The Veterinary Benchmark Indicator:

Towards transparent and responsible antibiotic prescription patterns in veterinary practice

Prof. Dick Heederik, PhD, Marian Bos, PhD, Prof. Dik Mevius, DVM, PhD, Prof. Johan Mouton,PhD
Inge van Geijlswijk, PhD, Prof. Jaap Wagenaar, DVM, PhD

August 2014
- Based on the SDa-report, March 2014 (in Dutch) -




Preface

In this report 'The Veterinary Benchmark Indicator: towards transparent and responsible antibiotic prescription patterns in veterinary practice', the SDa expert panel presents the Veterinary Benchmark Indicators (VBI) and the results of the first analysis of prescription patterns of antibiotics by Dutch veterinarians.

The Netherlands Veterinary Medicines Authority, SDa, is an independent agency established in 2010 to promote responsible drug use in Dutch animal husbandries in general and usage of antibiotics specifically. Thanks to the efforts of livestock farmers and veterinarians, the SDa is in a position to map out the usage of antibiotics on more than 40,000 farms. The benchmarking of livestock farms and, if necessary, the immediate application of improvement measures for quickly reducing the usage levels have shown to be effective. Antibiotic usage reduced almost 50% between 2009 and 2012, the year the analysis of prescription patterns of veterinarians described in this report refers to, and the decrease continued in 2013. However, the need for benchmark values for veterinarians was already voiced during the establishment of the SDa. After all, veterinarians do not just prescribe the antibiotics used by livestock farmers, but share the livestock farmers' responsibility for animal health at the farms concerned.

Last June the SDa published her report describing the Veterinary Benchmark Indicator in Dutch. As we want to share our approach of analyzing and describing veterinary prescription patterns, we present this publication in English. To fully understand the materials and methods of this VBI, some background information on the Dutch approach towards prudent antibiotic use has been added. We hope this publication provides every reader with insight in the Veterinary Benchmark Indicator and will contribute to establish prudent use of antibiotics in animal husbandry worldwide.

On behalf of the SDa expert panel,

Prof. D.J.J. Heederik, PhD
Chair

Contents

1. Terms and Definitions 5
2. Summary 7
3. Introduction 10
4. The Veterinary Benchmark Indicator (VBI) and Benchmarks 10
   - 4.1 Background 10
   - 4.2 The rationale and calculation of the Veterinary Benchmark Indicator (VBI) 11
   - 4.3 VBI example calculation 12
   - 4.4 Benchmark criteria 13
5. Application of the VBI to usage data of 2012 - 2013 14
   - 5.1 Methods 14
   - 5.2 Results 15
   - 5.3 Conclusions 25
6. Future developments regarding benchmark indicators 25
7. References 26

Appendix 1. The method used for calculating the Veterinary Benchmark Indicator (VBI) and examples. 27

Appendix 2. Distribution of the number of farms with which veterinarians have a one-to-one relationship 30

Appendix 3. Definitions 32

1. Terms and Definitions

Treatable kilograms	The number of kilograms of a particular type of livestock that, according to the package leaflet information, can be treated with a single mass unit of the antibiotic concerned.
$DDDA_{NAT}$	The 'Defined Daily Dose Animal' based on national antibiotic usage data. It is determined by first calculating the total number of treatable kilograms within a particular livestock sector for a specific year, and then dividing this number by the average number of kilograms of animal present within the livestock sector concerned. This measure is used to determine the amount of antibiotics used within a particular livestock sector, irrespective of the various types of livestock farms within the livestock sector concerned and any differences between these livestock farms. The $DDDA_{NAT}$ is used in other countries as well. It is similar to the parameter DDD per 1000 patient days used for people when multiplied by 1000/365. The $DDDA_{NAT}$ is expressed in DDDA/animal year (or DDDA/1000 animal days).
$DDDA_F$	The 'Defined Daily Dose Animal' based on the antibiotic usage data of a particular livestock farm. It is determined by first calculating the total number of treatable kilograms at a particular livestock farm for a specific year, and then dividing this number by the average number of kilograms of animal present at the livestock farm concerned. It reflects the amount of antibiotics used at a particular livestock farm level, and is used for benchmarking individual livestock farms. This is the measure used by the SDa since 2011 (see the Standard Operational Procedure for 'Calculation of ADDD/Y for antimicrobials'). The $DDDA_F$ data of all individual livestock farms within a particular livestock sector are used to determine the mean and the median (*unweighted*, all livestock farms contribute equally). The weighted mean of the $DDDA_F$ (weighted based on the value of the denominator, i.e. the number of kilograms of animal) is equall to the $DDDA_{NAT}$ based on all livestock farms within the livestock sector considered. The $DDDA_F$ is expressed in DDDA/animal year. In previous publications, this parameter was expressed in ADDD/Y.
ESVAC	European Surveillance of Veterinary Antimicrobial Consumption.

Mass balance	An equation for comparing the amount (in kilograms, kg) of an active substance sold as reported by the pharmaceutical industry with the reported used (in kg) of the active substance according to deliverance reports of veterinarians.
RPR	Relative Prescription Ratio. The animal-defined daily dosage of a livestock farm $DDDA_F$ divided by the corresponding action threshold for that livestock type.
VBI	Veterinary Benchmark Indicator. It represents the probability that the mean RPR (after transformation by its natural logarithm) attributed to a veterinarian exceeds 1.

2. Summary

Background

Since 2011, the Netherlands Veterinary Medicines Authority (Stichting Diergeneesmiddelenautoriteit, SDa) has been monitoring antibiotic use at Dutch livestock farms by means of benchmark indicators. Specific benchmark indicators have been defined for the various livestock sectors and types of livestock farms. The usage data collected facilitates detailed reporting by the SDa expert panel on developments regarding antibiotic use at Dutch livestock farms, and are used to set two benchmark values: a signaling threshold and an action threshold, defining three zones: the target zone, the signaling zone and the action zone. In 2013 the SDa expert panel identified livestock farms where antibiotic use had been within the "action zone" for several consecutive years. Benchmark values have shown their use for monitoring individual livestock farmers' usage data. However, the need for benchmark values for veterinarians was already voiced during the establishment of the SDa. After all, veterinarians do not just prescribe the antibiotics used by livestock farmers, but share the livestock farmers' responsibility for animal health at the farms concerned.

The Veterinary Benchmark Indicator (VBI)

The SDa expert panel has developed a framework for monitoring veterinarians' antibiotic prescription patterns and defined associated benchmark values: the Veterinary Benchmark Indicator (VBI). After several options were considered during the development of this framework, the expert panel eventually decided the approach set out in this report was the most suitable one for the purpose of benchmarking veterinarians. The expert panel considers the selected approach to be relatively conservative, as it only identifies veterinarians whose prescription patterns exceed action threshold considerably. A deviating prescription pattern for a single farm is unlikely to result in a marked VBI increase since the benchmark indicator is based on the antibiotic usage data of all of the farms the veterinarian concerned is responsible[1] for and the VBI is not sensitive to a high prescription pattern on one particular farm.
In line with the benchmark indicators used for livestock farmers, the SDa expert panel has defined signaling and action thresholds. A veterinarian's benchmark indicator indicates the probability that farms for which the veterinarian concerned is responsible for will fall within the action zone defined for farms, based on their antibiotic usage data. This probability is based on both the number of farms within the action zone and the extent to which these farms exceed the action threshold. The veterinary benchmark threshold values are defined as follows:

Prescription zone	Threshold values for the VBI
Action zone	>0.30
Signaling zone	0.10<VBI≤0.30
Target zone	≤0.10

[1] Veterinarians are responsible for all of the farms they have a contractually agreed one-to-one relationship with.

A VBI of 0.30 indicates that the responsible veterinarian has 1 out of 3 farms within the action zone. The SDa expert panel considers this to be a substantial systematic deviation from target prescription patterns, and feels this requires immediate action. A benchmark value of 0.10 (the upper limit of the target zone) corresponds to 1 in 10 farms falling within the action zone defined for farms. The expert panel considers the target threshold benchmark value as a future goal for prescription patterns. Veterinarians responsible for a single farm per livestock sector are automatically assigned the prescription zone corresponding to the usage of that farm. The table below shows how many veterinarians fall within the target, signaling and action zone based on their VBI. The VBI data are specified by type of livestock. Veterinarians responsible for several farms with the same type of livestock are included in the second column, and veterinarians responsible for a single farm per type of livestock are included in the third column.

The proportion of veterinarians within the action zone differs for the various types of livestock: veal calves 23%, pigs 13%, broilers 16% and cattle 3%. These differences are in part the result of differences in the antibiotic usage data between individual farms in a particular livestock sector, but also reflect the fact that in 2012, the SDa defined different benchmark values for the various types of livestock and the various types of livestock farms. The proportions may change following revision of the benchmark values to be used for livestock farms.

Number of veterinarians per prescription zone (target/signaling/action) for each livestock sector; specified for veterinarians responsible for several farms per livestock sector and for veterinarians responsible for a single farm per livestock sector.

Livestock sector	Number of veterinarians with several farms per livestock sector who fall within the target, signaling or action zone based on their Veterinary Benchmark Indicator (VBI)			Number of veterinarians with a single farm per livestock sector who fall within the target, signaling or action zone based on the usage level of the farm concerned		
	Target	Signaling	Action	Target	Signaling	Action
	≤0.10	(0.10<VBI≤0.30)	(VBI>0.3)	-	-	-
Veal calves	39	57	37	27	20	5
Pigs	77	142	33	12	1	1
Broilers	21	26	10	13	2	2
Cattle	272	366	17	22	7	1

With the publication of this report on veterinarians' prescription patterns, the SDa has achieved its objective to realize full transparency regarding antibiotic use at Dutch animal husbandries. The benchmark indicators enable veterinarians to compare their prescription patterns to those of their colleagues, and to determine whether they, or farms they are responsible for, should take action in order to improve their prescription patterns.

