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1 **Characterization and evolution of countries affected by bovine brucellosis (1996 - 2014)**

2

3 **Short title**

4 **Evolution of bovine brucellosis in the world (1996-2014)**

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19

20 **Summary**

21 This paper describes the global distribution and temporal evolution of bovine brucellosis due to
22 *Brucella abortus* during a 19-year period (1996 – 2014) using the information officially reported
23 to the World Organisation for Animal Health (OIE) by veterinary services of 156 countries.

24 Variables that can influence the health status of bovine brucellosis (i.e., year, per capita Gross
25 Domestic Product (GDP), continent, and bovine population) were also analysed. Countries were
26 classified into three categories of health situations: *ENZOOTIC*: countries infected, which may
27 have been free of brucellosis but for periods of fewer than 3 years; *NON-ENZOOTIC*: countries
28 where the disease was present but that had at least a 3-year period without the disease; and
29 *FREE*: countries where the disease remained absent during the whole period. The countries free
30 from bovine brucellosis, or in the process of eradication, were located in Oceania and Europe,
31 while the more affected regions were Central and South America, Africa, and parts of Asia.

32 Among the Non-Enzootic countries, the results showed that a very high proportion managed to
33 control the disease during the period of study, with a sharp decline in the percentage of infected
34 countries from 71% in 1996 to 10% in 2014. Among the Enzootic countries, a much smaller
35 proportion managed to control the disease, with a slight drop in the percentage of infected
36 countries from 92% in 1996 to 80% in 2014. A relationship was found between the status of the
37 disease and the availability of economic resources; thus, countries with a high GDP per capita
38 tended to be free from bovine brucellosis. On the other hand, countries with a larger bovine
39 population showed a greater probability to have the disease present. An increase in surveillance
40 programmes and implementation of control policies were observed during the period of study.

41

42

43 **Key words:** bovine brucellosis, brucellosis, global distribution, Handistatus, OIE, WAHIS

44 1. Introduction

45 Bovine brucellosis is widespread and is of major importance due to its impact on both
46 animal and human health (Alves et al., 2015). According to the World Health Organization
47 estimates, approximately 400,000 people become infected yearly from *Brucella* by a foodborne
48 route, with almost half of the cases appearing in the Eastern Mediterranean Region (World
49 Health Organization, 2015). It causes significant economic losses in cattle production due to
50 reproductive disorders (placentitis, metritis, retention of the placenta, and abortion in pregnant
51 cows and epididymitis, vesiculitis, and orchitis in bulls) and the consequent reduction in milk
52 production and increase in calving intervals. The annual economic losses attributable to bovine
53 brucellosis have been estimated to be US\$ 448 million in Brazil (Santos, Martins, Borges, &
54 Paixão, 2013) and US\$ 3.4 billion in India (Singh, Dhand, & Gill, 2015).

55 Control of bovine brucellosis requires significant resources and sustained efforts. Several
56 epidemiological factors linked to the disease can complicate its control and eradication: 1) the
57 presence of wildlife reservoirs (Bengis, Kock, & Fischer, 2002), 2) the spill-over effect
58 (Schumaker, 2013), and 3) the difficulties of clinical diagnosis due to non-specific symptoms,
59 which make bovine brucellosis underestimated at the farm level when diagnostic tests are not
60 applied (de Figueiredo, Ficht, Rice-Ficht, Rossetti, & Adams, 2015; Godfroid et al., 2013).

61 Brucellosis is a neglected disease in endemic developing countries, and the main reasons for this
62 are the absence of specific clinical signs, the lack of systematic application of laboratory tests,
63 which are essential for its diagnosis (Díaz, Casanova, Ariza, & Moriyón, 2011), and difficulty in
64 attracting the attention of health authorities.

