

1 **HOW MANY GAMEBIRDS ARE RELEASED IN THE UK EACH YEAR?**

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12 **ABSTRACT**

13 Large numbers of gamebirds (pheasants *Phasianus colchicus*, red-legged partridges *Alectoris rufa*
14 and mallard *Anus platyrhynchos*) are released annually in the UK to support recreational shooting. It
15 is important to know how many of these birds are being released because their release and
16 management has ecological effects on the wildlife and habitats of the UK. There is little regulation
17 governing their release and consequently the numbers being released are unknown. I made 71
18 estimates of the numbers released based on numbers being reported formally via import controls
19 and the Poultry Register, or extrapolated based on the breeding outputs of reared birds, or
20 extrapolated based on the likely numbers and behaviour of shoots, or extrapolated based on
21 observations of surviving birds. Based on the set of these estimates that fall within credible
22 boundaries (ranging from 14.3 to 70.1 million birds), I estimate a mean of 34.5 million birds (95%CI
23 30.9-38.1 million) and a median value of 32.1 million (IQR 22.0-44.9 million) being released. This
24 suggests that 24.3-25.3 million pheasants, 4.2-9.4 million partridges and 1.0-4.9 million mallard are
25 released annually in the UK. These figures are markedly lower than previous published estimates and
26 I discuss why such differences may occur. I set these figures in the context of the number and
27 behaviour of shoots operating in the UK.

28

29 **Keywords:** Gamebirds, hunting, shooting, pheasants, red-legged partridges, mallard

30 INTRODUCTION

31

32 Recreational hunting (aka shooting) in lowland UK is predominantly based on the harvest of birds
33 that have been specifically reared and released each year for the purpose (Martin 2011, 2012).
34 Pheasant *Phasianus colchicus* and Red-legged partridges *Alectoris rufa* are not native to the UK but
35 have been introduced as quarry species on several occasions over the past centuries and have
36 become naturalised (Lever 1977). Mallard *Anas platyrhynchos* are native and their breeding and
37 release for shooting is believed to have started in 1890 (Sellers & Greenwood 2019). It is estimated
38 and commonly stated that tens of millions of individuals of these three species are released annually
39 and an index of numbers being released has shown increases since the early 1960s of around nine
40 times for pheasants (Robertson et al. 2017), just over five times for mallard (Aebischer 2013) and
41 almost 200 times for red legged partridges (Aebischer 2013). However, the most recent estimate of
42 the numbers of pheasant and red-legged partridge involved is accompanied by very large margins of
43 error (being between 38-49% of the mean values). For pheasants, Aebischer (2019) calculated that
44 47 million birds were released annually, with 95% confidence intervals spanning 39 to 57 million. For
45 red-legged partridges, Aebischer (2019) calculated that 10 million birds were released annually, with
46 95% confidence intervals spanning 8.1 to 13 million. There was no estimate of the numbers of
47 mallard released. The only published mallard release numbers date back to 1985 when around
48 500,000 were estimated to be released (Harradine 1985)

49

50 An accurate understanding of the number of birds being released is important. The release
51 of large numbers of birds and their subsequent management is believed to cause a variety of
52 positive and negative ecological impacts on the habitats and wildlife of the UK (reviewed by Madden
53 & Sage 2020, Sage et al. 2020). Each year's release introduces a large amount of biomass into the
54 ecosystem (Blackburn & Gaston 2018). Releases usually occur in lowland UK during the late summer,
55 with cohorts of birds being placed in woodland release pens (pheasants), farmland pens (partridges)