Conclusions

The analysis of prescription patterns for veterinarians has shown a considerable inter-veterinarian variability in antibiotic prescription patterns. Within individual livestock sectors, prescription data of veterinarians can vary by a factor of 5 to 20, depending on the type of livestock concerned. The most substantial differences were observed in the veal farming and pig farming sectors, while inter-veterinarian differences turned out to be smallest in the cattle farming sector. Similar differences were observed when only veterinarians responsible for a large number of farms were included in the analyses. The SDa expert panel considers it unlikely for prescribing peaks due to animal diseases at a single farm to have a significant effect on inter-veterinarian differences. It is possible, however, that veterinary practices often assign “problem farms” to their most experienced veterinarians, which may increase the VBIs of these veterinarians. A farm's high level of antibiotic use is particularly likely to affect a veterinarian's VBI if it is the result of factors such as poor management or poor facilities at the farm, and is therefore structural in nature. Nevertheless, the SDa expert panel does not feel that such circumstances explain or warrant average prescription patterns that vary by a factor of 5 to 20. It is up to the veterinarians as a group to further determine the cause of these differences and to take action accordingly.

For some of the veterinarians, the VBI could not yet be calculated or could not yet be based on all of the farms the veterinarian was responsible for. This was due to the fact that several one-to-one relationships between veterinarians and livestock farms had not yet been contractually agreed or registered at the time the SDa expert panel was calculating the VBIs. The inclusion of the remaining VBIs may slightly alter the results set out in this report. It should also be emphasized that the VBI is sector specific and that one veterinarian therefore has a number of VBIs, the number being dependent on the number of sectors the veterinarian is involved in.

3. Introduction

Since 2011, the SDa has been monitoring antibiotic use at Dutch livestock farms by means of benchmark values. Two benchmark values have been set: a signaling threshold and an action threshold, defining three zones: the target zone, the signaling zone and the action zone. Specific benchmark values have been defined for the various livestock sectors and types of livestock farms. Farms that use amounts of antibiotics within the action zone should take immediate action (see also appendix 3).
Whereas the benchmark values defined for farms are valuable parameters for monitoring individual livestock farmers' usage data, there is also a clear need - already voiced during the establishment of the SDa- for benchmark values for the veterinarian who prescribes antimicrobials. After all, veterinarians do not just prescribe the antibiotics used by livestock farmers, but share the livestock farmers' responsibility for animal health at the farms concerned. In light of this, the SDa expert panel performed an exploratory study in order to find the most suitable method for quantitative benchmarking of veterinarians. Based on this study, the SDa opted for quantitative evaluation of the amount of antibiotics used at each of the veal, cattle, pig and broiler farms with which a particular veterinarian has a one-to-one relationship.

With this report, the SDa provides insight into differences in the amounts of antibiotics prescribed by individual Dutch veterinarians. This information together with the trend analyses for antibiotic use at veal, cattle, pig and/or broiler farms, results in full transparency regarding antibiotic use at Dutch animal husbandries.

4. The Veterinary Benchmark Indicator (VBI) and Benchmarks

4.1 Background

The SDa expert panel's first step was to determine whether it is possible to define absolute benchmark values for veterinarians' prescription patterns. Within the scope of this report, "absolute benchmark values" are taken to mean values that are directly associated with a certain risk of development of antibiotic resistance. For antibiotic usage below the absolute benchmark value, this risk would be deemed acceptable. As it turned out, however, such values cannot be determined or inferred based on current scientific knowledge. Another possibility would be to use values that are based on epidemiological data regarding animal diseases (such as frequency and prevalence data) and are thus indirectly associated with the frequency of antibiotic therapy. The SDa expert panel currently sees no application for these assessment options due to lack of data. Responsible benchmarking by means of these methods would require substantial additional research, which is beyond the SDa's responsibilities. The expert panel therefore opted for a more pragmatic approach for determining benchmark values for veterinarians. Analogous to the assessment of inter-farm differences in antibiotic usage, it decided to assess inter-veterinarian differences in the amounts of antibiotics prescribed and set threshold levels based on these differences. To do so, the prescription patterns of all veterinarians were analyzed and compared, after which a threshold value was determined based on the distribution of the prescription data of all veterinarians.

4.2 The rationale and calculation of the Veterinary Benchmark Indicator (VBI)

A useful benchmark parameter has to fulfill three criteria as defined by the SDa:

1) takes account of the fact that a veterinarian can be responsible for several livestock farms;
2) takes account of the extent to which a value deviates from the average prescription pattern;
3) is sensitive to differences in usage patterns between the various farms the veterinarian is responsible for.

These criteria indicate that simple parameters such as a direct calculation of the number of farms within the action level as a proportion of the total number of farms the veterinarian concerned is responsible for is unsuitable because it does not take into account the extent and variation to which a farm's antibiotic use exceeds the action value.

To fulfill all criteria as defined above, the expert panel first had to define the amount of antibiotics prescribed at a certain livestock farm relative to a certain reference value. The obvious reference value to that purpose is the action threshold defined for the type of farm and type of livestock concerned. The relative prescription ratio (RPR) for an individual farm is then defined as the ratio between the amount of antibiotics prescribed by the veterinarian for a livestock farm the veterinarian concerned is responsible for, expressed as the animal-defined daily dosages $DDDA_F$, and the corresponding action threshold. Thus, the RPR is a direct marker of the relative prescription pattern for a farm. A RPR value of 1 indicates that the amount of antibiotics prescribed for a certain livestock type equals the action threshold for that farm.

Since a veterinarian is responsible for several livestock farms, the mean of the RPRs attributed to a veterinarian is a good measure of the overall amount of antibiotics prescribed relative to the action thresholds. Because the relative prescription ratios are (assumed to be) log-normally distributed the mean is taken of the natural logarithms of the relative prescription ratios:

The mean $\overline{RPR} = \frac{1}{N} \sum_{i=1}^{N} \ln(RPRi)$

Similarly, the standard deviation (SD) of the mean RPR is a measure of dispersion, and indicates the variation in RPR values for a veterinarian:

And its standard deviation : $\sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\ln(RPRi) - \overline{RPR})^2}$

The Veterinary Benchmark Indicator is then defined as the probability that the RPR exceeds a ratio of 1 and can easily be calculated by first determining the corresponding Z-value as (ln (1) – mean (RPR))/ SD (RPR) and subsequently the probability that is associated with that Z-value using standard Z-value tables. An example of a VBI calculation is described in the next section. The advantage of this method is that the VBI increases as more of the farms have a ratio exceeding the action threshold as well as the extent to which a ratio exceeds the action threshold increases. The method for calculating is based on the assumption that the RPRs follow a skewed (log-normal) distribution, although the extent to which this holds true is not the same for each of the livestock sectors. As a result of this assumption, the VBI for veterinarians is a relatively conservative measure: it is unlikely to result in a markedly increased VBI if only a few of a veterinarian's farms have a ratio higher than 1. The expert panel deliberately opted for a conservative approach, and feels it improves the practical applicability of veterinary benchmark values.

In theory, the probability of a farm's usage data falling within the action zone is the same for all of the veterinarians responsible for farms with the same type of livestock. However, if the usage data of farms a particular veterinarian is responsible for indicate an above-average probability, the prescription pattern of the veterinarian concerned requires further attention. In that case, the veterinarian should decide on what to advise the livestock farmers concerned in order to reduce the amount of antibiotics the veterinarian has to prescribe.

4.3 VBI example calculation

This section shows an example how to calculate the Veterinary Benchmark Indicator for a veterinarian who is responsible for six farms within a single livestock sector. This veterinarian's VBI therefore needs to be calculated based on six livestock farms. The relative prescription ratios are calculated by dividing each of the $DDDA_F$ by the SDa-defined action threshold for the type of farm concerned.

Table 1. Example antibiotic usage data of six pig farms that are under the care of a particular veterinarian, with a specification by farm of the ratio of the annual antibiotic usage data ($DDDA_F$) to the action threshold defined for the type of livestock and type of farm concerned.

Farm	Type of farm	$DDDA_F$	Farm type-specific action threshold	RPR
1	Sow farm	66	22	3
2	Sow farm	22	22	1
3	Pig fattening farm	4	13	0.31
4	Pig fattening farm	11	13	0.85
5	Sow farm	39.6	22	1.8
6	Pig fattening farm	2	13	0.15

As can be observed, farms 1 and 5 have a RPR higher than 1. In the case of farm 5, the ratio is 1.8. This indicates that antibiotic use at farm 5– and prescribed by the veterinarian - exceeds the action threshold

for this type of farm by 80%. The veterinarian's VBI is based on the average and the distribution of the ratios of all six farms the veterinarian is responsible for as described in section 4.2.
In this example, the mean of the natural logarithms of the RPR is -0.257 and the SD is 1.109. The probability of exceeding an RPR of 1 for this veterinarian then is 0.41, as determined from Z = 0 - (-0.257) / 1.109. Two other examples are shown in Appendix 2.