65 In accordance with its characteristics, bovine brucellosis control and eradication can also
66 be complicated by several factors, such as the socio-cultural practices associated with the country

67 in which it occurs. The disease is more controlled in dairy bovine production systems than in
68 beef-only farms (de Alencar et al., 2016). Extensive beef-cattle animals located in agro-pastoral
69 systems are exposed to an environment (water-points and pastures) contaminated by
70 reproductive discharges (Adamu et al., 2016) of other herds or flocks that are moving through
71 different pastures depending on food availability (Jackson, Nydam, & Altier, 2014). Likewise,
72 nomadic livestock populations, low herd biosecurity, and lack of farmer sensitization (Alhaji,
73 Wungak, & Bertu, 2016; Aznar et al., 2015) can contribute to the persistence of the disease.

74 Availability of sufficient economic resources is of paramount importance in bovine
75 brucellosis control and eradication, as it is a determining factor in the capacity of the Veterinary
76 Service to respond to an epidemiological episode. In most cases, co-operation between
77 government and industry is key for coordinating efforts and eradicating the disease (More,
78 Radunz, & Glanville, 2015). Some examples of this success are the eradication of the disease in
79 the Czech Republic (Kouba, 2003) and in the United States in domestic animals (Ragan, 2002).

80 Meanwhile, in a country where there is inadequate economic investment in health
81 policies, this impedes the application of appropriate control measures over time (Howe, Häsler,
82 & Stärk, 2013; Ibrionke, McCrindle, Fasina, & Godfroid, 2008; Kouba, 2003; McDermott,
83 Grace, & Zinsstag, 2013; Pavade, Awada, Hamilton, & Swayne, 2011; Ragan, 2002).

84 Despite the global importance of bovine brucellosis, few studies have described its global
85 distribution and long-term evolution (Lopes, Nicolino, & Haddad, 2010; Seleem, Boyle, &
86 Sriranganathan, 2010). Such studies provide useful information on disease trends in different
87 world regions and on surveillance and control strategies implemented according to the situation
88 of the disease.

89 The main objective of this paper was to characterize and describe changes in bovine
90 brucellosis-affected countries in the period 1996 - 2014 in order to improve the understanding of
91 the mechanisms applied for its control and eradication. To do this, 18 years of bovine brucellosis
92 data at the international level were used to 1) characterize the countries' health situations as
93 regards bovine brucellosis; 2) determine the characteristics associated with each health situation
94 in the countries; 3) present the evolution of the proportion of affected countries falling into each
95 health situation; 4) describe the evolution of surveillance programmes and implementing control
96 policies addressing each health situation; and 5) evaluate the stability of these surveillance
97 programmes and implementing control policies over time. The findings should provide valuable
98 information about the status of the disease worldwide and insights for improving the measures
99 necessary to minimize the impacts of this disease.

100

101 **2. Materials and methods**

102

103 ***2.1. Materials***

104 The data used to determine the health status of countries, surveillance programmes, and
105 control policies implemented, as well as yearly figures on national bovine populations, were
106 obtained from the World Organization for Animal Health (OIE), which has a mandate that
107 includes ensuring transparency in the global animal disease situation. These data are submitted to
108 the OIE by the National Veterinary Authorities of 180 Member Countries, who have the legal
109 obligation to report information concerning highly impacting animal diseases, including bovine
110 brucellosis. Additionally, more than 20 other countries and territories provide information to the
111 OIE on a voluntary basis. Data used in this study were derived from two related collection

112 systems. From 1996 to 2004, countries provided information stored in Handistatus II (OIE,
113 2017a); from 2005 to 2014, countries provided information via the World Animal Health
114 Information System (WAHIS) (OIE, 2017b). A quality check was performed, and
115 inconsistencies or missing records in the information collected by the OIE were systematically
116 clarified by contacting the National Veterinary Services of the reporting countries. To be
117 consistent with the data over these 19 years, only the 156 countries that remained Members of
118 the OIE during the whole study period (1996-2014) were considered for the study (42 countries
119 located in Africa, 25 in America, 40 in Asia, 45 in Europe, and 4 in Oceania).

120 Information on national Gross Domestic Product (GDP), corresponding to annual income
121 values per capita (in US\$), was obtained from the World Bank for the period between 1996 and
122 2014, and its value was deflated to the year 2014 for comparison purposes (The World Bank,
123 2017). The average deflated GDP over the period of analysis was then calculated for each
124 country. Census data (number of animals) of bovine and bubaline populations were obtained
125 from WAHIS for each country and year evaluated (OIE, 2017c).

