AAEP Internal Parasite Control Guidelines

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Take-Home Messages

- Perform fecal egg count reduction tests (FECRT) annually to ensure that you are using effective dewormers in every herd or barn.
- Recognize that no anthelmintic will eliminate all parasitic stages from a horse.
- Continue using fecal egg counts (FEC) once or twice a year to stratify horses into low, medium, and high shedders to reduce pasture contamination.
- Deworm all horses at a baseline rate (once or twice a year) and target selected horses more often based on FEC (strongyle high shedders).
- Do not use FEC to diagnose disease in horses; there is no correlation between FEC and disease-causing parasite life stages.
- Discontinue deworming all horses with fixed intervals year-round (e.g., every 2 months), and stop blindly rotating anthelmintic classes.

1. Goals of Parasite Control

The true goal of parasite control in horses is to keep animals healthy and reduce the risk of clinical illness. The goal is NOT to eradicate all parasites from a particular individual. Not only is eradication impossible, the inevitable result of pursuing this goal is accelerated development of parasite drug resistance.

The **goals** of any parasite control program can be summarized as follows:

- To minimize the risk of parasitic disease.
- To delay further development of anthelmintic resistance and maintain efficacious drugs for as long as possible.

2. Introduction

2.1. Cyathostomins (Small Strongyles)

Equine strongyles represent the most commonly encountered internal parasite group in horses worldwide. Cyathostomins (small strongyles) are truly ubiquitous in grazing horses, but they are rarely associated with disease. Acute Larval Cyathostominosis is a disease syndrome caused by mass synchronous excystment of cyathostomin larvae from the large intestinal walls leading to a generalized typhlocolitis. This disease is described with a 50% case-fatality rate in the United Kingdom (Reid et al., 1995, Lawson et al., 2023), but it is rarely encountered in the U.S. and does not appear to constitute a major concern.

In arid regions or in horses that are not kept on green pastures, strongyle parasites are unlikely to require primary attention in parasite control programs.

2.2. Large strongyles

The group of large strongyles includes *Strongylus vulgaris*, which is considered the most pathogenic equine gastrointestinal helminth. Also known as the bloodworm, this parasite can cause thromboembolism and life-threatening peritonitis (Pihl et al., 2019). Decades of intensive anthelmintic treatment appear to have reduced the occurrence of this parasite to often undetectable levels within the U.S. (Nielsen et al., 2012a). However, in Scandinavian countries, where anthelmintic products are available on a prescription-only basis and treatment intensities are substantially lower than in the U.S., a re-emergence of this parasite has been reported (Nielsen et al., 2012b; Tydén et al., 2019) and infection has been associated with clinically significant disease (Nielsen et al., 2016; Hedberg-Alm et al., 2022).

2.3. *Anoplocephala perfoliata* (Tapeworms)

Necropsy surveys performed in Kentucky reported *Anoplocephala perfoliata* prevalence of approximately 50% both prior to and after the introduction of widespread use of cestocidal drugs in horses (Lyons et al., 1984; 2000). The prevalence in other parts of the U.S. is unknown; however, tapeworms must be considered common in grazing horses.

Several studies have documented an association between the presence of tapeworms and colic originating from the ileocecal region (Nielsen, 2016a). Tapeworms produce small mucosal erosions at the site of attachment, and infection has been associated with ileal impactions, ileocecal intussusceptions, and spasmodic colic (Nielsen, 2016a). However, most horses infected with tapeworms tend to have relatively few worms, and these likely produce little in the way of pathogenic consequences.

In arid regions or in horses that are not kept on green pastures, tapeworms are unlikely to require primary attention in parasite control programs.

2.4. *Parascaris* spp. (Roundworms; Ascarids)

This parasite is common in breeding operations worldwide, and it is the most important helminth pathogen in foals. Migrating larvae can cause signs of airway inflammation, including cough and nasal discharge (Clayton, 1986), although this appears to be rare. The most clinically important manifestation of *Parascaris* spp. infection in horses is a verminous small intestinal impaction, which occurs in a small subset of infected foals. This condition is associated with a guarded prognosis for survival, and it can be further complicated by intestinal volvulus, intussusception, and rupture, as well as post-operative adhesions in foals that required surgical intervention (Nielsen, 2016b).

Current evidence suggests that deworming a heavily parasitized foal with an efficacious anthelmintic can trigger an impaction of dead or dying worms in the intestinal lumen (Nielsen, 2016b). Claims have been made that this may be primarily associated with anthelmintics with a paralytic mode of action (such as ivermectin and pyrantel), and it remains possible that benzimidazole-type drugs may represent a safer treatment choice for *Parascaris* spp. infections due to their non-paralytic mode of action and slower onset of effect. However, these claims are not supported by strong evidence.

Parascaris spp. infections may occasionally be diagnosed in apparently immunocompetent adult horses, but clinical disease is an extremely rare event in this age group.

2.5. *Strongyloides westeri* (Threadworms)

Strongyloides westeri infection is common in young foals (Lyons and Tolliver, 2014), but this parasite is rarely associated with disease. Further, it is generally not considered part of the panel of pathogens known to commonly cause diarrhea in this age group. Larvae of this parasite are known to transmit lactogenically from mares to foals, but it should be kept in mind that it can also infect through fecal/oral and percutaneous routes. In addition, *S. westeri* is a facultative parasite, which can maintain a full life-cycle in the environment without entering a host. Thus, focusing solely on interrupting one route of transmission may not be successful.

2.6. *Oxyuris equi* (Pinworms)

Clinical disease from pinworms historically was seen mostly in young horses. However, cases in adult horses appear to be becoming more common (Reinemeyer and Nielsen, 2014). Pinworm infections tend to be sporadic, and usually a subset of horses are affected out of a group. Clinical signs vary in intensity, but in severe cases, intense tail rubbing and hindquarter and/or perineal skin excoriations are seen. Horses may have patent pinworm infections without showing any specific clinical signs. As a consequence of the rubbing, horses can spread pinworm eggs throughout their environment, and transmission can potentially occur in many locations including stalls and from contact with grooming materials, tail wraps, fence posts, etc.

2.7. *Gasterophilus* spp. (Bots)

Botfly larval infections are common in horses, and two species are primarily encountered in North America: *Gasterophilus nasalis* and *G. intestinalis*. Of these, *G. intestinalis* is by far the most common. Botfly larvae are generally mild pathogens and are rarely associated with clinical disease. However, they are a common incidental finding in the stomach during gastroscopic examination, causing unwarranted horse owner concern. The oral stages of infection have been associated with periodontitis with salivation, head shaking, lingual irritation, and chewing problems (Lind et al., 2012).

2.8. *Habronema* and *Draschia* spp. (Stomach Worms)

Habronema and *Draschia* spp. are vector-borne nematodes, whose adult stages reside in the stomach, but they are rarely associated with clinical disease. Cutaneous habronemosis (summer sores) is a well-described manifestation of larvae being aberrantly deposited into wounds or on mucosal membranes by their fly vectors. This causes persistent granulomatous lesions that are often challenging to treat. In some arid regions of the U.S., particularly the Southwest, cutaneous habronemosis may be more common than clinical conditions caused by tapeworms or strongyles.

2.9. *Onchocerca cervicalis* (Neck Threadworm)

The Neck Threadworm has gained increasing attention in recent years, although very few studies have focused on this parasite. Studies performed in the 1980s and 1990s demonstrated *O. cervicalis* prevalence in the 20-80% range in U.S. horses (Klei et al., 1984; Cummings and James, 1985; Lyons et al., 2000), but more recent surveys are lacking. Adult worms are considered refractory to anthelmintic treatment (Lyons et al., 1988), and females appear to remain viable for up to 20 years, which can explain why prevalence has been demonstrated to increase with horse age (Lyons et al., 1986).