4.4 Benchmark criteria

To define action zones and signaling zones, thresholds have to be set. Following a recommendation to that end by the expert panel, the SDa has set the veterinary action threshold at 0.30. Veterinarians with a VBI over 0.30 fall within the action zone for veterinarians. A VBI of 0.30 indicates that the probability that a livestock farm falls within the action zone is 0.3, or, in other words, corresponds to roughly 1 in 3 farms falling within the action zone for livestock farms.
As a result of the calculation method used, veterinarians can also be assigned a VBI exceeding the action level threshold value of 0.30 if the antibiotic usage data of several farms the veterinarian is responsible for are at the upper end of the signaling zone. In addition, the VBI is sensitive to the actual amount of antibiotics used, i.e. the relative prediction ratio value. A veterinarian whose farms have animal-defined daily dosages at the higher part of the action zone will be assigned a higher VBI than a veterinarian with the same number of farms in the action zone but whose farms have animal-defined daily dosages closer to the threshold value. This means that the VBI does not just indicate how many farms exceed a certain threshold value, but is also sensitive for the extent to which the benchmark value for a specific type of farm is exceeded.
The threshold value that limits the target zone for veterinarians has been set at 0.10. In line with the interpretation of the action threshold described above, this corresponds to roughly 1 in 10 farms falling within the action zone for livestock farms, or to several farms falling within the signaling level for livestock farms.
The benchmark values for veterinarians apply to all of the livestock sectors because of the use of the relative prescription ratio. Thus, no livestock sector-specific benchmark values are used for veterinarians.

Table 2. Prescription zones and threshold values for the VBI defining each zone

Prescription zone	Threshold values
Action zone	>0.30
Signaling zone	0.10<VBI≤0.30
Target zone	≤0.10

5. Application of the VBI to 2012 usage data.

5.1 Methods

In June 2013, the SDa published the 2012 antibiotic usage data of livestock farms, specified by type of livestock. Those usage data form the basis of the benchmarking method for veterinarians described in the previous section. Additional data regarding one-to-one relationships between livestock farmers and veterinarians were provided by the various livestock sectors. Those data were subsequently linked to databases containing the 2012 antibiotic delivery data for each of the livestock farms concerned. At that time, however, the quality assurance schemes for the livestock sectors concerned had not yet registered the so called “one-to-one relationships” for all of the veterinarians and livestock farms. As a result, not all of the farms with available delivery data and not all of the veterinarians have been included in the analyses for this report. Table 3 shows how the number of farms and veterinarians analyzed differ between the report published in June 2013 and this report. The cover ratio should be taken into account when interpreting the results. Furthermore, the databases included some livestock farms that had one-to-one relationships with more than one veterinarian (due to a change of veterinarian). For cattle farms, it was decided to use the veterinarian with whom the farm concerned had a recorded one-to-one relationship as of December 31, 2012. It was not always clear which of the relationships should be used in the calculations. Farms with ambiguous one-to-one relationships were therefore completely excluded from the analyses for this report.

When calculating relative prescription ratios for farms with calves, cattle or pigs, the respective previously reported usage data (in $DDDA_F$) were used. For broiler farms, the calculated number of treatment days/year for the farm concerned and the associated benchmark values were used.

Table 3. Size comparisons for the databases used in the analyses (2012 usage data, reported in June 2013; 1-to-1 relationship data according to veterinarian databases, provided by the quality assurance schemes in October 2013; SDa-combined data).

	2012 usage data	1-to-1 relationship data, as of October 2013		Combined data	
Type of livestock	**# UBNs[1]**	**# UBNs**	**# 1-to-1 vets**	**# UBNs**	**# 1-to-1 vets**
Veal calves	2175	2175 (97 without 1-to-1 vet)	185	2078	185
Pigs	6428	4643 (124 without 1-to-1 vet)	266	4370	266
Broilers	762	670	75	661	74
Cattle	32254	23152	689	22716	685

[1] UBN: Dutch livestock farm identification code (Uniek Bedrijfsnummer)

Due to the approach used, a veterinarian's VBI values may change once the data for the remaining farms become available. It should also be taken into account that several veterinarians have not yet been included in the analysis. Although individual veterinarians' prescription data may have to be revised at a later date, the SDa expert panel does not expect this to markedly affect the overall picture.

5.2 Results

Table 4 shows the overall variability in the relative prescription ratios as well as how the ratios are distributed over the various usage levels for farms with a particular type of livestock. A RPR higher than 1 indicates that the level of antibiotic use of the farm concerned exceeds the action threshold. As can be seen, the distribution of the RPRs differs per livestock sector. It strongly corresponds to the distribution of the $DDDA_F$-based data of farms within the various livestock sectors referred to in the June 2013 report.

Table 4. Livestock farm-level data: variability in the Relative Prescription Ratio(RPR) for all livestock farms, specified by livestock sector, plus the distribution of the farms over the three usage zones.

	Relative Prescription Ratio (RPR)					Number of farms per usage zone (in %)		
Livestock sector	**Mean**	**P50**	**P75**	**P90**	**SD**	**Target**	**Signaling**	**Action**
Veal calves	0.88	0.66	0.96	1.55	1.86	729 (35)	874 (42)	475 (23)
Pigs	0.74	0.42	0.92	1.65	1.87	2954 (62)	734 (15)	1059 (22)
Broilers	0.62	0.54	0.90	1.23	0.49	303 (46)	231 (35)	127 (19)
Cattle	0.53	0.39	0.61	0.86	5.12	14343 (63)	6902 (30)	1471 (6)

Figures 1-4 show how the RPRs are distributed for farms within the various livestock sectors. It turns out the ratio distributions differ between the four livestock sectors represented, with the mean ratio being lowest for the cattle farming sector and highest for the veal farming sector. The ratios for the cattle farming sector do, however, show the largest amount of variability (standard deviation). This is the result of several peak values. Similar differences can be observed at the veterinarian level (there are two veterinarians – both responsible for a large number of farms – with a high mean ratio). The proportion of cattle farms falling within the action zone based on the current data (October 2013) is lower than the expected proportion of about 10%. Most cattle farms are currently within the target zone. This means that the results for this livestock sector are particularly likely to change once the data of the remaining veterinarians become available.

Figure 1. Distribution of Relative Prescription Ratios for calf fattening farms (x-axis being cut off at a maximum ratio of 5.0)

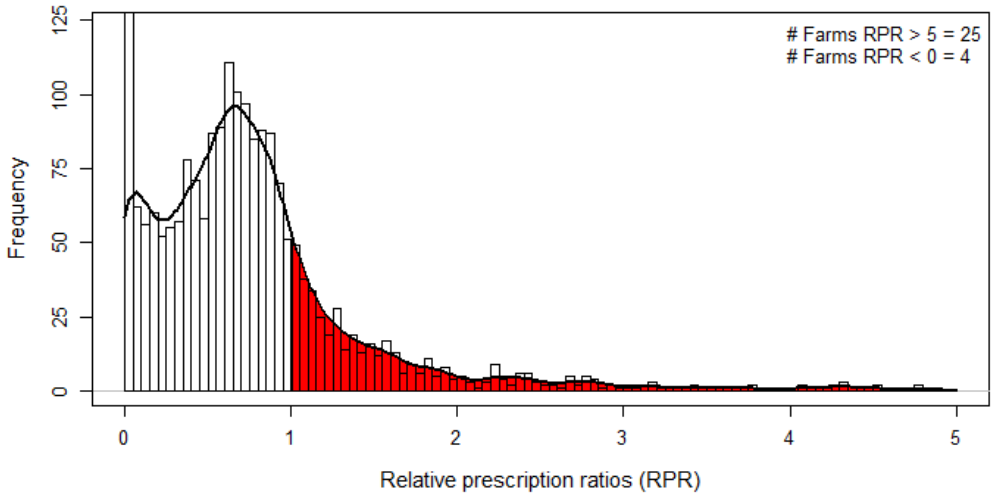


Figure 2. Distribution of Relative Prescription Ratios for pig farms (x-axis being cut off at a maximum ratio of 5.0)

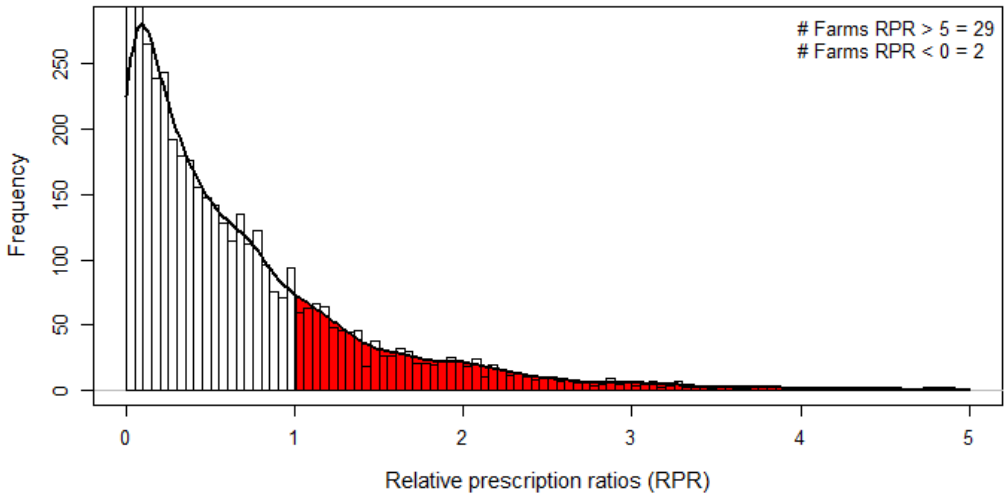


Figure 3. Distribution of Relative Prescription Ratios for broiler farms (x-axis being cut off at a maximum ratio of 5.0)