126

127 **2.2. Methods**

128

129 *2.2.1. Classification of countries based on their health situation from 1996 to 2014*

130 Countries were classified into three categories of health situations from 1996 to 2014: a)
131 *FREE countries*: countries where the disease remained absent throughout the whole study period;
132 b) *NON-ENZOOTIC countries*: countries where the disease was present for one or more years,
133 but there was at least a 3-year period without the disease (according to *OIE Terrestrial Animal*
134 *Health Code* (OIE, 2017d), a period of 3 years represents the minimum time needed to reach

135 disease-free status); and c) *ENZOOTIC countries*: countries where the disease was present and
136 for which all periods of absence were less than 3 years.

137 Countries were mapped according to their health situation using Quantum GIS version
138 2.18.11 (Quantum GIS Development Team, 2017).

139

140 2.2.2. *Country characteristics associated with each health situation and their evolution*

141 The health situation of bovine brucellosis along the period was described, and the status
142 of bovine brucellosis was compared with the economic resources and bovine populations of
143 countries.

144 The evolution of surveillance programmes and implementing control policies are
145 described for the three defined groups of countries. Reporting at least one of the following
146 measures was considered as a proxy for the application of a *surveillance programme*: “disease
147 notifiable”, “monitoring”, “screening”, “targeted surveillance”, “general surveillance”. Countries
148 that applied at least one of the control measures included in WAHIS (“control of movements
149 within the country”, “stamping out”, “modified stamping out”, “zoning”, “vaccination”) were
150 classified as *implementing control policies*.

151 For each country, the continuity of the surveillance and control measures was evaluated
152 by counting the number of times there was a switch from “activities applied” to “no activities
153 applied” and vice versa. The Chi-squared test was calculated, and the results were plotted for the
154 three groups of countries.

155

156 2.2.3. *Statistical analysis*

157 For the comparison of the GDP and population size with the three categories of countries,
158 normality of the data was tested using the Shapiro-Wilk test. As the tests showed non-normality
159 distributions (Shapiro-Wilk test, $p < 0.05$) in all cases, the differences between the three groups
160 were evaluated using a non-parametric test, the Kruskal-Wallis test. Pairwise comparisons were
161 tested using the Mann-Whitney U test. All statistical analyses were performed using R software
162 version 3.3.3 (R Development Core Team, 2017).

163 The relationship between the absence or presence of the disease in the countries and the
164 years and health categories was evaluated using a Generalized Linear Model (GLM) with a
165 binomial distribution (for the model, Enzootic health category was considered the reference).
166 GLM were also used with the application, or not, of surveillance programmes and control
167 policies using the same explanatory variables as the disease status model.

168

169 **3. Results**

170 The global distribution of countries based on their health situation from 1996 to 2014 is
171 presented in Figure 1. The majority of the countries (67.3%) are classified as *ENZOOTIC*,
172 especially those from America and Asia. Europe has most of the *NON-ENZOOTIC* countries,
173 with the Free countries being located in Eastern and Northern Europe and Oceania (Table 1).

174 Figure 2 shows that Enzootic countries had much lower GDP values than *FREE* and
175 *NON-ENZOOTIC* countries (median of \$2,694 vs \$12,140, and \$18,191, respectively). The
176 differences between the three groups were statistically significant (Kruskal-Wallis Chi-squared =
177 24.2, $df = 2$, p -value < 0.001), and the Pairwise comparisons between groups also showed
178 significant within-group differences ($p < 0.001$).

179 The bovine population size showed different patterns between the three groups: the
180 median of the bovine population in *ENZOOTIC* and *NON-ENZOOTIC* countries was higher than
181 in *FREE* countries (median of 3 and 2.5 vs 0.55 million, respectively) (Figure 3). The differences
182 were statistically significant (Kruskal-Wallis Chi-squared = 17.8, df = 2, p-value < 0.001), and
183 the Pairwise comparisons showed a significant difference between *ENZOOTIC* and *FREE*
184 countries (p<0.001) but not between *ENZOOTIC* and *NON-ENZOOTIC* countries.