Microfilariae of *O. cervicalis* may cause dermatitis of the ventral midline and/or limbs, shoulders, thorax, and withers, which responds positively to ivermectin treatment (French et al., 1988). As opposed to the adult stages, the microfilariae have been demonstrated to be susceptible to both ivermectin and moxidectin treatment (French et al., 1988; Monahan et al., 1995).

3. Parasite Diagnostics and Their Performance

3.1. Diagnosing parasitic disease

Diagnosing cases of equine parasitic disease is not as straightforward as it might appear. Detecting parasite eggs in fecal samples does not indicate parasitic contribution to a clinical presentation since parasite egg shedding is a normal finding in clinically healthy animals. Instead, diagnosing parasitic disease should rely on pattern recognition among clinical findings and other test results. Below are examples of hallmark findings.

Larval cyathostominosis: Diarrhea/loose feces, hypoalbuminemia, neutrophilia, weight loss, dehydration, ventral edema, and thickened large intestinal walls on ultrasonography.

Ascarid impaction: Colic presentation in foals, weanlings, and yearlings with ultrasonographic evidence of a large ascarid burden in the small intestine.

Tapeworm-associated colic: Ileal impactions or intussusceptions may be evident upon rectal palpation or ultrasonography.

3.2. Fecal egg counts

Numerous techniques exist for determining fecal egg counts (FECs) and the use of these in equine practice has recently been reviewed (Nielsen, 2022a). Some misconceptions are common regarding the interpretation of these counts, and the following should be emphasized:

- FEC magnitude **does not** correlate with the size of the parasite burden.
- FECs **cannot** be used to evaluate possible parasitic involvement in a horse displaying clinical manifestations.
- FECs **do not** indicate a risk of disease or possible adverse reactions to anthelmintic treatment.

Box 1: Use of Fecal Egg Counts

Purposes:

To evaluate anthelmintic efficacy using the fecal egg count reduction test (FECRT).

To evaluate and monitor the strongyle egg reappearance period (ERP) of the most recently administered dewormer.

To determine the strongyle egg shedding status of the adult horse at the time of sampling (*e.g.,* high or low shedder).

To determine the relative makeup of parasite burdens in foals and weanlings (*i.e.,* whether the primary parasites are *Parascaris* spp., strongyles, or both).

Limitations:

They do not detect immature or larval stages of parasites including migrating large strongyles and ascarids, and/or encysted cyathostomins.

Egg morphology does not allow identification of large strongyles, nor species differentiation of small strongyles.

Tapeworm infections are often missed or underestimated by standard FEC techniques, and modified techniques are required.

Pinworm infections are usually missed since the eggs are adhered to the perianal region rather than being shed in the feces.

Fecal sampling and storage:

Samples should be stored in airtight and leak-proof containers or plastic bags.

Collected manure should be as fresh as possible. Samples less than 12 hours old are acceptable but should be refrigerated immediately after collection (Nielsen et al., 2010b).

Refrigeration is always recommended for storage of fecal samples, but anaerobic storage at room temperature will also prevent eggs from hatching. Anaerobic storage can be achieved by squeezing all the air out of the bag, or by using a vacuum-sealing device.

Samples should preferably be tested within 7 days of collection, although there are indications that eggs can remain intact for longer if adequately refrigerated.

Fecal samples that are or have been frozen are not acceptable, as this will damage the eggs and decrease the recovery rate.

Diarrhetic samples are not acceptable for FEC but can be used for qualitative testing.

Microscope Use and Maintenance

Make sure that microscope lenses are adjusted to the working distance offered by parasitology slides used for the egg counts.

Make good use of contrast (aperture condenser) to help visualizing morphological features.

To improve skills at parasite egg identification, several resources are available online and in textbooks. One should consider review by a veterinary parasitologist if questions arise.

It is recommended that microscopes be equipped with an ocular micrometer so that eggs and other questionable objects can be measured. Having measurements can greatly assist in the identification. Cheap digital cameras can be acquired with software allowing these measurements.

A large number of FEC techniques are available today, and the choice of technique will depend on the purpose of the count (Nielsen, 2022a). Appendix A contains a protocol for the McMaster technique, which is the most useful technique in equine veterinary practice. The McMaster is useful for monitoring strongyle egg shedding status and presence of ascarids, while other techniques may offer better accuracy and precision, which would make them better choices for the FECRT. In recent years, automated image-analysis based egg counting techniques have been made available and validations demonstrate good precision of some of these (Cain et al., 2020), suggesting that these could be useful as well.

3.3. Strongyles

Strongyle FECs are used to estimate the level of strongyle egg shedding contributed by each horse in a given herd, and to evaluate treatment efficacy with the fecal egg count reduction test (FECRT, see this section). Quantitative performance is summarized for two commonly used techniques in Table 1. The Wisconsin technique is generally not considered suitable for equine usage due to its low accuracy and precision. For identification of high strongyle shedders, techniques with moderate to high accuracy levels are recommended.

Table 1. Accuracy and precision levels for determining equine strongyle fecal egg counts for two commonly used manual fecal egg counting techniques.

Technique	Multiplication factor	Accuracy[1]	Precision[2]	References
McMaster	25, 50	Moderate-high	Moderate	Noel et al., 2017; Cain et al., 2020
Wisconsin	1	Low	Low	Cain et al., 2020

[1] Accuracy is a measure of how close the test measurement is to the true fecal egg count.
[2] Precision is a measure of how close repeated measurements are to each other.

Strongyle egg counts typically follow an overdispersed distribution within herds of horses with most horses shedding low or moderate levels and a minority of the horses being high strongyle shedders. This is often described as the 20/80 rule, since 20% or less of the horses in each herd excrete 80% of the total egg output (Kaplan and Nielsen, 2010). Furthermore, research has documented that mature horses have a strong tendency to consistently maintain the same level of strongyle egg shedding across time (Nielsen et al., 2006; Becher et al., 2010; Scheuerle et al., 2016). Therefore, FEC testing is recommended to identify high strongyle shedders within a herd and treat them appropriately. FECs can be determined year-round, and there are no fluctuations in reliability across seasons.

3.4. Ascarids

Ascarid shedding is most often limited to specific age ranges and varies widely over time, which means that there is no long-term shedding consistency in individual horses. Thus, the most important applications of ascarid FECs are 1) qualitative detection of infection (positive/negative) and 2) treatment efficacy evaluation (see FECRT section). There is very limited validation information available on the performance of various techniques for ascarid FECs; therefore, no specific technique can be recommended at this time. A recent study suggested that the McMaster technique performed with good precision for determining ascarid FECs (Ripley et al., 2023).

3.5. Tapeworms

Tapeworm eggs are not shed directly into the intestinal tract; rather, gravid proglottids containing eggs break off and eggs are subsequently released into the feces. This has practical implications for the detection of tapeworm eggs in feces; the diagnostic sensitivity of the general McMaster technique is less than 10% for diagnosing equine tapeworm (*A. perfoliata*) infections (Nielsen, 2016a). A modification of a centrifugation-based egg counting technique using 40 grams of feces has been validated to have a diagnostic sensitivity and specificity of 0.61 and 0.98, respectively (Proudman and Edwards, 1992). For detecting tapeworm burdens of 20 worms and above, the sensitivity of this method was found to be 0.90, which is very good for a parasitological diagnostic test. Results are typically not reported as eggs per gram of feces, but rather as the number of eggs counted. Samples should generally be interpreted as being either negative or positive, since there is no correlation of tapeworm egg counts and number of worms infecting a horse. However, egg counts are useful when treatment efficacy is being evaluated. Studies have shown a higher proportion of positive samples in horses treated with effective anthelmintics 24 hours prior to sampling (Slocombe, 2006), and this represents a pragmatic approach to increasing diagnostic sensitivity of tapeworm FECs.