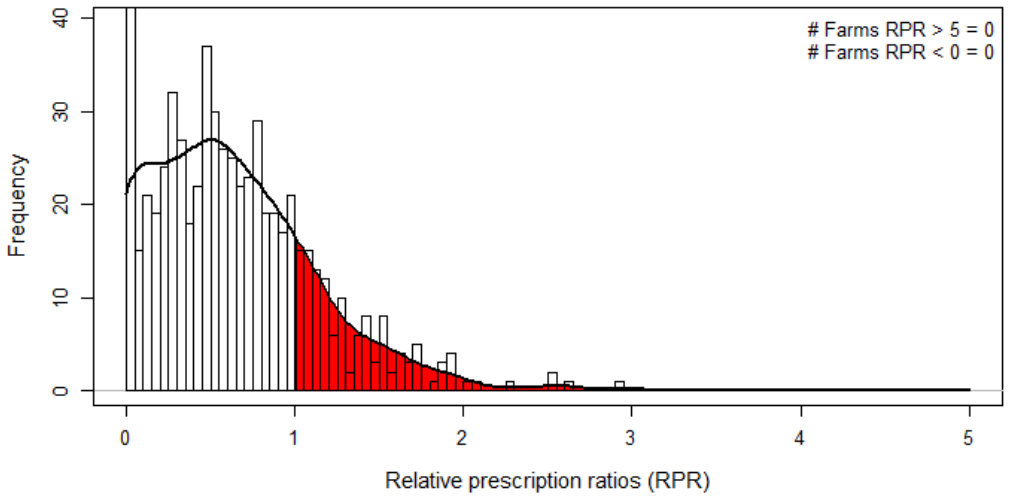
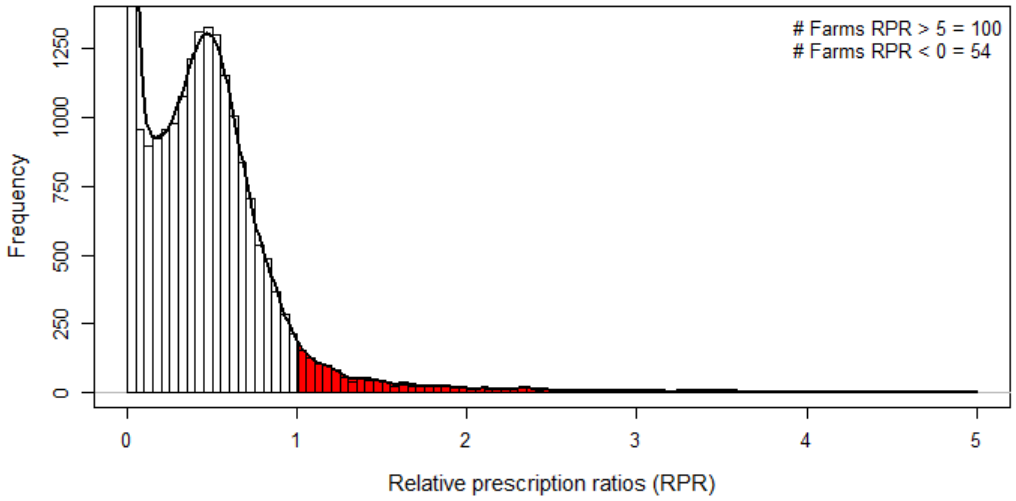


Figure 4. Distribution of Relative Prescription Ratios for cattle farms (x-axis being cut off at amaximum ratio of 5.0)



The databases used show that the average number of farms per veterinarian is quite similar for the veal farming sector and the pig farming sector (11.2 (range: 1-134) and 16.4 (1-84), respectively). In the broiler farming sector, the average number of farms per veterinarian is lower (8.9 (1-39)), while it is considerably higher in the cattle farming sector (33.2 (1-177)).

Figures 5-8 and Table 5 show the descriptive statistics of the relative prescription ratios per veterinarian for the various livestock sectors. As can be seen, the distribution of the ratios for veterinarians reflect the distribution of the $DDDA_F$-based ratios for livestock farms, with higher values for the veal farming sector and lower values for the broiler and cattle farming sectors. The standard deviation is relatively high for cattle farming, as a result of a few outliers with ratio's >3, while visual inspection shows, apart from these outliers a relatively narrow distribution. Table 5 also includes the descriptive statistics for the VBIs per livestock sector.

Figure 5. Frequency distribution of mean relative prescription ratios for veterinarians at calf fattening farms (x-axis being cut off at a maximum ratio of 3.0; number of veterinarians with a ratio >3 = 0)

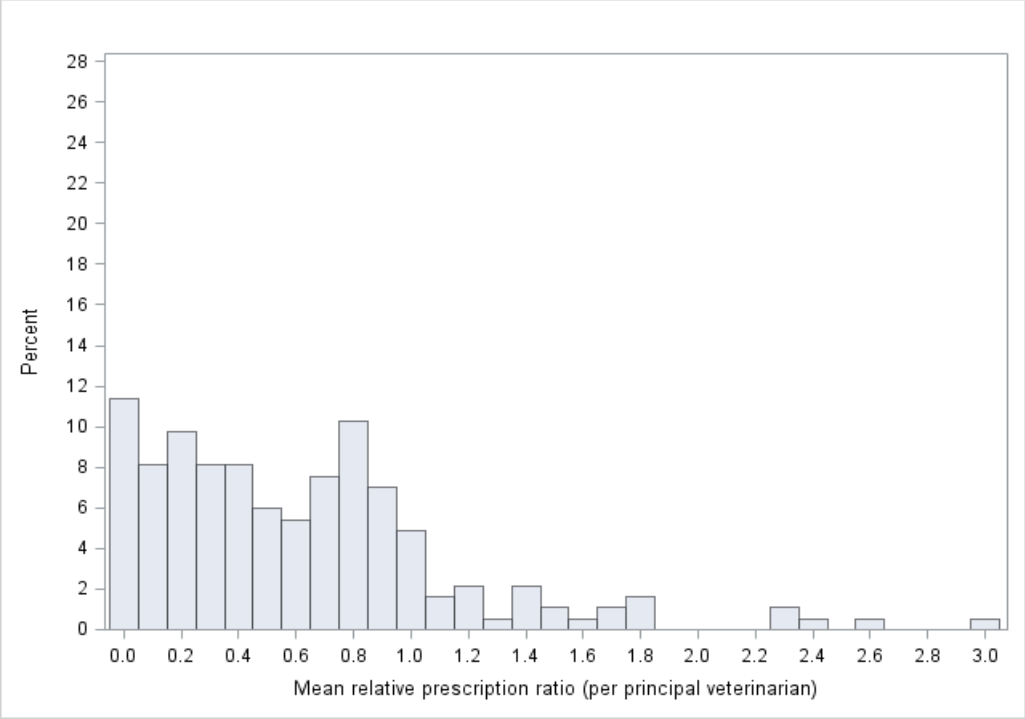


Figure 6. Frequency distribution of mean relative prescription ratios for veterinarians at pig farms (x-axis being cut off at a maximum ratio of 3.0; number of veterinarians with a ratio >3 = 2)

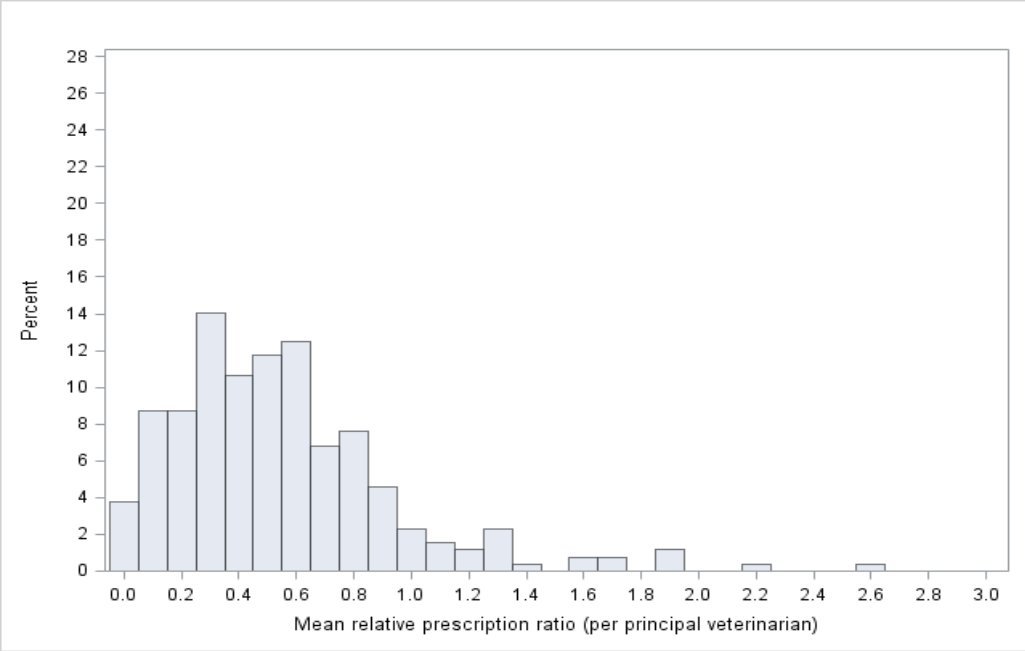


Figure 7. Frequency distribution of mean relative prescription ratios for veterinarians at broiler farms (x-axis being cut off at a maximum ratio of 3.0; number of veterinarians with a ratio >3 = 0)