185 The health situation was very different in the *ENZOOTIC* and *NON-ENZOOTIC* groups.
186 Countries categorized as *NON-ENZOOTIC* had a lower probability of reporting the disease than
187 Enzootic countries (OR=0.09), and the presence of the disease decreased significantly, with an
188 OR=0.92 (Table 2). In *NON-ENZOOTIC* countries, the percentage of affected countries
189 considerably decreased from 71% in 1996 to 10% in 2014. In *ENZOOTIC* countries, the
190 percentage of affected countries remained between 80% and 94% during the studied period
191 (Figure 4).

192 The application of surveillance programmes increased significantly over the period
193 (Table 2) but without a clear trend (Figure 5). There were no differences between the groups.

194 Countries from the *ENZOOTIC* group applied control policies more often than the *NON-*
195 *ENZOOTIC* and *FREE* group countries (OR=0.49 and OR=0.35, respectively). The control
196 policies increased 0.02 each year (Table 2, Figure 6).

197 With regards to surveillance programmes and the implementation of control policies,
198 another important aspect is the stability of the measures throughout the period. In total, 47% of
199 Free countries maintained surveillance without variations, while these percentages were 33% and
200 30% for *NON-ENZOOTIC* and *ENZOOTIC* countries, respectively. The median number of times
201 that countries switched from applying surveillance policies to not, or vice versa, was 2 in

202 Enzootic countries and 1 in *NON-ENZOOTIC* and *FREE* countries, with no significant
203 differences between the groups (Kruskal-Wallis Chi-squared = 4.8345, df = 2, p-value = 0.089)
204 (Figure 7).

205 Implementing control policies in affected countries were maintained, with no variations
206 in 38% of *ENZOOTIC* countries and 19% of *NON-ENZOOTIC* countries. The median number of
207 changes of control policies was 1 in *ENZOOTIC* countries and 3 in *NON-ENZOOTIC* countries,
208 but the differences between groups were not significant (Kruskal-Wallis test p-value = 0.08)
209 (Figure 8).

210

211 **4. Discussion**

212 Bovine brucellosis is one of the priority animal diseases due to its impact on public
213 health, economics, and trade (OIE, 2014). Historical health data at a global level can help to
214 understand the evolution of diseases as well as improve the surveillance programmes and the
215 management of animal diseases, Therefore, they can be very useful in health policy planning by
216 the Veterinary Services (Stärk & Häsler, 2015). These results provide a good picture of the
217 health distribution and evolution of bovine brucellosis in the world and in different regions.

218 More than two-thirds of the countries encountered enzootic situations, with this group
219 being comprised mostly of developing countries, consistent with other studies. Corbel (1997),
220 reported that the disease is a major problem in the Mediterranean region, western Asia, and parts
221 of Africa and Latin America. Regional studies in South America found countries with a high
222 prevalence of brucellosis for a long period of time. The reasons for this enzootic situation have
223 been attributed to the limited economic resources invested for the diagnosis and control of
224 infectious diseases, being discontinuous, non-systematic measures, and a lack of incentives in

225 beef cattle to achieve the brucellosis-free certification, among other reasons (Aznar, Samartino,
226 Humblet, & Saegerman, 2014; Moreno, 2002). Another study of Sub-Saharan Africa describes
227 the role of different wild mammals as reservoirs and a lack of diagnosis, both at individual and
228 population levels, as reasons for endemicity in this region (Ducrotoy et al., 2017). Finally, Ali et
229 al. (2017) and Lindahl-Rajala et al. (2017) showed high incidence rates in livestock in Central
230 Asia and the Middle East areas due to the close contact between people and livestock and that
231 brucellosis is considered a neglected zoonosis.

232 Thirty countries remained free of bovine brucellosis during the whole period of analysis,
233 and 21 countries showed the presence of the disease in one or more periods of three years
234 without being reported. These numbers might be overestimated given that, in some countries,
235 diseases can remain under-reported due to deficient surveillance.