56 and ponds (mallards). The direct effects, caused by the birds themselves, are typically bad for
57 habitats and wildlife in the immediate areas where releases happen and might be expected to scale
58 with the numbers of birds released in a rather predictable manner (Sage et al. 2005). At high
59 densities, the released birds may exert effects including physical disturbance of soils, altering
60 nutrient levels, changes in floral composition and changes in invertebrate community composition
61 (Reviewed in Madden & Sage 2020, Sage et al. 2020). The birds disperse from the release pens over
62 the following months and during this time they are commonly killed or scavenged by generalist
63 predators including foxes and raptors (Madden et al. 2018). The carcasses provide a nutrient resource
64 and it has been suggested that they support higher numbers of predators than might naturally be
65 expected (Roos et al. 2018). These releases are accompanied by associated effects on habitats and
66 wildlife that are the result of human management motivated by gamebird release, including
67 retaining, planting or managing areas of cover vegetation, the control of predators deemed a threat
68 to the released birds, and the provision of supplementary feed. Unlike direct effects, and the
69 relationship between the numbers of birds released and the occurrence or scale of associated
70 effects is not likely to be so straightforward (Reviewed in Madden & Sage 2020, Sage et al. 2020). In
71 general, bird release is accompanied by larger areas of woodland being established or maintained,
72 higher levels of predator control and large quantities of supplementary feed is provided either via
73 hoppers or seed-bearing crops (Reviewed in Madden & Sage 2020, Sage et al. 2020). In order to
74 better understand the scale of the direct and associated effects accompanying the release of birds
75 for shooting, it is essential to have a reliable figure of the numbers of birds being released.

76

77 It would appear that the Poultry Register, administered by the Animal and Plant Health
78 Authority (APHA) should be able to provide a definitive number of birds being released. Prompted by
79 the growing recognition of risks to poultry and wild birds from avian influenza, a registration system
80 was established in 2006 as a requirement of the Avian Influenza (Preventative Measures) (England)

81 Regulations 2006. This Register is obligatory for holdings with flocks of more than 50 birds and
82 voluntary registration of flocks that are smaller than 50 birds is encouraged. It covers the whole UK,
83 explicitly includes birds kept for ‘restocking game birds’, and demands detailed numerical and spatial
84 data about how many birds of what species are held where and for what purposes. It asks for separate
85 numbers of birds of each species that are held for breeding for shooting, rearing for shooting and
86 released for shooting. The APHA Poultry Register records for 2019 (obtained under an FOI request on
87 29 Jan 2020 with a response on 13 Feb 2020) show that: 10,039,379 pheasants and 3,819,423
88 partridges and 435,907 duck (species unspecified) were reported as held for release for shooting. This
89 indicates that a total of 14.3 million birds (of all species) are released annually. These figures are 21-
90 38% of the totals estimated by Aebischer (2019) and fall well outside the confidence intervals that he
91 presented. This disparity between the two current best estimates of release sizes suggests that at least
92 one of the two current measures is likely to be very inaccurate.

93

94 Alternative estimates of the numbers of birds being released may be possible by conducting
95 a series of extrapolations based on other current and historical datasets that relate to their rearing,
96 release, management and shooting (Fig 1). First, indications of the numbers of birds that are reared
97 annually may be available from import figures relating to the numbers of chicks or eggs brought into
98 the country. It may also be possible to calculate the number of eggs or chicks being produced in the
99 UK based on the anticipated productivity of adult birds reported as being held for breeding. Second,
100 non-regulatory, economic surveys of shoots may provide data on the numbers of birds that are
101 being released on shoots of different types and sizes. By extrapolating these numbers while
102 accounting for the size and type of shoots, estimates may be obtained. Third, released birds require
103 intensive management and so by considering the area over which the birds might be released and
104 the numbers of gamekeepers available to manage them as well as the numbers of birds that a
105 keeper may be able to manage, estimates may be obtained. Fourth, many shoots are commercial

106 entities and so advertise the numbers of birds that they offer to be shot per day. Using these figures
107 in conjunction with numbers of days when shooting occurs and incorporating measures of
108 harvesting efficiency, estimates may be obtained. Fifth, individual hunters (known as and hereafter
109 referred to as 'guns') may record the numbers of birds that they shoot and when considered in
110 conjunction with numbers of guns, perhaps divided into classes relating to the scale and regularity of
111 their shooting, estimates may be obtained. Finally, released birds that survive to the following
112 breeding season may be counted as part of national Breeding Bird Survey (Woodward et al. 2020).
113 By incorporating mortality rates (both natural and from harvest) for released birds, it is possible to
114 back-calculate how many birds might have had to be released in order that the observed
115 populations might be surveyed. All six approaches (like the published work of Aebischer (2019) and
116 the poultry register data) are probably flawed with each one relying on partial data that may not be
117 representative. Consequently, I have adopted a multilateration approach in which I search for
118 consistencies or inconsistencies across the eight methods of estimates and crucially, ask how those
119 estimates correspond to the reported behaviour of game shoots in terms of the numbers of birds
120 that an 'average' shoot reports releasing and shooting.