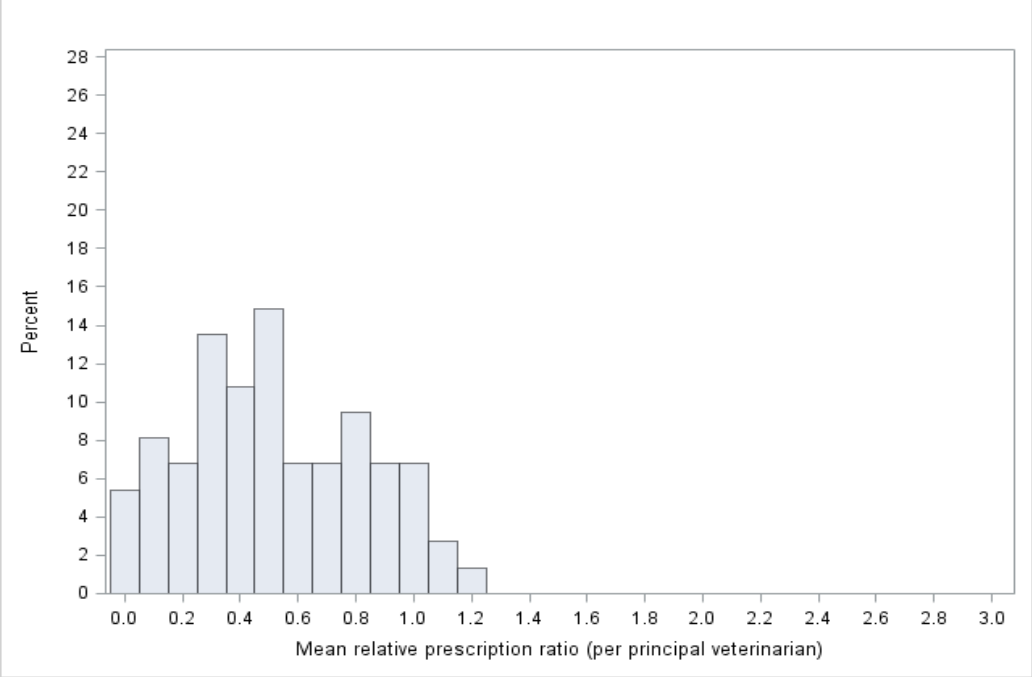


Figure 8. Frequency distribution of mean relative prescription ratios for veterinarians at cattle farms (x-axis being cut off at a maximum ratio of 3.0; number of veterinarians with a ratio >3 = 3)

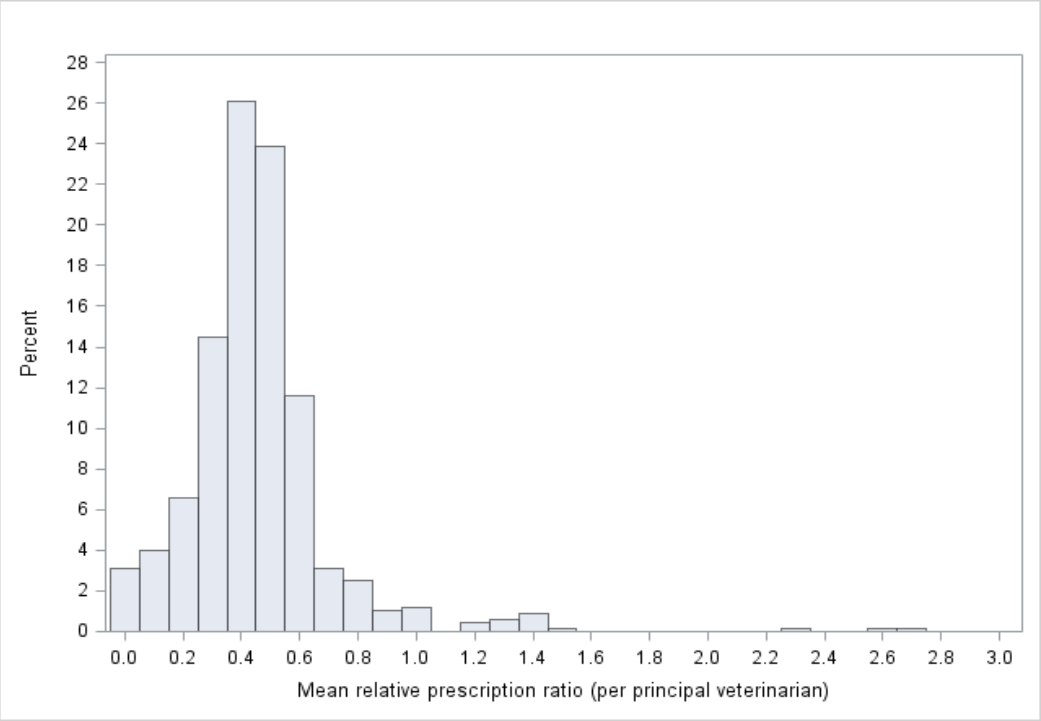


Table 5. Veterinarian-level data: distribution characteristics of mean **RPRs and in VBIs for veterinarians, specified by livestock sector**

	Mean RPRs for 1-to-1 vets					VBI for 1-to-1 vets					
Livestock sector	**Mean**	**P50**	**P75**	**P90**	**SD**	**# 1-to-1 vets**	**Mean**	**P50**	**P75**	**P90**	**SD**
Veal calves	0.62	0.55	0.86	1.21	0.54	133	0.21	0.21	0.31	0.40	0.16
Pigs	0.57	0.49	0.74	1.04	0.48	252	0.18	0.16	0.25	0.32	0.14
Broilers	0.51	0.49	0.75	0.95	0.31	57	0.17	0.16	0.26	0.34	0.13
Cattle	0.51	0.44	0.54	0.66	1.04	655	0.12	0.11	0.15	0.19	0.08

The VBIs in the veal farming, pig farming and poultry farming sectors show a slightly higher variability (represented by the standard deviation (SD)) than the VBIs in the cattle farming sector. This is due to the fact that the differences in usage between individual farms are bigger in the former sectors. Furthermore, the benchmark value for cattle farms is based on the 90-percentile value rather than the 75-percentile value, which also results in a slightly less VBI variability in the cattle farming sector.

The distribution of the Relative Prescription Ratio-based VBIs of individual veterinarians per livestock sector is shown in Figures 10-13, with the ratios pertaining to antibiotic use at the farms the veterinarian concerned is responsible for (in $DDDA_F$) and the action threshold applicable to those farms. The tail on the right side of the distributions indicates that in each of the livestock sectors some of the veterinarians have a markedly increased VBI. This generally concerns veterinarians responsible for several farms who prescribe substantially more antibiotics than their colleagues. This can be illustrated by the data of two veterinarians at cattle farms. Both veterinarians are responsible for 45 farms, and their VBIs are 0.67 and 0.47, respectively, with both values exceeding the action value for veterinarians. For veterinarian A, the proportion of farms with a ratio higher than 1 (and therefore exceeding the action value) is 70%, and the proportion of farms within the signaling level is 4%. The proportions exceeding the action and signaling values are different for veterinarian B: 27% and 31%, respectively.
As can be seen in Figures 10-13, different VBI distributions are observed for the various livestock sectors. The differences in VBI distributions are in part due to differences in the distribution of antibiotic usage data ($DDDA_F$) between the various farms in the livestock sectors concerned. Additionally, differences in the extent to which the antibiotic usage data of farms within a particular livestock sector exceed the action value also have an effect on the VBI distribution.