236 There are important geographic variations in bovine brucellosis status. The success of Oceania
237 countries was based on a strict control programme that included animal identification,
238 classification of herds according to their health status, severe restrictions on the movement of
239 cattle between areas, monitoring of herds, compensation to producers for elimination of positive
240 animals, optimization of laboratory procedures, registration of data on epidemiological
241 information, and training for all participants (Shepherd, Simpson, & Davidson, 1980; Tweddle &
242 Livingstone, 1994). In addition, the absence of known wildlife reservoirs in these countries has
243 been contributed to the maintenance of the status (Radunz, 2006).

244 Since the 1940s, European countries have implemented programmes for the brucellosis
245 eradication; in 1964, the European Union (EU) established a common eradication programme.
246 More recently, they have established combined clinical surveillance and risk-based screening of
247 herds to have early warning in case of a resurgence to allow for a rapid response (Hénaux &

248 Calavas, 2017). As a result of these policies, 44% of European countries were brucellosis-free
249 during the whole period. Despite the eradication programme, some countries of Southern Europe
250 remain infected. Some authors (Calistri et al., 2013; Taleski et al., 2002) have suggested the
251 following reasons to explain the difficulties of bovine brucellosis eradication in this region: lack
252 of stability of eradication policies, lack of epidemiological data, difficulties of disease
253 eradication in rural areas, lack of laboratory capabilities, and the existence of wildlife reservoirs.

254 In Africa, Asia and the Americas, the impact of the disease is still huge, and many factors
255 are involved in the endemicity of the disease (Lindhahl-Rajala et al., 2017):

- 256 □ *Lack of eradication policy*: a test-and-slaughter programme with compensation to producers
257 is not implemented in many countries due to insufficient financial resources (Cárdenas,
258 Melo, & Casal, 2017; Ducrotoy et al., 2017; Ibironke et al., 2008). The predominant strategy
259 of eradication in Latin America is a voluntary programme based on removing positive
260 animals from the herd. This strategy is very advantageous for dairy farmers because milk is
261 better paid, but this is not the case for beef farmers. Similar conditions have been pointed
262 out in Africa, where the trade dairy products require baseline information about the health of
263 dairy cattle due to the public health implications (Terefe, Girma, Mekonnen, & Asrade,
264 2017). In Asian Hindu-culture countries, elimination of infected animals is not feasible due
265 to the prohibition of slaughtering cattle. Finally, the absence of veterinary services in remote
266 areas may have contributed to the high occurrence of the disease (Mekonnen, Kalayou, &
267 Kyule, 2010).
- 268 □ *Lack of a surveillance strategy and disease monitoring*: Insufficient financial resources of
269 governments is a big constraint to the establishment of surveillance and control actions
270 against bovine brucellosis in sub-Saharan Africa (Ibironke et al., 2008). Control of animal

271 movements is of paramount importance to limit the spread of infections, but it is not always
272 applied. In India, there is no pre-movement control of animals; furthermore, selling positive-
273 reactor animals to other farmers is a usual practice (Singh et al., 2015). The same situation
274 has been described in Africa, where the exchange of bulls for mating between herds and the
275 free introduction of new cattle is common (Alhaji et al., 2016). Finally, other species can
276 become infected and spread the infection, but they are neglected in the brucellosis
277 surveillance activities (Cárdenas et al., 2017).

278 □ *Natural disasters:* Tropical countries are periodically affected by different meteorological
279 phenomena, such as drought, with the consequent poor body conditions and low resistance
280 against diseases. The highest density of animals during the dry seasons along the riverfronts
281 facilitates contacts between animals (Alexander et al., 2012; Deqiu, Donglou, & Jiming,
282 2002). Tropical storms and floods can increase the movement of animals and disrupt bovine
283 brucellosis-control measures over certain periods of time (Cárdenas et al., 2017).

284 □ *Livestock production systems:* Some pastoral areas have high sero-prevalence that is related
285 to the movements of animals through different pastures depending on food availability
286 (Jackson et al., 2014). This allows contact with animals from other herds or flocks, either
287 directly or indirectly through the water points and pastures contaminated by reproductive
288 discharges (Adamu et al., 2016). The transhumance production systems are common in
289 Africa, and pastoralists have little sensitization or health education on this disease (Alhaji et
290 al., 2016). In developing countries, livestock production is based on small farmers, where a
291 subsistence economy prevails. These are traditional systems of pastoral agriculture, with
292 mixed extensive systems that depend on the available natural resources and that are not well
293 regulated. This is in contrast with developed countries that base their production on modern

294 systems, with high economic investment (Herrero, Thornton, Gerber, & Reid, 2009).