121

122 **METHODS**

123

124 **Overview**

125 I drew on a variety of data sets to supply measures of: numbers of birds reared; numbers of birds
126 being released; numbers of days when shooting occurred; harvest sizes; number of people that
127 shoot; and numbers of birds observed in the wild. I then multiplied various permutations of these
128 measures in order to generate estimates of numbers of released birds (see Results and Table 1).

129

130 **1) Data Sets**

131

132 *1) APHA Poultry Register (APHAPR2019)*

133 Compulsory registration is required for individuals or organisations that breed, rear or release >50
134 gamebirds. Voluntary registration is available to those releasing <50 birds (Anon 2020a). During the
135 registration process, registees are asked to report: Species (pheasant, partridge (no separation of
136 red-legged and grey) and duck (no distinction by species); Livestock Unit Animal Production Usage
137 (Shooting, Other); Livestock Unit Animal Purpose (breeding for shooting, rearing for shooting,
138 release for shooting); and Usual Stock Numbers. I made a FOI request for this information on 29 Jan
139 2020 and received a response on 13 Feb 2020. There were 7902 records, but this does not
140 correspond to 7902 separate locations because a single location may include all three species (three
141 records) and/or up to three Animal Purposes per species. When filtered by Species and Animal
142 Purpose (specifically release for shooting), we can be more certain that a single record relates to a
143 single location and/or shoot and represents the number of birds of that species released there.

144

145 *2) Import Figures*

146 Daniel Zeichner MP asked DEFRA how many pheasant and partridge (a) poults and (b) fertilised eggs
147 were imported into the UK in 2019. They responded on 21 July 2020 (Prentice 2020) with details of
148 import figures for both partridges (presumed red-legged partridge) and pheasants during 2019.

149

150 *3) Data extracted from Guns on Pegs advertising website (GOPDB2019)*

151 Guns on Pegs (<https://www.gunsonpegs.com/>) is a commercial advertising site where shoots looking
152 to let days or attract syndicate members can advertise. They can enter free-text descriptions of their

153 shoot. Entry dates are not recorded but it has been operating for 7-8 years. Between January and
154 March 2020, I read through descriptions of 697 lowland shoots in England that advertised shooting of
155 pheasant, partridge (no attempt is made to distinguish red-legged from grey partridge) and 'duck' (not
156 specified as mallard but often contrasted with 'wildfowl'). I extracted data on the quarry species and
157 the bag sizes offered at each shoot, and any information about the numbers of birds released,
158 although only 22 shoots reported this. Shoots advertising on the Guns on Pegs website (and
159 consequently also those that participate in the website's surveys of shoot owners and gun clients (see
160 below)) are likely to be a non-random sample of shoots and guns in the UK, with a bias towards larger
161 commercial shoots.

162

163 *4) Guns on Pegs Game Shooting Census 2017 (GOPGSC2017)*

164 Guns on Pegs conducts an annual survey of guns. The results from their 2017 survey are available
165 [https://2391de4ba78ae59a71f3-](https://2391de4ba78ae59a71f3-fe3f5161196526a8a7b5af72d4961ee5.ssl.cf3.rackcdn.com/1815/3011/2351/1110_0118_Guns_on_Pegs_Four_Page_Leaflet_Hayley_Clifton_Final_Web.pdf)
166 [fe3f5161196526a8a7b5af72d4961ee5.ssl.cf3.rackcdn.com/1815/3011/2351/1110_0118_Guns_on_](https://2391de4ba78ae59a71f3-fe3f5161196526a8a7b5af72d4961ee5.ssl.cf3.rackcdn.com/1815/3011/2351/1110_0118_Guns_on_Pegs_Four_Page_Leaflet_Hayley_Clifton_Final_Web.pdf)
167 [Pegs_Four_Page_Leaflet_Hayley_Clifton_Final_Web.pdf](https://2391de4ba78ae59a71f3-fe3f5161196526a8a7b5af72d4961ee5.ssl.cf3.rackcdn.com/1815/3011/2351/1110_0118_Guns_on_Pegs_Four_Page_Leaflet_Hayley_Clifton_Final_Web.pdf). The survey included responses from 12,143
168 guns and reported numbers of days shot per gun and daily bag size with separation of participants
169 by their patterns of spend.