Validated serum and salivary ELISAs are commercially available in the United Kingdom (Proudman and Trees, 1996; Lightbody et al., 2016). These assays measure *A. perfoliata*-specific antibodies and titer levels and have been found to correlate with worm burdens. However, being antibody-based tests, they may reflect exposure rather than actual infection, and horses can remain positive for months after treatment (Abbott et al., 2008). A different serological test for the presence of antibodies to *A. perfoliata* is available at the University of Tennessee Diagnostic Laboratory Services, but the test lacks sufficient validation as a quantitative assay for use in detecting current infections or for measuring worm burdens in individual horses. More useful ELISAs may become available in the U.S. in the future.

3.6. Pinworms

Pinworm eggs (*O. equi*) can sometimes be found on a fecal exam, but the Scotch tape test or a microscopic examination of perineal scrapings (using a tongue depressor and lube) are expected to be more sensitive.

3.7. Neck Threadworms

Onchocerca spp. microfilariae can be detected by microscopic examination of skin biopsies collected from affected areas along the neck or ventral midline. This technique has been demonstrated to provide useful estimates of anti-microfilarial treatment efficacy (French et al., 1988; Monahan et al., 1995), but is rarely used as a standard test in practice.

4. Anthelmintic Treatment Evaluation

Anthelmintic treatment efficacy is evaluated for the **parasite population**, of which each horse is a biological sample. Conclusions are drawn for the given population, not the individual horses tested. A general and pragmatic rule of thumb is that any anthelmintic should reduce both ascarid and strongyle fecal egg counts by **more than 95% at 14 days after treatment.**

This is evaluated by following these simple steps:

Determine fecal egg counts from a group of horses grazing together.

Deworm these horses at the labeled dosage and route of administration of the anthelmintic product being evaluated.

Determine egg counts from the same individual horses at 14 days treatment.

Make an assessment of the percent reduction for the overall population; unless only a single horse is tested, do not make interpretations for individual horses of the group tested.

If the mean fecal egg count reduction **falls below expected levels**, the following steps are recommended:

Check storage conditions, expiration date, and dosage of the product administered.

Repeat the treatment and determine new fecal egg counts at 14 days post treatment. If the efficacy still falls below expected levels, it is strongly suggestive of anthelmintic resistance.

Choose a different anthelmintic class and repeat the exercise.

In case of documented resistance to all available drug classes, it is recommended to use the class with the highest observed efficacy.

4.1. Resistance testing

Guidelines for anthelmintic resistance testing using the FECRT have been thoroughly revised by a committee of experts appointed by the World Association for the Advancement of Veterinary Parasitology (WAAVP). These guidelines were published in 2023 (Kaplan et al., 2023), and veterinarians can read these for more detailed guidance. Note that the guidelines manuscript is published as open-access and is available free of charge at the publisher's website. A general description of this new approach for anthelmintic resistance screening is outlined in the following paragraphs.

There are three new principles introduced within the WAAVP guidelines:

1) Thresholds for expected treatment efficacy are now based on historic efficacy data recorded for the anthelmintics when the products were first introduced to the equine market. These thresholds differ slightly between the different anthelmintic classes and parasite categories, and these differences impact the optimal protocol for testing each of the drug classes and/or parasite types.

2) Recommendations are based on an "eggs counted" principle, which refers to the number of eggs counted under the microscope before the conversion to eggs per gram (EPG) of feces. Defining the minimum number of eggs counted pre-treatment ensures adequate statistical power for the test. This also provides flexibility in the choice of FEC method depending on the mean FEC of the group of horses.

3) The conclusions are no longer based solely on calculating mean percent egg count reductions, but instead on statistical confidence limits, which consider the variation observed in the levels of egg count reduction seen between horses.

The guidelines have two efficacy thresholds for interpreting the results: an upper threshold, which represents the expected level of efficacy (when there is no resistance) of the product based on historic information; and a lower threshold, below which the efficacy can be interpreted as significantly reduced and indicative of drug resistance. The interval between the two thresholds is considered a grey zone, where more information is needed before a conclusion of resistance or susceptibility can be drawn. These principles are described in Figure 1.

Anthelmintic Efficacy Testing Step by Step

1. Find a group of egg count positive horses sharing the same pastures.

    a. At least 5 horses are recommended, but more will provide better precision.

    b. If less than 5 horses are available, proceed with the test but exercise more caution with interpreting the results.

    c. A treatment check can be carried out for a single horse.

2. Count as many parasite eggs as possible pre-treatment.

    a. 40 counted eggs/horse or more.

    b. Some techniques will count more eggs than others.

    c. Counting more slides from each horse will also increase the number of eggs counted.

3. Administer the anthelmintic at the labelled dosage.

4. Collect new fecal samples at 14 days post treatment.

5. Determine fecal egg counts using the same technique and number of slides as for the pre-treatment samples.

6. Calculate the 90% confidence intervals for the percent reduction for the group by use of online calculation software https://www.fecrt.com/.

    a. You can also calculate the mean percent reduction for the group or a single horse using the formula: ((total eggs counted pre – total eggs counted post)/ total eggs counted pre) X 100%.

7. Interpret your results according to the thresholds and guidance provided in the report generated from fecrt.com and herein.

4.2. Interpretation of the FECRT

For good reliability of the FECRT, it is recommended to count an average of 40 eggs/horse pre-treatment in the group. An egg counting technique with a low multiplication factor will count more eggs than one with a higher multiplication factor, and this can be especially useful in scenarios where FECs are generally low.

Uncertainty in the group mean FECR should be calculated with 90% confidence intervals, which quantify the variation of the data and are measures of the precision of the efficacy estimate. An online interface for analysis of FECRT data is available from the University of Copenhagen: https://www.fecrt.com/. With this calculation, each mean FECR will have an upper and a lower confidence interval limit. The interpretation of the FECRT results is based on these confidence limits. It is important to note that a diagnosis of resistance only means that the efficacy is reduced from the expected, and that drug-resistant worms are infecting the horses. However, efficacy might still be fairly high if resistant worms are present in a low frequency, or efficacy may be almost zero if resistant worms are present in a high frequency.