Figure 9. Distribution of VBIs for veterinarians at calf fattening farms

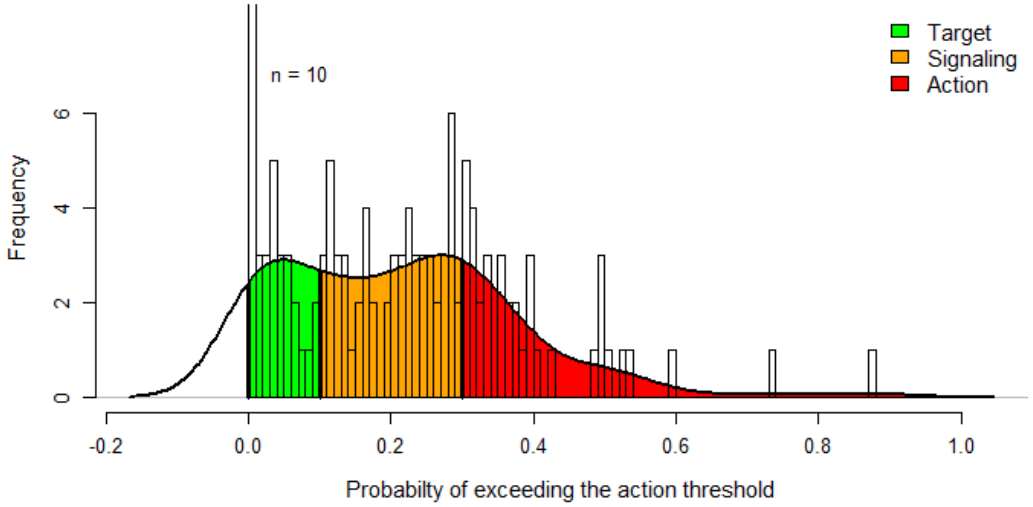


Figure 10. Distribution of VBIs for veterinarians at pig farms

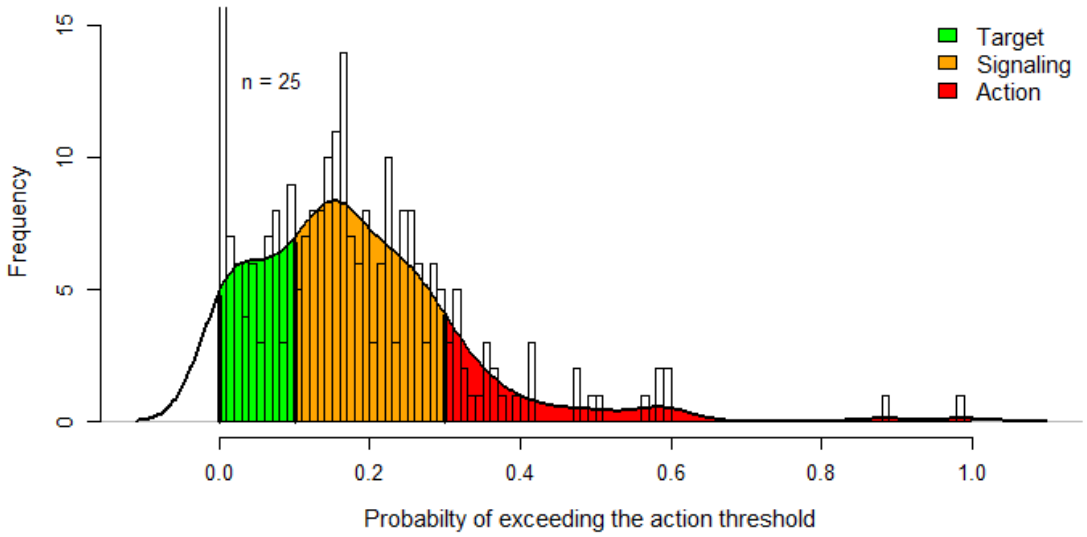


Figure 11. Distribution of Veterinary Benchmark Indicators for veterinarians at broiler farms

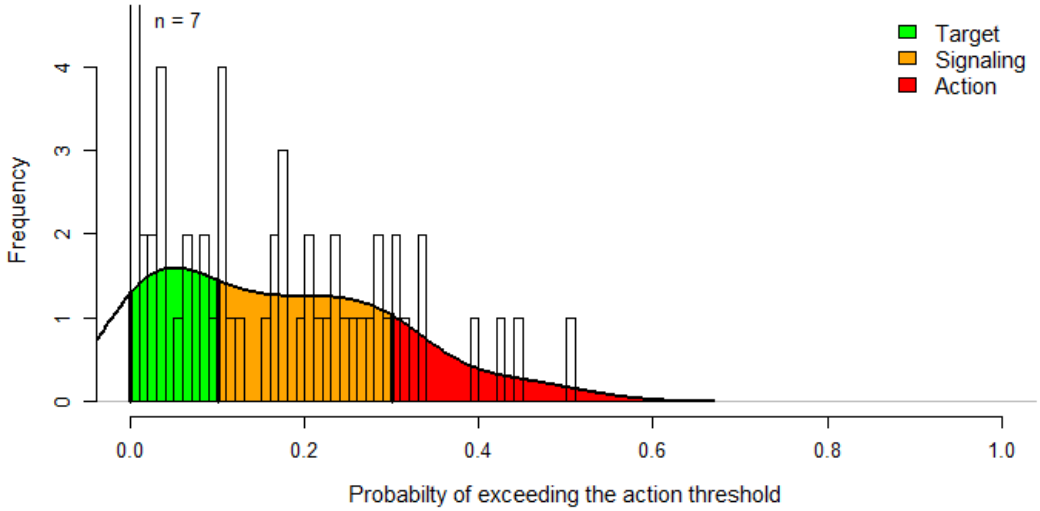
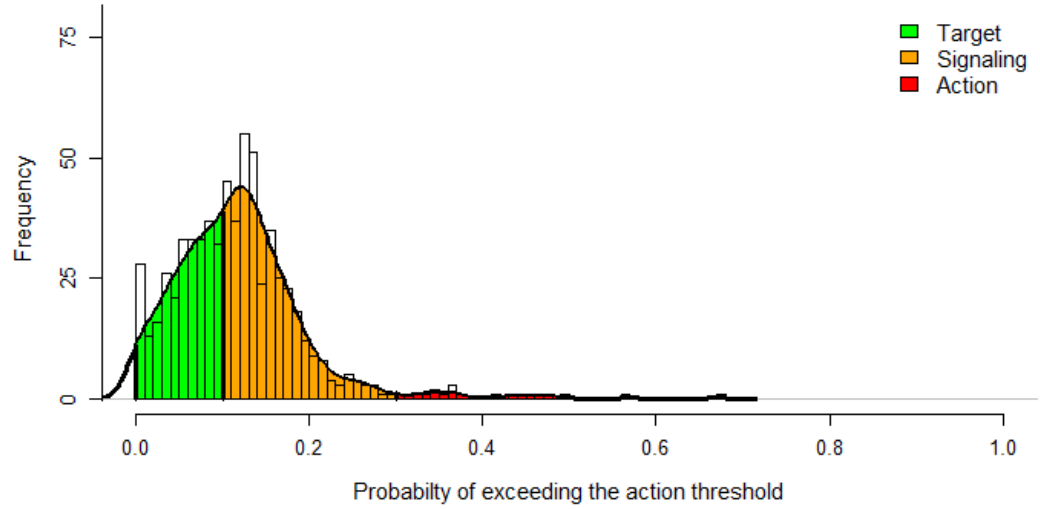


Figure 12. Distribution of Veterinary Benchmark Indicators for veterinarians at cattle farms



At calf fattening farms, 37 out of 185 veterinarians (28% of the benchmarked veterinarians, and 20% of the total number of veterinarians) fall within the action zone (VBI>0.3), as do 33 out of 266 veterinarians at pig farms (13% and 12%, respectively), 10 out of 74 veterinarians at broiler farms (18% and 14%, respectively), and 17 out of 685 veterinarians at cattle farms (3% and 3%, respectively) (Table 6, second column).

Table 6. Number of veterinarians per zone by livestock sector; specified for veterinarians responsible for several farms per livestock sector (second column) and for veterinarians responsible for a single farm per livestock sector (third column).

Livestock sector	Number of veterinarians with several farms per livestock sector who fall within the target, signaling or action zone based on their Veterinary Benchmark Indicator (VBI)			Number of veterinarians with a single farm per livestock sector who fall within the target, signaling or action zone based on the usage level of the farm concerned		
	Target	Signaling	Action	Target	Signaling	Action
	(VBI≤0.10)	(0.10<VBI≤0.30)	(VBI>0.3)	-	-	-
Veal calves	39	57	37	27	20	5
Pigs	77	142	33	12	1	1
Broilers	21	26	10	13	2	2
Cattle	272	366	17	22	7	1

In every livestock sector there were some veterinarians for whom no VBI could be calculated, either because according to the database they were linked to just one farm, or because an $DDDA_F$ of 0 was recorded for every farm to which they were linked. Table 6 (third column, right) shows the number of veterinarians with a single farm per livestock sector, and the usage levels of those farms. After all, veterinarians with just one farm per livestock sector are assigned the prescription level corresponding to the usage level of the farm concerned. If these veterinarians were to be included in the analysis, the proportion of veterinarians falling within the action level for veterinarians would be 23% for veterinarians at calf fattening farms, 13% for veterinarians at pig farms, 16% for veterinarians at broiler farms, and 3% for veterinarians at cattle farms.

All of the veterinarians falling within the action zone are responsible for farms that fall within the SDa-defined action zone for farms with that particular type of livestock. However, most of the veterinarians falling within the action zone are also responsible for farms that do in fact fall within the target zone. Conversely, it is possible for veterinarians falling within the target zone to be responsible for several farms that are included in the action zone for farms with that particular type of livestock. This is the case for 2 veterinarians at calf fattening farms, 18 veterinarians at pig farms, 4 veterinarians at broiler farms, and 127 veterinarians at cattle farms. In these cases, however, the number of farms falling within the action zone is small enough not to result in a VBI over 0.30.

5.3 Conclusions

This analysis has shown that there is considerable inter-veterinarian variability in antibiotic prescription patterns. Within similar livestock sectors, prescription data of veterinarians turned out to sometimes vary by a factor of 5 to 20, depending on the type of livestock concerned. The most substantial differences were observed in the veal farming and pig farming sectors, while inter-veterinarian differences turned out to be smallest in the cattle farming sector. Similar differences were observed when only veterinarians responsible for a large number of farms were included in the analyses. The SDa expert panel considers it unlikely for prescribing peaks due to animal diseases at a single farm to have a significant effect on these differences. It is possible, however, that veterinary practices often assign “problem farms” to their most experienced veterinarians, which may increase the VBIs of these veterinarians. A farm's high level of antibiotic use is particularly likely to affect a veterinarian's VBI if it is the result of factors such as poor management or poor facilities at the farm, and is therefore structural in nature. Nevertheless, the expert panel does not feel that these circumstances explain or warrant average prescription patterns that vary by a factor of 5 to 20. It is up to the veterinarians as a group to further determine the cause of these differences and to take action accordingly. For some of the veterinarians, the VBI could not yet be calculated or could not yet be based on all of the farms the veterinarian was responsible for. As explained in a previous chapter, this was due to the fact that several one-to-one relationships between veterinarians and livestock farms had not yet been contractually agreed or registered at the time the SDa expert panel was calculating the VBIs. The inclusion of the remaining VBIs may slightly alter the results set out in this report.