170

171 *5) Guns on Pegs Shoot Owner Census 2017 (GOPSOC2017)*

172 This survey, also by Guns on Pegs, was conducted at the level of the shoot rather than individual
173 guns and the results from their 2017 survey are available
174 <https://www.gunsonpegs.com/articles/shooting-talk/the-shooting-world-by-numbers-2018-season>.
175 The survey included responses from 652 shoots across the UK and reported numbers of days shot

176 per season, numbers of birds released, numbers of birds shot providing measures of bag size and
177 harvest efficiency and an estimate of the numbers of UK shoots.

178

179 *6) The Savills Shoot Benchmarking Survey (SSBS2017)*

180 Savills and the Game and Wildlife Conservation Trust conducted a shoot benchmarking survey for the
181 2016/17 season and a summary of their findings is available
182 [https://www.gwct.org.uk/media/664264/shoot-benchmarking-example-participants-benchmarking-](https://www.gwct.org.uk/media/664264/shoot-benchmarking-example-participants-benchmarking-report-fictional.pdf)
183 [report-fictional.pdf](https://www.gwct.org.uk/media/664264/shoot-benchmarking-example-participants-benchmarking-report-fictional.pdf). The survey included responses from 155 shoots and reported the numbers of
184 shoots, numbers of birds released, number of days shot per season, and average bag sizes across three
185 different size classes. Small shoots released up to 3,000 birds; Medium shoots released 3,000-10,000
186 birds and Large shoots released >10,000 birds.

187

188 *7) The Economic and Environmental Impact of Sporting Shooting/The Value of Shooting*
189 *(PACEC2006/PACEC2014)*

190 PACEC (Public and Corporate Economic Consultants) conducted surveys of shooting providers and
191 participants in 2004 and again in 2011/12 (PACEC 2006, 2014), with responses from 2,096 in 2004 and
192 16,234 in 2011/12. These reported numbers of people engaged in game shooting and the total number
193 of gun-days when game shooting occurred.

194

195 **2) Estimating numbers of shoots in the UK**

196 In order to make sense of the various mean values of numbers of days shot per season, mean bag size
197 or mean numbers of birds released which could be obtained from the surveys described above, it is
198 necessary to know how many shoots operate in the UK. This number is unknown, so I made a series

199 of estimates to encompass a possible range of numbers that could then be used to calculate the
200 numbers of birds being released.

201

202 The GOPSOC2017 reports, without any supporting information, that there are between 8000
203 and 10000 shoots in the UK. The PACEC2006 report states that 91% of shoots in the UK harvest
204 released birds. Therefore, I corrected their reported figures to include only shoots where birds were
205 released to gives estimates of between 7280 and 9100 sites.

206

207 A report by the Farm Animal Welfare Commission (FAWC 2008) provides an estimate of ~7000
208 shoots in the UK that release pheasants (presumably including 300 that release partridges), derived
209 from the opinions of various stakeholders with no further detail to substantiate this.

210

211 The APHAPR2019 indicates that 3307 sites hold pheasants for release, 1323 sites hold
212 partridges for release and 578 sites hold duck for release. Given that few sites release only partridge
213 or only duck, but that these generally all release pheasants, this suggests a minimum of 3300 sites
214 release any birds for shooting.