Evidence of good efficacy:	The lower limit is above the lower threshold. *The worst possible efficacy is still within the acceptable range.*
Evidence of resistance:	The upper limit **i**s below the upper threshold. *The best possible efficacy is still less than the expected efficacy for that drug.*
Inconclusive:	Both limits fall outside the thresholds. *The data are too variable to make a clear determination of adequate efficacy or resistance.*

The interpretation of the FECRT is described in Figure 1 and is as follows:

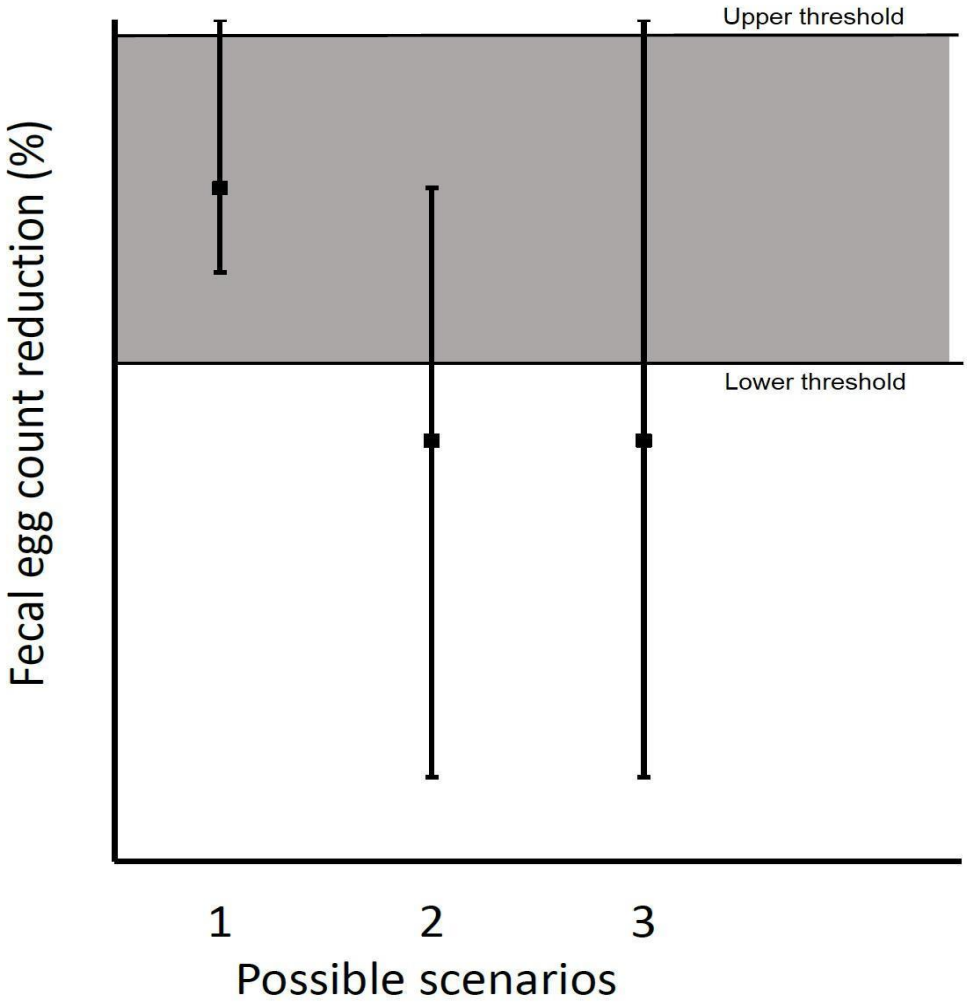

***Figure 1**. Thresholds and interpretation of the FECRT. The grey area represents the interval between the upper and lower thresholds. Scenario 1: Evidence of good efficacy. The lower confidence interval limit is above the lower threshold. Scenario 2: Evidence of resistance. The upper confidence limit is below the upper threshold. Scenario 3: Inconclusive. Both confidence limits fall outside the established thresholds.*

4.3. Guideline thresholds and group sizes

The full guidelines for FECRT testing can be found in the WAAVP guideline paper, which includes protocols for research studies as well as clinical on-farm testing (Kaplan et al., 2023). This includes details on recommended group sizes depending on the number of eggs counted for each anthelmintic being tested. Note that the number of eggs counted is a function of the number of horses tested, as well as the mean FEC of the horses being tested and the method used for performing the FEC. In the following tables, a summary of these guidelines is presented for scenarios where the minimum number of eggs counted exceeds 40 eggs/horse for both strongyles and ascarids (Tables 2 and 3). For scenarios with fewer eggs counted, the recommended group sizes will be larger. Further details can be found in the WAAVP guidelines.

Table 2. Efficacy thresholds and recommended group sizes for FECRT testing of equine cyathostomins (small strongyles).

	Ivermectin/Moxidectin	Benzimidazole	Pyrantel pamoate
Upper threshold	99.9%	99%	98%
Lower Threshold	92%	90%	80%
Group size[1]	5	7	7
Group total eggs counted[1]	200	280	280

[1] Based on counting a minimum of 40 eggs/horse pre-treatment

Table 3. Efficacy thresholds and recommended group sizes for FECRT testing of equine ascarids.

	Ivermectin/Moxidectin	Benzimidazole	Pyrantel pamoate
Upper threshold	99.9%	99.9%	99.9%
Lower Threshold	90%	90%	90%
Group size[1]	5	5	5
Group total eggs counted[1]	200	200	200

[1] Based on counting a minimum of 40 eggs/horse pre-treatment

4.4. Treatment check with fewer than five horses?

While a FECRT should optimally follow the guidelines summarized above, it can still be meaningful to evaluate the treatment efficacy in scenarios with fewer than the recommended number of animals, or with fewer eggs counted pre-treatment. However, in these scenarios, results should be interpreted with more caution due to a higher potential for variability and uncertainty. Furthermore, results are more likely to fall in the inconclusive category when group sizes are small.

Even though it would not be considered a true resistance test, it can still be useful to perform a treatment check **on a single horse** in situations where this is the only animal available for testing, such as a newly arrived horse in quarantine. In these cases, a general guideline is that any anthelmintic should reduce both ascarid and strongyle fecal egg counts by **more than 95% at 14 days after treatment**. For a single horse, we must rely solely on the arithmetic mean reduction, since it is not possible to calculate a confidence interval. Again, the number of eggs counted pre-treatment will largely affect the reliability of the result.

As a rough guideline, more than 40 counted eggs can provide a reasonably meaningful test, while 20-40 counted eggs can be expected to be moderately useful. Fewer than 20 counted eggs may not provide reliable results. If a low number of eggs is counted, a result indicating high efficacy could easily be attained due to variance, thus, such a result should be interpreted carefully. However, since the expectation is for high efficacy when resistance is not present, and since dead worms do not shed eggs, a result from a single horse that yields poor efficacy can be reasonably assumed to be due to resistance.

5. Anthelmintic Resistance Status

Current levels of anthelmintic resistance in equine parasites are summarized in Table 4. The occurrence of resistance is consistent in managed horses across the world, but notable differences can be found between individual farms, and resistance cannot be concluded on any given farm without proper testing. It is important to remember that a given regional prevalence only tells you what to expect across many farms/stables; it will not tell you what the resistance status is for a specific farm/stable. Thus, Table 4 only presents which parasite groups are most likely to show resistance to which drug class.

Table 4. Current levels of resistance documented in peer-reviewed studies in equine cyathostomin, pinworm, ascarid, and tapeworm parasites to the four anthelmintic classes in managed horse herds. Generally, these are worldwide trends that have also been reported in several US surveys.

Drug class	Cyathostomins	Pinworms	*Parascaris* spp.	Tapeworms
Benzimidazoles	Widespread	None	Early indications	-
Pyrimidines	Widespread	None	Early indications	Early indications
Macrocyclic lactones	Early indications	Widespread	Widespread	-
Praziquantel	-	-	-	Early indications

Widespread: reported on multiple continents with high farm prevalences often above 80%
Early indications: few single farm cases of reduced efficacy

5.1. Tapeworms

Recent data suggest treatment failure of praziquantel and pyrantel pamoate against *A. perfoliata* in Central Kentucky (Nielsen, 2023; Finnerty et al., 2024). Veterinarians should consider periodically screening for the presence of tapeworm eggs in fecal samples 14 days post-treatment to ensure that the treatment had adequate apparent efficacy. A standardized FECRT protocol has not been developed for equine tapeworms at this stage, but recent data suggest that even a routine FEC screening technique can provide indication of treatment efficacy, when counts are determined before and 14 days after administration of the anthelmintic to a group of horses (Nielsen, 2023). However, it should be emphasized that, due to the randomness of finding tapeworm eggs in feces, a high level of variation can be expected and diagnostic sensitivity may be poor. Thus, as with testing only a few horses for strongyle resistance, data indicating poor efficacy will be more reliable than data indicating high efficacy, which might occur by chance.