295 A strong relationship was observed between economic resources and health situations of
296 countries in this study, in which developing countries, with lower resources, are more exposed to
297 enzootic situations. Goutard et al. (2015) also described that implementation of control and
298 eradication plans is difficult in enzootic countries with a low GDP per capita.

299 These results also highlight the relationship between the size of the bovine population
300 and the health situations of countries: Countries with a high bovine census were also associated
301 with enzootic situations, as had been previously observed in other studies (Calistri et al., 2013;
302 Yoon et al., 2010). In contrast, high GDP per capita and small bovine populations were
303 associated with free countries (Godfroid et al., 2013; Ragan, 2002). Economic resources enable
304 proper surveillance implementation and the introduction of control strategies, and small bovine
305 populations might be correlated with fewer animal movements, leading to a reduction in the risk
306 of introducing the disease (Economides, 2000).

307 A gradual increase in the implementation of surveillance programmes for bovine
308 brucellosis has been observed over the years. Eradication of the disease is possible, but it needs
309 strong economic resources and support. An important step towards this goal is the
310 implementation of adequate surveillance activities. The odds ratio observed in the results
311 indicate that there was a significant increase of surveillance efforts in the study period.

312 The implementation of control programmes in Enzootic countries, and especially
313 vaccination, was greater in comparison to the Free and Non-Enzootic countries. However, there
314 was not a trend in Enzootic countries to increase the implementation of control measures along
315 the study period.

316 Less than 50% of the countries maintained their surveillance policies without variations

317 during the entire period of study. In some cases, variations are a response to new problems or
318 new situations, but, in some cases, variability is a reflection of planning errors or budget
319 constraints, which can be a problem for bovine brucellosis control.

320 It is important to consider several limitations of this study. First, there was a possible bias
321 due to the two different tools used for reporting (Handistatus until 2004, and WAHIS until
322 2014). Both interfaces and storage platforms are distinct (Jebara, Cáceres, Berlingieri, & Weber-
323 Vintzel, 2012), the second one being more complete. Additionally, the verification procedure
324 performed by the OIE on data provided by countries before publication evolved over time. It is
325 reasonable to assume that the information provided in recent years is more reliable than that
326 provided in the 1990s because there is an in-depth process of verification of the information
327 before publication by the OIE.

328 Additionally, since 2002, the OIE has implemented an active search of non-official
329 information in order to increase the sensitivity of the OIE reporting system (WAHIS). This
330 information is evaluated in the context of the animal health situation prevailing in the country or
331 region concerned and, where appropriate, verified with the OIE Members for the purposes of
332 official confirmation and potential publication. The disease report allows for the early warning
333 and monitoring system for emergency situations and for detailed knowledge of the
334 epidemiological situation (OIE, 2017e; Thiermann, 2005). To minimize bias as much as possible
335 due to inaccurate reports sent by Member Countries or due to the lack of information in some
336 specific years, this study permitted the verification of historical data by communication between
337 the OIE and the corresponding countries. Through this approach, 90% of the information was
338 verified, with 6% of the information being added to the database with the aim of updating and
339 completing the historical information.

340 In addition, bovine brucellosis is a neglected disease in some regions of Africa and Asia
341 (Ducrotoy et al., 2014, 2017; Hegazy, Moawad, Osman, Ridler, & Guitian, 2011; Lindahl-Rajala
342 et al., 2017). Therefore, the accuracy of official information provided by these countries for
343 bovine brucellosis could be limited. Finally, another bias is related to the number of countries
344 included in the analysis (156) *versus* all existing countries in the world (more than 193 according
345 to the UN) (United Nations, 2017).

