vet.*
 782 *Parasitol.* 98, 89-109.
 783 Sidak, Z., 1967. Rectangular Confidence Regions for the Means of
 784 Multivariate Normal Distributions. *J. Am. Stat. Assoc.* 62,
 785 626-633.
 786 Stratford, C.H., Lester, H.E., Morgan, E.R., Pickles, K.J., Relf, V.,
 787 McGorum, B.C., Matthews, J.B., 2014. A questionnaire study
 788 of equine gastrointestinal parasite control in Scotland.
 789 *Equine Vet. J.* 46, 25-31.

790 Traversa, D., von Samson-Himmelstjerna, G., Demeler, J., Milillo, P.,
 791 Schürmann, S., Barnes, H., Otranto, D., Perrucci, S., di
 792 Regalbono, A.F., Beraldo, P., Boeckh, A., Cobb, R., 2009.
 793 Anthelmintic resistance in cyathostomin populations from
 794 horse yards in Italy, United Kingdom and Germany. *Parasit.*
 795 *Vectors* 2, 1-7.
 796 Tzelos, T., Barbeito, J.S., Nielsen, M.K., Morgan, E.R., Hodgkinson,
 797 J.E., Matthews, J.B., 2017. Strongyle egg reappearance
 798 period after moxidectin treatment and its relationship with
 799 management factors in UK equine populations. *Vet.*
 800 *Parasitol.* 237, 70-76.
 801 Tzelos, T., Matthews, J., 2016. Anthelmintic resistance in equine
 802 helminths and mitigating its effects. In *Pract.* 38, 489-499.
 803 van Doorn, D.C.K., Ploeger, H.W., Eysker, M., Geurden, T.,
 804 Wagenaar, J.A., Kooyman, F.N.J., 2014. *Cylicocycclus* species
 805 predominate during shortened egg reappearance period in
 806 horses after treatment with ivermectin and moxidectin. *Vet.*
 807 *Parasitol.* 206, 246-252.
 808 von Samson-Himmelstjerna, G., 2012. Anthelmintic resistance in
 809 equine parasites - detection, potential clinical relevance and
 810 implications for control. *Vet. Parasitol.* 185, 2-8.
 811 von Samson-Himmelstjerna, G., Fritzen, B., Demeler, J., Schurmann,
 812 S., Rohn, K., Schnieder, T., Epe, C., 2007. Cases of reduced
 813 cyathostomin egg-reappearance period and failure of
 814 *Parascaris equorum* egg count reduction following
 815 ivermectin treatment as well as survey on pyrantel efficacy
 816 on German horse farms. *Vet. Parasitol.* 144, 74-80.

817

818