Given these challenges, group sizes are important. In the recently published study, yearling groups were in the range of 10-16 horses (Nielsen, 2023), which was enough to produce treatment efficacy information. Using a technique such as the modified centrifugation-based technique mentioned above for detection and enumeration of equine tapeworm eggs in fecal samples (*e.g.*, Proudman and Edwards, 1992) will count more eggs (Anderson et al., 2024) and will, thus, provide more useful indications of treatment efficacy. In general, both pyrantel pamoate (13.2 mg base/kg) and praziquantel (1.0-2.5 mg/kg) should be expected to reduce anoplocephalid egg counts by at least 95% at 14 days post treatment.

5.2. Pinworms

Apparent resistance to ivermectin and moxidectin has been described in *O. equi* in Europe, New Zealand, and both North and South America (Nielsen, 2022). However, testing for resistance in *O. equi* is challenging and FECRT cannot be used. Published studies have made use of the Scotch tape test for evaluating treatment efficacy (Nielsen, 2022). If macrocyclic lactone resistance is suspected based on lack of clinical response, the available evidence suggests benzimidazoles should be given priority over pyrantel salts due to better historic efficacy levels (Reinemeyer and Nielsen, 2014).

5.3. Other parasites

Some veterinarians report an apparent lack of response to macrocyclic lactone treatment of lesions suspected to be caused by *Habronema* spp. larvae. However, no such reports exist in the peer-reviewed literature, so it is not possible to evaluate the evidence underlying these claims. Furthermore, it should be emphasized that no anthelmintic formulation has ever been scientifically evaluated for efficacy against *Habronema* spp. larvae present in skin or mucosal lesions, no products are registered with label claims against these, and there is no practical means to measure efficacy against these larvae in a farm environment. Thus, it is scientifically impractical to determine if these observations are due to anthelmintic resistance.

6. Strongyle Egg Reappearance Periods

The term egg reappearance period (ERP) describes the amount of time it takes from the date of an effective deworming in a group of horses with positive strongyle fecal egg counts until eggs can be found in the feces again. In other words, this is a measure of how long the treatment, if effective, can suppress strongyle egg shedding, which is a meaningful additional measure of performance of the anthelmintic. While ERP can be measured for all anthelmintics, it is generally only relevant to ivermectin and moxidectin. This is because resistance is widespread to the two other anthelmintic classes, which means that they most often do not effectively reduce strongyle FECs to begin with. Furthermore, even if they are effective, there is not a lot of useful information that can be gained from the ERP of these drug classes.

Over the past three decades, ERP following both ivermectin and moxidectin treatment has decreased dramatically (Table 5). In the 1990s, moxidectin performed with ERPs in the 12–16-week range, which was substantially longer than any other anthelmintic. In comparison, ivermectin ERPs were in the 8–10-week range (Nielsen, 2022). However, since 2017, several studies have reported ERPs to be 4–5 weeks for both drugs (Nielsen, 2022).

Table 5. Strongyle egg reappearance periods reported for ivermectin and moxidectin in the 1990s compared to several studies conducted since 2017.

	1990s	Now
Ivermectin	8–10 weeks	4–5 weeks
Moxidectin	12–16 weeks	4–5 weeks

Data derived from Nielsen, 2022

6.1. Shortened ERP: Interpretation

For many years it was assumed, without evidence, that shortened ERP is a sign of emerging resistance (Sangster, 1999). However, this is not necessarily the case, and recent data suggest that selection of parasites with life cycles of shorter duration may have occurred (Nielsen et al., 2022a). The practical consequence of reduced ERPs is that egg output suppression is not maintained for extended periods following treatment. This can lead to a significant increase in egg shedding onto the pastures leading to a reduction in the level of parasite control. A computer simulation study suggested that parasite burdens may increase up to several fold when ERPs are reduced to 4–5 weeks, depending on age group, climatic conditions, and treatment protocols (Nielsen et al., 2023).

6.2 Determining ERP

The World Association for the Advancement of Veterinary Parasitology (WAAVP) has recently published guidelines for determining ERP (Nielsen et al., 2022b). The determination is based on fecal egg counting reductions (FECRs), so many of the principles outlined for the fecal egg count reduction test (FECRT) apply to ERP determination as well. While best practice would entail sampling a group of horses on a weekly basis for several weeks following treatment, a more realistic and pragmatic approach would be to "spot-check" ERP by determining FECR at a strategically chosen time interval, such as 4, 6, or 8 weeks. Egg reappearance for the macrocyclic lactone class occurs when the upper 90% confidence interval for the calculated FECR falls below a threshold of 90% reduction. This will provide useful information about the performance of ivermectin and moxidectin.

7. Larvicidal Treatment

The term larvicidal treatment is used for anthelmintics with activity against encysted cyathostomin larvae. Currently, there are two anthelmintics with registered efficacy against these stages: moxidectin and fenbendazole. However, contrary to commonly held beliefs, neither of these can be expected to perform with high larvicidal efficacy. Several recent studies have demonstrated that both compounds reduce larval burdens by less than 85% (Nielsen, 2022). For the five-day regimen of fenbendazole, this is a pronounced reduction from historically reported efficacy levels and fulfills the criteria for anthelmintic resistance. For moxidectin, the larvicidal efficacy has always been variable with most studies reporting efficacies in the 50–70% range against developing larval stages (Nielsen, 2022). Thus, moxidectin appears to have maintained this larvicidal efficacy level, although a recent study suggested that the reduction in encysted larval counts may be short-lived among horses kept on pasture (Nielsen et al., 2022a).

There are currently no data demonstrating a clinical benefit of larvicidal treatment. Larval cyathostominosis, the clinical syndrome caused by encysted cyathostomins, appears to be extremely rare in North American horses, and the efficacy of routine larvicidal treatments to reduce its risk is unknown. This makes assessing the prophylactic value of larvicidal treatments in populations of horses very challenging. Furthermore, the expected efficacy of a larvicidal treatment is substantially below 100%, with significant proportions of encysted larvae expected to survive treatment regardless of the anthelmintic. Larval reductions are also transient, with larval counts rebounding within 5 weeks post-treatment (Nielsen et al., 2022a).

While recent studies suggest that moxidectin and the five-day fenbendazole regimen may be performing at approximately the same level of larvicidal efficacy (Reinemeyer et al., 2015; Bellaw et al., 2018), moxidectin generally maintains efficacy against adult parasites within the intestinal lumen, whereas fenbendazole does not (Table 4). Consequently, though larvicidal efficacy may not differ greatly, moxidectin can be expected to yield much greater overall reductions of cyathostomin burdens and suppression of egg shedding following treatment (Mason et al., 2014).

Some veterinarians and horse owners express concerns over larvicidal treatment of horses with perceived large encysted larval burdens. However, a series of studies of inflammatory reactions to treatments with moxidectin, the five-day fenbendazole regimen as well as ivermectin (non-larvicidal) in heavily parasitized horses only found very subtle responses, which were most pronounced in the untreated control groups (Nielsen et al., 2015; Steuer et al., 2018; 2020). Thus, adverse inflammatory reactions to dying worms do not appear to be a major concern.