6. Future developments regarding benchmark indicators

Monitoring and revising the benchmark values to be used for livestock farms is a never-ending process. The values are expected to be revised at some point in the future. The SDa expert panel and several livestock sectors are currently discussing the possibility of applying livestock- and farm-based subgroups that are more narrow than the ones used currently. Since the VBI is linked to the benchmark thresholds used for livestock farms (which are based on the ratio $DDDA_F$: action threshold for the type of farm concerned), revision of a benchmark threshold for livestock farms will directly affect the benchmarking of veterinarians. This link guarantees the application of coherent benchmarking methods for livestock farms and veterinarians.

7. References

- Bos MEH, Taverne FJ, van Geijlswijk IM, Mouton JW, Mevius DJ, Heederik DJJ. Consumption of antimicrobials in pigs, veal calves, and broilers in the Netherlands: quantitative results of nationwide collection of data in 2011.; Netherlands Veterinary Medicines Authority (SDa). PLoS One. 2013; 8 (10):e77525.

- CEN. European Standard EN689. Workplace atmospheres—guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy. Brussels, Belgium: Comité Européen de Normalisation; 1995.

- The Netherlands Veterinary Medicines Authority. Usage of antibiotics in livestock in the Netherlands in 2012. July 2013 (http://www.autoriteitdiergeneesmiddelen.nl/Userfiles/sda-report-usage-of-antibiotics-in-livestock-in-the-netherlands-in-2012-july-2013.pdf).

Appendix 1.

The method used for calculating the Veterinary Benchmark Indicator (VBI) and examples

Every veterinarian is assigned a Veterinary Benchmark Indicator (VBI). The VBI is calculated based on usage data of the farms with which the veterinarian concerned has a one-to-one relationship. The VBI represents the overall probability of those farms having a usage that exceeds the action threshold. Several calculation steps are required to determine this probability.

- First, the relative prescription ratio of the animal-defined daily dosages per year ($DDDA_F$) to the farm type-specific action threshold[2] for each of the livestock farms the veterinarian is responsible for is calculated:

  $RPRi_i$ = $DDDA_F$: action threshold for the livestock sector and type of farm concerned

  RPR_i is the ratio for farm i. Each livestock sector or subsector has its own action value (see Table 1 in Appendix 3). For example, a pig fattening farm with an $DDDA_F$ of 26 has a RPR of 26 : 13 = 2, with 13 being the benchmark thresholdrepresenting the action threshold for pig fattening farms. The RPR for a farm with sows and piglets that has an $DDDA_F$ of 11, amounts to 11 : 22 = 0.5, with 22 being the action threshold for this particular type of farm. The relative prescription ratios have to be calculated for every single farm, and form the basis of the subsequent calculation steps.
- Subsequently, the mean and the standard deviation are then calculated, after log transformation has been applied:
- $\overline{RPR} = \frac{1}{N} \sum_{i=1}^{N} \ln(RPRi)$

- SD : $\sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\ln(RPRi) - \overline{RPR})^2}$

- A value of 0.1 is assigned to farms with an $DDDA_F$ of 0, so that log transformation will result in a real number. Empirical research has shown that the animal-defined daily dosages roughly follow a log-normal distribution, and the same holds true for the distribution of mean ratios for individual veterinarians. This is why log transformation is applied to the ratios. Using the natural logarithms of the ratios "normalizes" the skewed distribution. More information on this can be found in another SDa publication (Bos et al, 2013).
- The next step is to calculate the VBI by determining the area of the log normalized ratio distribution beyond a ratio value of 1, assuming a normal distribution. This calculation is performed in line with a CEN (European Committee for

[2] The action value is the threshold value separating the signaling and action levels. If a farm's antibiotic usage data exceed the action value, the livestock farmer responsible has to take action immediately to quickly reduce the amount of antibiotics used.

Centralization) standard (CEN, 1992). This is done by first calculating the Z value (ln(1)-mean RPR)/SD and subsequently finding the probability associated with the Z-value

- As the final step, the resulting probability is used to categorize the veterinarian into one of three zones: the target zone, signaling zone or action zone. The exact benchmark values used for determining the VBI are provided in Appendix 3, Table 1.

Example calculations

The first step is to calculate the relative prescription ratios by dividing a farm's animal-defined daily dosages per year ($DDDA_F$) by the action threshold applicable to that farm, and repeating this process for each of the farms for which the veterinarian concerned is responsible. For a livestock farm with sows that has an $DDDA_F$ of 20 and for which an action value of 22 has to be used, the ratio will be 20 : 22 = 0.91.

The example below shows the ratios ($DDDA_F$: action value) for the farms of a particular veterinarian.

Farm	1	2	3	4	5	6
RPR	**1.11**	**3.63**	**5.55**	**2.51**	**1.96**	**2.26**
ln RPR[1]	0.10436	1.289233	1.713798	0.920283	0.672944	0.815365
Mean ln RPR	[0.10436 + 1.289233 + 1.713798 + 0.920283 + 0.672944 + 0.815365] : 6 = 0.91933. This number is rounded off to **0.919**					
Associated standard deviation, calculated in EXCEL	0.548					

[1] natural logarithm of the RPR

The associated mean and standard deviation are 0.919 and 0.548, respectively. With the mean and the standard deviation being known, it is possible to determine the probability of a farm's ratio having a value higher than 1.
Since a normal distribution is assumed following log transformation, the standard score (Z-score) can be used in the calculation, with Z = (ln (ratio 1) - mean) : standard deviation.
As ln(1) equals 0, Z = -m : SD = -0.919 : 0.548= -1.68. Standard normal tables (Z tables) indicate that this Z-score corresponds to a VBI of approximately 0.95 (95%). This means that for this veterinarian about 95% of the ratios will likely have a value higher than 1 (equivalent to 9.5 in 10 farms, or 95 in 100 farms). However, the 6 calculated ratio values in this example tell us that all 6 of them have a value higher than 1. Apparently, the ratios are distributed in such a way that there is still a small probability (5%) of values below 1 being observed. It is obvious that all of the farms for which the veterinarian concerned is

responsible exceed the action value. In short, with a value of 0.95 (VBI = 0.95), this veterinarian clearly exceeds the action value of the VBI: the veterinarian falls within the action zone.

The example below shows the ratios ($DDDA_F$: action value) for the farms of another veterinarian.

Farm	1	2	3	4	5
RPR	1.05	0.1	0.25	0.23	0.35

The RPRs of this veterinarian's farms are generally low, although one of the farms has an excessively high RPR. For this veterinarian, the probability of a RPR exceeding the action value is 0.07 (7%). In other words: only 7 in 100 farms will fall into the red zone, which means the veterinarian's VBI is within the target zone.

The example below shows the RPRs ($DDDA_F$: action value) for the farms of yet another veterinarian.

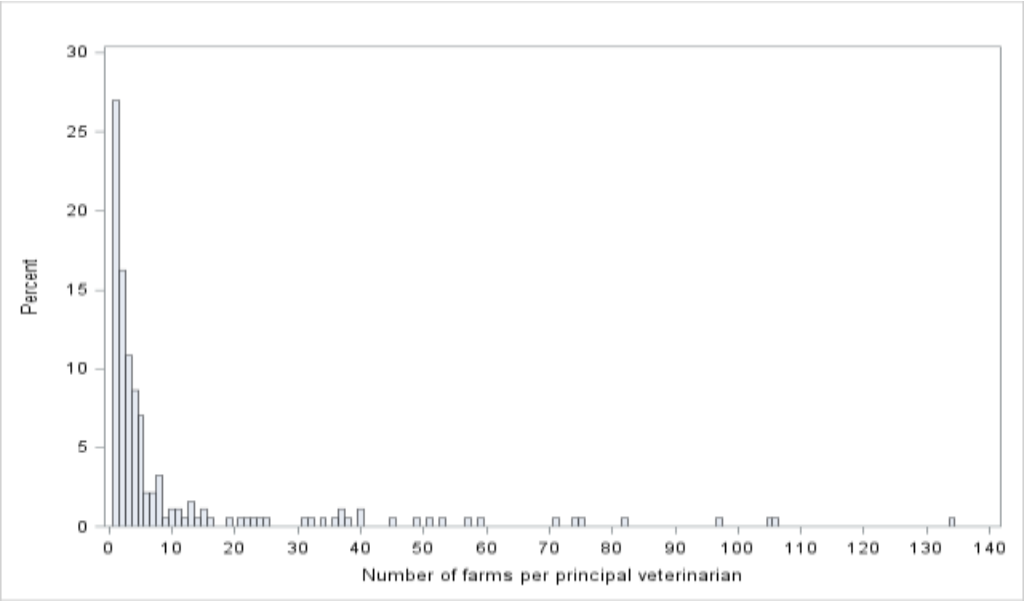
Farm	1	2	3	4
RPR	1.10	0.88	0.93	0.85

The RPRs of this veterinarian's farms are generally high, just below the action threshold, with one of the farms having a markedly higher relative prescription ratio. For this veterinarian, the probability of a RPR exceeding the benchmark value is 0.28 (28%), corresponding to fewer than 3 in 10 (or 30 in 100) farms exceeding the action threshold. This means the veterinarian's VBI is within the signaling zone.