215

216 Shoots of any appreciable size require a gamekeeper to manage them. Therefore, by knowing
217 the number of gamekeepers in the country, it may be possible to estimate the number of shoots. The
218 occupation of gamekeeper was last recorded in the 1981 census when ~2500 were recorded (Tapper
219 1992). The National Gamekeepers Organisation (NGO) website reports, without any supporting
220 information, that there are currently 3000 full time and a similar number of part-time gamekeepers
221 in the UK (Anon 2020b). This number includes gamekeepers on grouse moors (perhaps 500 such moors
222 (Anon 2016)) and wild-bird shoots (where releasing does not occur) and likely a small number of deer

223 stalkers. However, I have used the original data in my further analyses. Any correction for
224 gamekeepers not working on shoots that release birds will only reduce the estimated number of
225 shoots in the UK. This ratio of full time to part time gamekeepers is supported by the Gamekeepers
226 and Wildlife Survey that reported that of 965 gamekeepers participating, 52% were full time, 30%
227 were amateur and 18% were part time (Ewald & Gibbs 2019) The PACEC2006 Survey reports the mean
228 % of shooting providers employing various numbers of keepers. I excluded providers defined as ‘clubs’
229 which are described as shooting a variety of quarry on an area rather than the similar ‘syndicates’
230 which specifically shoot game. 33% of providers didn’t employ anyone. 24% employed one person
231 part time. 24% employed one person full time. 19% employed more than one person full time (10%
232 two or more; 9% three or more). These figures, suggesting that there are almost three times as many
233 full time gamekeepers as part time ones and that about one third of people acting as gamekeepers
234 are amateurs/unpaid, are similar to those reported by Ewald & Gibbs (2019) which gives us some
235 confidence in them. These ratios from the gamekeeper survey and PACEC data, when combined with
236 the absolute numbers reported by the NGO indicate that there are around 2000 shoots in the UK that
237 have no paid gamekeeper (but each has an amateur gamekeeper managing their birds), a further
238 thousand that employ a part time gamekeeper, a thousand that employ a full time gamekeeper and a
239 further thousand that employ more than one game keeper. This suggests that there are around 5000
240 shoots in the UK that are managed by a gamekeeper. Some small shoots may be managed by
241 individuals or groups of individuals who do not identify themselves as gamekeepers, even amateur
242 ones. PACEC (2014) suggests that 91% of shoots release birds, so we might reduce the total
243 accordingly, however, the ADAS (2005) report states that the NGO estimates that only 80-90% of
244 gamekeepers are members. Therefore, I will not attempt to correct for either errors in membership
245 or release behaviour and assume that the two errors cancel one another out so that the figure of 5000
246 shoots is reasonable.

247

248 Given the large uncertainty over the total number of shoots in the UK, I conducted four
249 estimates for each shoot-level release measure These ranged from the 3300 shoots reported in the
250 APHAPR2019, through the 5000 shoots that I estimate are active based on the numbers of
251 gamekeepers in the UK to the reported (but unsubstantiated) 7000 (FAWC 2008) to 7300-9100
252 (GOPSOC2017).

253

254 **3) Estimating the distribution of size classes of shoots in the UK**

255 Shoots are not homogeneous in their structure or behaviours. Larger shoots may release more birds,
256 shoot more days in the season and harvest larger bags on each shoot day. The SSBS2017 divides shoots
257 into three classes based on the mean number of birds released, the average acreage shot, days shot
258 per season and mean bag size. In their survey of 155 shoots, there are approximately equal numbers
259 in each class, but given that larger shoots are more likely to be interested in their financial
260 performance, I suspect that larger shoots are overrepresented in that survey. A more accurate
261 reflection of the size class composition may be obtained by considering the distribution of shoots
262 reporting release numbers in the APHAPR2019 following the definitions given in the SSBS2017. For
263 pheasants, of the 3307 shoots reporting, 2,464 (75%) are classed as small; 543 (16%) are classed as
264 medium; and 300 (9%) are large. For red-legged partridges, of the 1323 shoots reporting, 536 (41%)
265 are classed as small; 344 (26%) are classed as medium; and 451 (34%) are large. For mallard, of the
266 578 shoots reporting, 413 (72%) are classed as small; 119 (21%) are classed as medium; and 45 (8%)
267 are large. Therefore, considering all species, 63% shoots may be described as small, 21% as medium
268 and 17% as large according to the definitions in the SSBS2017.