8. Methods of Parasite Control

A summary of currently available anthelmintics can be found in Appendix B.

8.1. Environment-based approaches

Equine strongyle parasites begin life as eggs in a manure pile, which then must develop to infective larvae in the feces, get out onto the pasture, and be ingested by a horse. Thus, infection of horses could be prevented if all feces were promptly removed from the pasture.

8.2. Environmental control

A summary of development and survival of strongyle eggs and larvae on pasture at different temperatures can be found in Appendix C. Strongyle eggs hatch and develop into infective larvae under conditions of moderate temperature and moisture. Cold slows the rate of development or stops it altogether, and excessive heat kills eggs and larvae. Proper composting of manure and soiled bedding will generate relatively high internal temperatures, and strongyle larvae in manure are virtually eradicated by exposure to temperatures over 104˚F (40˚C) for a minimum of one week (Gould et al., 2012).

Non-composted horse manure should never be spread onto pastures grazed by horses as this will increase the level of parasite contamination and transmission. This practice has been associated with higher *Parascaris* spp. prevalence in Germany (Fritzen et al., 2010).

Leaving pastures unoccupied for several months of the year may or may not significantly reduce the levels of contamination depending on climate and time of the year. Infective strongyle larvae (L3) can survive for only a few days to a few weeks in hot weather (temperatures over 100°F), but for as many as six to nine months during colder weather (Nielsen et al., 2007). Consequently, L3 survival in the environment will vary greatly from region to region and season to season.

It is practically feasible to temporarily turn a grazing pasture into a hay field and recover the forage, which should greatly reduce the number of surviving infective larvae. However, evidence supporting this suggestion is lacking. Grazing contaminated pastures with ruminants may also assist in control (Eysker et al., 1986). Equine strongyle larvae are host-specific and cannot infect cattle, sheep, goats, or camelids. The only exception is the stomach worm, *Trichostrongylus axei*, which can infect both ruminants and equids, but this parasite rarely causes disease in either ruminants or horses. Ruminant liver flukes (*Fasciola hepatica*) can potentially infect horses as well, but this will be a rare and localized event and can only occur in areas enzootic for liver fluke.

The environmental control of strongyles using nematophagous fungi delivered to horses in feed has shown promising results (Healey et al., 2018), and a product is now available in North America. However, information is currently lacking on how to successfully integrate the product into a meaningful parasite control program.

8.3. Combination deworming

Combination deworming has been shown to improve parasite control and reduce the development of resistance in both simulation and field studies performed on sheep, and is increasingly recommended in ruminants (Leathwick et al., 2012; 2015; Kaplan, 2020). However, there is scant data on this issue in horses. Equine anthelmintic products containing more than one active ingredient targeting the same parasite(s) are available in several countries in the Southern Hemisphere. Computer simulation studies have suggested that combining two new active ingredients, to which no resistance has developed, will effectively reduce the rate of resistance development (Leathwick et al., 2017). Furthermore, one study suggested value in combining a novel anthelmintic with an active ingredient for which anthelmintic resistance has already decreased the efficacy (Scare et al., 2020).

However, no new anthelmintic classes have been introduced for equine usage in the past 40 years, and no such products are expected within the foreseeable future. Thus, the evaluated scenarios described above do not exist and instead, combination deworming involves active ingredients which have been in use for decades, and anthelmintic resistance is often either already established or developing. One study evaluated a combination of oxibendazole and pyrantel pamoate against a population of cyathostomins resistant to both and found that the initially gained increase in efficacy was lost after a single administration of the combination (Scare et al., 2018), demonstrating that this approach was not sustainable.

Based on the above, we currently lack evidence to endorse combination deworming as a sustainable treatment approach for strongyle control. Veterinarians can attempt the combination of two or more active ingredients as an extra-label treatment approach on a case-by-case basis. However, it should be noted that in case of treatment of foals and weanlings, current drug efficacy profiles may result in the need for treatment with two different active ingredients in case the animals harbor both strongyles and ascarids. The off-label use of anthelmintics labelled for other species (e.g., ruminants), is inappropriate and may not be sustainable and is, thus, not recommended.

8.4. Alternative remedies

An increasing number of so-called organic or herbal dewormers are appearing in tack shops and online, but the efficacy of these products has never been demonstrated in formal, controlled evaluations. Similar products are also sold for ruminants, and several studies in sheep have consistently demonstrated little or no efficacy of these products (Burke et al., 2020). These products exist primarily because they exploit differences in the labeling requirements for drugs vs. non-drug items. Before a drug can earn label claims for activity against parasites, this fact must be proven unequivocally to the Food and Drug Administration by extensive efficacy and safety testing. Once an anthelmintic is approved by the FDA, the claims that can be made in advertising that drug are regulated by the FDA. In contrast, products that are not considered drugs do not require FDA approval for marketing, and therefore have little to no oversight regarding their label claims and the safety and efficacy of their products.

9. Recommendations for Parasite Control Programs

As a general principle, it should not be a goal to eliminate cyathostomin burdens. All grazing horses are expected to harbor these parasites, which are only mildly pathogenic. Instead, recommendations aim to reduce the infection pressure with these parasites by reducing overall herd strongyle egg output, and thus preventing the rare scenario where clinical disease might occur. However, there are other parasites that deserve consideration as well.

Strongyle control programs should be constructed around strongyle transmission seasons, which vary greatly between regions of the U.S. Figure 2 presents data on development of strongyle eggs to infective larvae in six states representing six different climates. Surveillance-based treatments aimed at suppressing strongyle egg output should always be administered during the active transmission season. This is because there is no need to suppress egg output if most of the eggs are destined to die due to intense cold or hot weather conditions.

Recommendations follow a two-tiered principle. Baseline treatments aim at controlling non-cyathostomin parasites, such as large strongyles, ascarids, and tapeworms, whereas the surveillance-based treatments aim at controlling pasture contamination with cyathostomin eggs.

Two-Tiered Parasite Control Principle

Baseline anthelmintic treatments, which should be considered for all horses.

Surveillance-based treatments administered based on fecal egg counts.