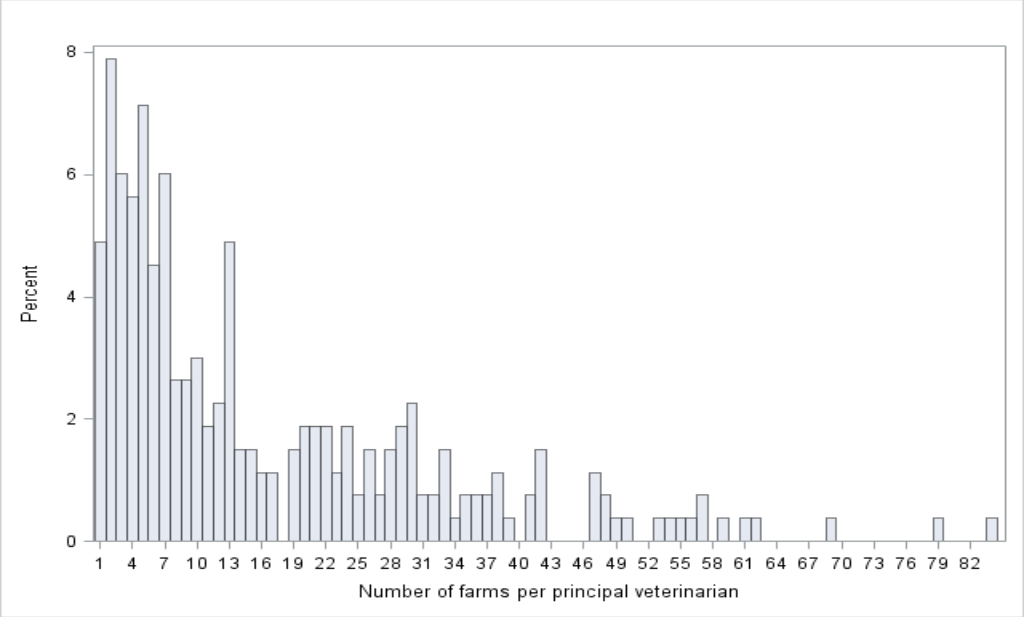
Appendix 2.

Distribution of the number of farms with which veterinarians have a one-to-one relationship

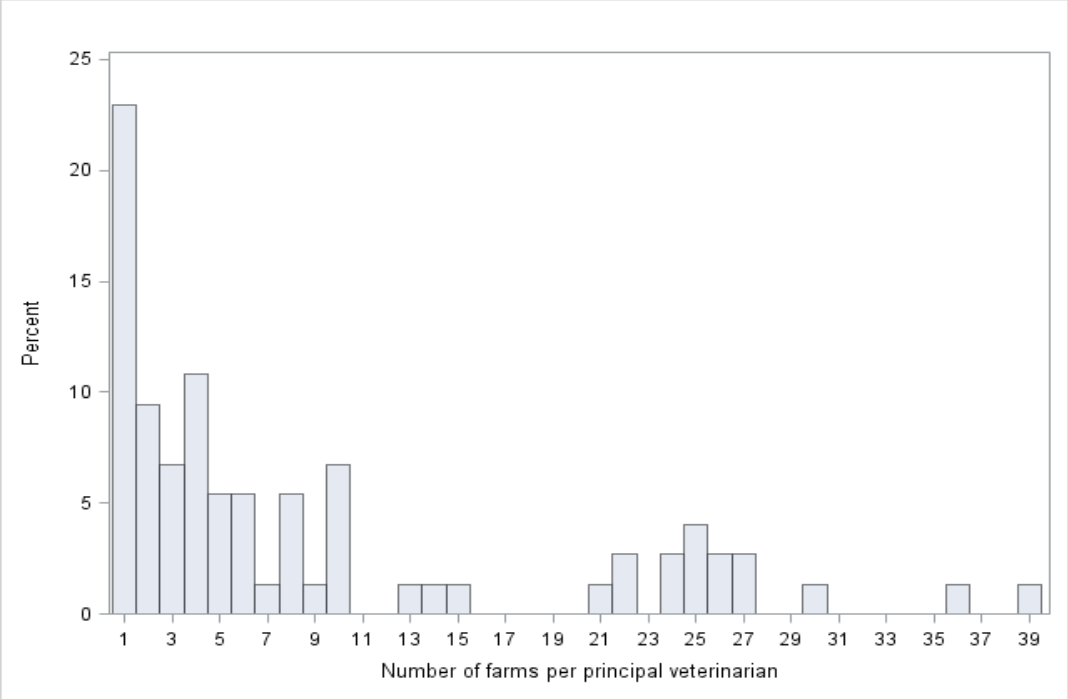
Veal farming sector



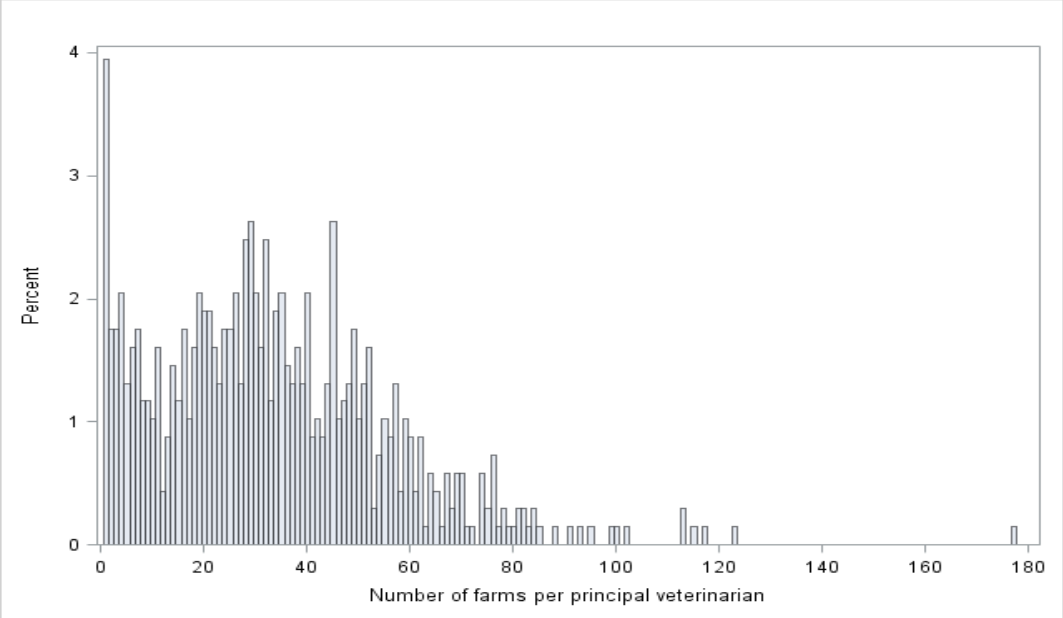
Pig farming sector



Broiler farming sector



Cattle farming sector



Appendix 3.

Definitions

Benchmarking

Benchmarking is the process of periodically comparing one's performances and practices to those of one's peers or colleagues.

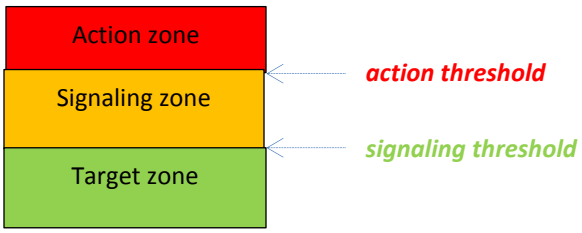
Benchmark values

The SDa expert panel sets and applies two threshold values (benchmark values): a signaling threshold and an action threshold. The two values separate three usage or prescription levels:

1. The target zone (green): the amount of antibiotics used is acceptable – it is equal to or below the ***signaling threshold***.

2. The signaling zone (amber): the amount of antibiotics used is somewhat increased – it exceeds the signaling threshold but is below the action threshold. If a livestock farm's antibiotic use falls within this zone, further attention is required and action may have to be taken to reduce the amount of antibiotics used to a target zone value.

3. The action zone (red): the amount of antibiotics used is markedly increased – it exceeds the ***action threshold***. The livestock farmer concerned has to take action immediately to quickly reduce the amount of antibiotics used.



Benchmark indicators by type of livestock farm

When benchmarking livestock farmers, the SDa expert panel uses benchmark values that are defined specifically for the type of livestock and the type of livestock farm concerned. This approach provides the most accurate comparison of the performances and practices of livestock farmers.

Based on the usage data of livestock farms, the SDa expert panel has defined benchmark values for several types of livestock and several types of livestock farms (see Table 1 below).

Table 1:

	Threshold values for individual livestock farms ($DDDA_F$)		
Species of animals	**Target zone** **2012 - 2015**	**Signaling zone** **2014**	**Action zone** **2014**
Poultry			
- Broilers	0 - 15	> 15 - 30	> 30
- Turkey	0 - 19	> 19 - 31	> 31
Catttle			
- Dairy cattle	0 - 4	> 4 - 6	> 6
- Suckler cows	0 - 1	> 1 - 2	> 2
- Beef bulls	0 - 1	> 1 - 2	> 2
- Rearing	0 - 1	> 1 - 2	> 2
Pigs			
- Sows/piglets	0 - 10	> 10 - 22	> 22
- Finishers	0 - 10	> 10 - 13	> 13
Veal calves			
- White veal	0 - 23	> 23 - 39	> 39
- Rosé veal starter farms	0 - 67	> 67 - 110	> 110
- Rosé veal fattening farms	0 - 1	> 1 - 6	> 6
- Rosé combination farms	0 - 12	> 12 - 22	> 22

SDa - The Netherlands Veterinary Medicines Authority
Yalelaan 114
3584 CM Utrecht
The Netherlands

Telephone: 088 – 0307 220
Email: info@autoriteitdiergeneesmiddelen.nl
www.autoriteitdiergeneesmiddelen.nl

The Veterinary Benchmark Indicator:
Towards transparent and responsible antibiotic prescription patterns in the veterinary practice
SDa/1146/2014