346 It would be desirable to update these analyses in the future, including adding more
347 explanatory factors and sources of information, such as data from human health or from regional
348 platforms, to avoid under-reporting. Other approaches, such as space-time model analysis, with
349 the inclusion of time-dependent variables, may help to understand the relationship between
350 factors and to predict areas with the highest potential for bovine brucellosis. Updating such an
351 analysis in the future would likely show continuous improvement of the bovine brucellosis
352 situation, as eradication strategies are ongoing throughout the world. An alternative method to
353 improve the estimation is to identify countries that have implemented programmes to eradicate
354 the disease and to understand the disease over time in affected areas, not only the presence and
355 absence in the country.

356

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363

364 **Conflict of interests statement**

365 The authors declare that they have no conflicts of interest.

366

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543 **Tables**544 **Table 1.** Distribution of category of countries at the continental level (n=156).

	Africa	America	Asia	Europe	Oceania	World
Enzootic*	34	22	31	18	0	105
Non-Enzootic**	4	1	6	10	0	21
Free***	4	2	3	17	4	30

545 *Enzootic: countries infected, which may have been free of brucellosis, but for periods less than
546 3 years. **Non-enzootic: countries where the disease was present one or more years, but there
547 was at least a 3-year period without the disease. ***Free: countries where the disease remained
548 absent during the whole period.

549

550 **Table 2.** Results of the GLM for the presence of the disease and the application of surveillance
 551 and control programmes in Enzootic and Non-enzootic countries and year

Dependent variable	Independent Variable	Beta	SE (beta)	OR (95% CI)	p-value	
Presence of the disease	Enzootic			1		
	Non-Enzootic	-2.40	0.13	0.09 (0.07 - 0.12)	<0.001	***
	Year	-0.08	0.01	0.92 (0.90 - 0.94)	<0.001	***
Application of Surveillance	Enzootic			1		
	Free	0.07	0.13	1.07 (0.83 - 1.39)	0.598	NS
	Non-Enzootic	-0.01	0.15	0.99 (0.74 - 1.33)	0.935	NS
	Year	0.12	0.01	1.12 (1.10 - 1.15)	<0.001	***
Application of Control Policies	Enzootic			1		
	Free	-1.05	0.10	0.35 (0.29 - 0.43)	<0.001	***
	Non-Enzootic	-0.71	0.12	0.49 (0.39 - 0.62)	<0.001	***
	Year	0.02	0.01	1.02 (1.00 - 1.04)	0.011	*

552 NS = Not significant ($p > 0.05$); * = Significant ($p < 0.05$); ** = Very significant ($p < 0.01$); *** =

553 Highly significant ($p < 0.001$).

554 See footnote, description of countries in Figure 1.

555

556 **Figure legends**

557 **Fig. 1.** Distribution of bovine brucellosis in countries based on their health situation from 1996
558 to 2014.

559 Enzootic: countries infected, which may have been free of brucellosis, but for periods less than 3
560 years. Non-enzootic: countries where the disease was present for one or more years, but there
561 was at least a 3-year period without the disease. Free: countries where the disease remained
562 absent during the whole period.

563 **Fig. 2.** GDP values per health situation.

564 See footnote, description of countries in Figure 1.

565 **Fig. 3.** Bovine population in the three groups according to the health situation.

566 See footnote, description of countries in Figure 1.

567 **Fig. 4.** Evolution of the percentage of Enzootic and Non-Enzootic countries that declared the
568 disease present each year between 1996 and 2014.

569 See footnote, description of countries in Figure 1.

570 **Fig. 5.** Evolution of the percentage of Enzootic, Non-Enzootic and Free countries applying
571 Surveillance programmes between 1996 and 2014.

572 See footnote, description of countries in Figure 1.

573 **Fig. 6.** Evolution of the percentage of Enzootic (dotted line) and Non-Enzootic (plain line)
574 countries with implementing control policies between 1996 and 2014.

575 See footnote, description of countries in Figure 1.

576 **Fig. 7.** The number of changes in the implementation of surveillance programmes between 1996
577 and 2014 per category of countries.

578 See footnote, description of countries in Figure 1.

579 **Fig. 8.** The number of changes in the implementation of control policies between 1996 and 2014
580 per category of countries.
581 See footnote, description of countries in Figure 1.