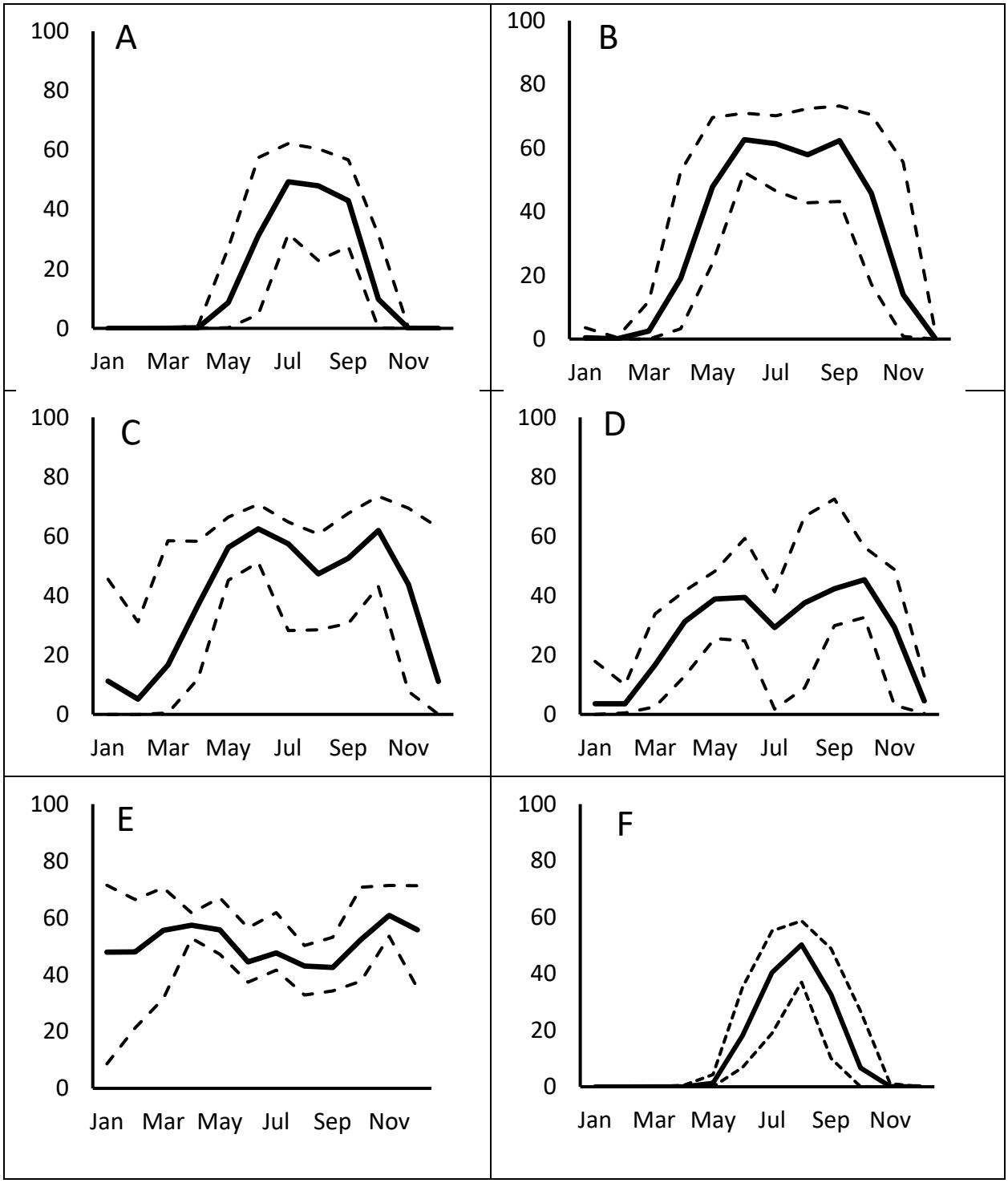

Figure 2. *Strongyle transmission seasons. Examples of data generated with Cyathostomin life-cycle computer simulation predictions of the percent successful development of eggs to infective L3 on pasture (Leathwick et al., 2015) based on weather station data from six different locations: A) Dickinson, North Dakota, B) Lexington, Kentucky, C) Washington, Georgia, D) Pecos, Texas, E) Saint Leo, Florida, and F) Denio, Nevada. Solid lines represent mean across 10 years of data, whereas the dashed lines represent minimum and maximum values during the 10 years.*

9.1. Recommendations for mature horses (5-15 years)

Primary target parasites are strongyles and tapeworms.

- Evaluate the efficacy of the anthelmintic products used on each operation on an annual basis using the FECRT.
- Baseline treatments should consist of one or two macrocyclic lactone treatments per year to target large strongyles, bots, and spirurid nematodes responsible for causing summer sores (*Habronema* spp. and *Draschia* spp.), where indicated. Praziquantel should be included for tapeworms at least once a year, if horses have access to green pastures. Additional treatments for tapeworms should be given only based on positive evidence of infection.
- All further treatments should be targeting high strongyle shedders (> 500 EPG). Depending on the duration of the strongyle transmission season (Figure 2), high shedders should be treated with one or two additional treatments. All treatments aimed at reducing pasture infectivity should be administered during the transmission season.

9.2. Considerations for seniors (>15 years)

Senior horses should generally follow the recommendations given for mature horses. However, some seniors can revert to becoming high strongyle shedders (Adams et al., 2015), and pituitary pars intermedia dysfunction, which is commonly occurring in this age group, has been associated with higher counts as well (McFarlane et al., 2010). Thus, it is important to monitor egg shedding status in this age group and treat accordingly.

9.3 Recommendations for foals, weanlings, yearlings, and youngsters

In order of appearance, primary target parasites are ascarids, strongyles, and tapeworms.

- Perform FECRT yearly to evaluate the efficacy of anthelmintics against strongyles and ascarids. The ideal age range for ascarid FECRTs is 4–6 months of age, when ascarid egg shedding is most likely to be abundant.
- Targeted treatments (selective therapy) based on FEC is NOT recommended in this age group. However, FECs are still important for monitoring the presence of ascarids, as these will often require different anthelmintic classes than strongyles.
- Although *S. westeri* larvae are known to transmit lactogenically, the possible benefits to treating the mare around the time of foaling are unknown, and there is no basis for recommending this practice at present.
- Foals should be treated twice for ascarids. The first treatment should be administered at about 2–3 months of age, while the second is recommended at about 5 months of age. The benzimidazole drug class is recommended for these treatments, although pyrantel pamoate may also be effective. The labeled dose of fenbendazole and oxibendazole for ascarids is 10 mg/kg orally once.
- At about 5–6 months of age, the first FEC is recommended to track the expected natural decline of ascarids and the subsequent dominance of strongyles.

- If turned out on green pastures, weanlings should be first treated with a macrocyclic lactone for strongyles at about 6–9 months of age. This treatment should include praziquantel for tapeworms. If FECs demonstrate ascarids still present, additional treatments with a benzimidazole should be considered for positive individuals.
- During the yearling year, the majority of horses should be expected to exceed 1,000 strongyle EPG, and a few may test positive for ascarids as well. Treatments should generally follow the protocol for high strongyle shedders. Based on this, yearlings will often receive anti-strongyle treatments in the spring, middle of the transmission season, and in the fall. Based on the duration of the strongylid transmission season (Figure 2), one or two additional treatments might be warranted. Praziquantel should be considered during the second half of the year.
- Two to 3-year-olds are expected to gradually decrease their strongyle shedding level, although a proportion will still be expected to be high strongyle shedders. In most scenarios, this age group will receive 3–4 annual treatments, with praziquantel included at least once in the second half of the year.

9.4. Parasite-specific treatment considerations

9.5. Strongyles

Benzimidazole and pyrantel resistance should both be assumed until proven otherwise using a FECRT. This leaves the macrocyclic lactone class as the only option in many locations. However, efficacy should be routinely monitored regardless of the chosen class.

9.6. Ascarids

Macrocyclic lactone resistance should be assumed until documented otherwise. Both benzimidazoles and pyrantel pamoate usually are valid treatment options, however surveillance of efficacy is still recommended. Theoretically, the benzimidazoles may be a safer choice because of their non-paralytic mode of action and slower onset of effect. However, this assumption is not supported by solid evidence. Fenbendazole when administered at 10 mg/kg for five consecutive days has demonstrated larvicidal efficacy against migrating ascarid larvae (Vandermyde et al., 1987). However, this would be an extra-label use of this product and the clinical benefits of such a treatment are unclear.

9.7. Tapeworms

Drug choices for treatment of tapeworms include praziquantel (licensed in the U.S. for horses only in combination with ivermectin or moxidectin), or a cestocidal dose (double the nematode dose) of pyrantel pamoate. In most areas, this treatment should be given in the late fall after tapeworm transmission ends due to cold weather.

9.8. Pinworms

Macrocyclic lactone resistance should be assumed until proven otherwise. Because the pruritus secondary to pinworm infections is caused by the material secreted by the female when depositing her eggs, washing the perineum and perianal region may help to relieve symptoms. After scrubbing, all materials should be discarded or washed in hot water with soap and/or

disinfectants. It should be emphasized that **rectal lavage using various anthelmintic products is very unlikely to have any effect**, as *O. equi* does not inhabit the rectum or descending colon.

9.9. Bots

Bots, though aesthetically displeasing, are very mild pathogens and should not dictate treatment decisions. However, the recommended baseline treatments include a macrocyclic lactone administered in the fall, which would help reduce bot occurrence. Recent data suggest variable efficacy of moxidectin against bot larvae (Reinemeyer et al., 2015), and ivermectin may be a more effective choice.

10. Six Changes Worth Making

- Check anthelmintic efficacy routinely by fecal egg count reduction testing.
- Do not deworm with fixed intervals year-round.
- Abandon rotational deworming.
- Reduce anthelmintic treatment frequency.
- Tailor strongyle parasite control to the active transmission season.
- Do not use fecal egg counts to diagnose clinical disease.

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Appendix A: Egg Counting Technique

Modified McMaster Fecal Egg Count (FEC) Procedure

The method described below has a multiplication factor of 25, which makes it useful for identifying high strongyle egg shedders, but less appropriate for the FECRT. For video instructions, view HERE.

Supplies needed:

- Disposable paper cup (Dixie cup) or small container for feces
- Small strainer (household)
- Pipette, eye dropper, or syringe to dispense fecal solution
- Cheese cloth or gauze sponge
- McMaster slide
- Flotation medium (specific gravity > 1.25)

Procedure Steps:

1. Weigh out 4 g of feces in a small container or paper cup.
2. Add 26 mls of flotation medium (to bring the volume up to 30 ml) to the feces. Mix well.
    a. Note: If you do not have a scale, you can add feces to the 26 ml of solution and when the volume reaches 30 mls, you have added 4 g.
3. Strain through one or two layers of cheesecloth, one layered gauze squares, or tea strainer, mix well.
4. Mix the sample well and then immediately withdraw about 1 ml of the suspension with a pipette or syringe and fill the first counting chamber of the McMaster slide.
    a. Repeat the process to fill the second chamber.
    b. Let the slide stand for two to five minutes to allow eggs to float to top.
        i. If visible air bubbles are present, the chamber should be emptied and refilled.
5. Steps three and four should be done at the same time without letting the sample sit between steps, since eggs are in flotation fluid and will immediately begin to rise to the top of the fluid. You want to be sure to get a representative sample of the mixed solution.
6. Once chambers are filled, step three can be started for the next sample.
7. Once filled, the chambers can set for 60 minutes before counting without causing problems if using sodium nitrate. Longer than this and drying/crystal formation can begin. With sodium chloride, crystal formation occurs much more quickly.
8. Count all eggs inside of grid areas (only count the eggs which have more than half of their area inside the outer lines of the grid) at 100x total magnification (10x ocular lens and 10x objective lens). Focus on the top layer, which contains the very small air bubbles (small black circles). Count both chambers.
    a. Count strongyle (oval-shaped, about 90 microns long) and ascarid eggs (round, about 80-90 microns long). Tapeworm eggs (D-shaped about 80 microns), if present, should be counted as well. Do not count *Strongyloides* (oval, about 50 microns long) or *Eimeria leuckarti* (large brown oocysts of the same size as strongyle eggs) – only notations are made as to the presence of these other parasites.
9. Multiply the number of counted eggs in each category by 25 to achieve the number of eggs per gram (EPG) per egg type.

Appendix B: Anthelmintic Formulations Available

Table 1. Anthelmintic drug classes currently marketed in the U.S., and their general gastrointestinal parasite label claims.

Drug class	Label claims*
Benzimidazoles (fenbendazole, oxibendazole)	Cyathostomins, large strongyles, ascarids, pinworms, threadworms
Tetrahydropyrimidines (pyrantel)	Cyathostomins, large strongyles, ascarids, pinworms, tapeworms
Macrocyclic lactones (ivermectin, moxidectin)	Cyathostomins, large strongyles, ascarids, pinworms, threadworms, bots
Isoquinoline-Pyrozines (praziquantel)	Tapeworms

*Red = Widespread resistance
*Blue = Resistance reported
*Black = No resistance reported

Benzimidazoles: These drugs interfere with a worm's energy metabolism on a cellular level. They bind to beta tubulin and prevent its polymerization into microtubules. They are available in paste, liquid and pelleted formulations.

Tetrahydropyrimidines: Pyrantel pamoate and pyrantel tartrate act at the neuromuscular junction causing an irreversible rigid paralysis. Pyrantel salts only affect adult parasites that reside in the lumen of the gastrointestinal tract. Pyrantel pamoate is available in suspension and paste formulations, while pyrantel tartrate is formulated in alfalfa pellets and must be fed on a continual basis, serving only as a preventive, not a purge dewormer.

Heterocyclic Compounds: Several dewormers are classified as heterocyclic compounds, but piperazine is the only one used in horses. Piperazine works by depolarizing muscular membranes, which renders them resistant to the action of acetylcholine. The action of piperazine is limited to adult parasites. Piperazine is used infrequently in horses, and there is currently no formulation marketed for equine usage in the U.S., but one product is listed in Canada. It was available as a liquid or powder formulation which required nasogastric intubation.

Macrocyclic Lactones: These act on glutamate-gated chloride channels in nematode nerve and muscle cells, disturbing the normal transmission of nervous stimuli to muscles. The result is flaccid paralysis. Macrocyclic lactones are the most potent killers of worms, being effective at less than one-tenth the dosage of other classes of dewormers. They also have the unique quality of killing arthropod parasites such as bot larvae, lice, and mites. Macrocyclic lactones are available in paste (ivermectin) and as an oral gel (moxidectin).

Isoquinoline-Pyrozines: Praziquantel is the sole member of the isoquinolone class used in horses. It is also unique in that it has no activity against nematodes. Praziquantel is effective only against tapeworms. In

North America, praziquantel is currently marketed only in combination with macrocyclic lactones, and the combination formulation is that of the parent compound (ivermectin if paste, moxidectin if a gel).

Appendix C: Effects of Temperature on Infective Strongyle Larvae

Table A1. Effects of temperature on the survival, development, and persistence of free-living stages (eggs, L1, L2, L3) of strongyles (Nielsen et al., 2007).

Development	Temperature Range	Survival
No development above this level	> 40 °C > 104 °F	Free-living stages die rapidly. Intact fecal balls may retain enough humidity to enable L3 to survive for some weeks.
Optimal temperature range for development of eggs and larvae. Reach infective L3 stage in as little as 4 days.	25–33 °C 77– 91 °F	Larvae survive on the shorter term (i.e., a few weeks), but conditions are too warm for long-term survival
Eggs develop into L3 within 2-3 weeks.	10–25 °C 50–77 °F	L3 capable of surviving for several weeks to a few months
Lower limit for egg hatching is about 6 °C. At temperatures in this range, development will take several weeks to a few months.	6–10 °C 43–50 °F	L3 survive for many weeks and months under these circumstances
No hatching and no development	0–6 °C 32–43 °F	Eggs and L3 can survive for several months at temperatures just above the freezing point
No development during frost	< 0 °C < 32 °F	Developing larvae (L1 and L2) are killed, but unembryonated eggs and L3 can survive and persist for long periods (*i.e.* months)
Alternation between freezing and thawing will usually not lead to development unless temperatures exceed 6 °C	< 0 > °C < 32 > °F	Repeated freeze-thaw cycles are detrimental to egg and larval survival