269

270 **4) Estimating harvest efficiency**

271 The harvest or bag size represents only a fraction of the birds that will have been released. Based on
272 figures available for pheasants, it might be assumed that a third of released birds are harvested
273 (Robertson et al. 2017). Other surveys have reported higher return rates, with the GOPSOC2017
274 reporting 40% return, and SSBS2017 reporting 38%. Consequently, in estimates that involved harvest
275 figures, I multiplied them by three (assuming 33% harvest) or 2.5 (assuming 40% harvest) to
276 estimate release sizes.

277

278 **RESULTS**

279 I initially calculated 71 estimated release sizes to be compared against the published figure from
280 Aebischer 2019 (Fig 2). The initial set of estimates ran from 10.5 to 177.7 million birds released
281 annually across all species. These had a mean value of 41.2 million birds (95%CI 34.1-47.9 million)
282 and a median value of 33.1million (IQR 21.4-49.6 million). However, these initial estimates were
283 later refined (see below).

284

285 **1) Published data estimating numbers of released birds (Aebischer 2019)**

286 A mean estimate of 47 million pheasants and 10 million partridges released annually was calculated.
287 Estimates of mallard release was not made. A total of 0.94 million mallard were reported shot and if
288 we assume that half of these were released birds and that these represent one third of the mallard
289 that were released (matching similar ratios for pheasant and partridges), then I estimate that 1.5
290 million mallard were released, giving a total of 58.5 million birds being released annually.

291

292 **2) Poultry Register Data reporting numbers of birds held for release**

293 The APHAPR2019 shows that: 10,039,379 pheasants and 3,819,423 partridges and 435,907 duck
294 (species unspecified) were reported as held for release for shooting. This produces a total of 14.3
295 million birds (of all species) released annually.

296

297 **3) Estimates based on numbers bred and reared for release**

298 Gamebird eggs and chicks are commonly produced outside the UK where more clement conditions
299 stimulate higher and earlier productivity. Therefore, to estimate the numbers of birds that may be
300 being bred for release it is necessary to consider numbers of eggs and chicks from UK and EU origins.

301

302 *a) Birds bred in the UK based on breeding adults reported in the Poultry Register*

303 There were 43,250 duck, 347,610 partridges and 1,052,436 pheasants registered as held for breeding
304 in the APHAPR2019. Mallard and pheasants are both naturally polygynous, with a single male in the
305 wild mating with several females. Game breeders take advantage of this situation to decrease the
306 number of birds that they have to house (and feed) by placing several females with each male. This
307 varies between breeders, but a ratio of one male to between seven and ten females is reported
308 (Konteka et al. 2014), so we might presume that 88-91% of the birds registered for breeding are
309 females. Using published productivity (57%) and hatchability (68%) figures (Datuin et al. 1996) for
310 mallard I calculate that about 1.1 million mallard chicks could be bred for release. In the UK, pheasants
311 used for egg production may be kept in cages or aviaries and these have implications for production
312 rates and hatchability. Caged hens produce 29.9 chicks each while those in aviaries produce 9.8 chicks
313 per hen (Konteka et al. 2014). It is unknown what proportion of the ~947,000 hens are held in each
314 housing condition, with Matheson et al. (2015) reporting that their use is currently rare but increasing
315 and Canning (2005) stating that 5% of rearers were using such cages. Assuming that 25% of hens are
316 housed in cages (with larger scale rearers investing in cages), then around 14.0 million pheasant chicks

317 could be produced annually in the UK. Partridges vary in their productivity and egg hatchability with
318 age (Mourão et al. 2010). Partridges are naturally socially monogamous and this mating system is
319 replicated by breeders with partridges kept in pairs, so I estimate that about 6.8 million partridge
320 chicks could be bred for release. In total, I estimate that ~21.9 million gamebird chicks could be bred
321 in the UK for release annually.

322

323 *b) Birds bred outside the UK and imported as eggs or chicks*

324 Records for 2019 show that 28,248,773 pheasant eggs were imported into the UK from Europe
325 (Prentis 2020). Assuming hatching rates of 61% (Konteka et al. 2014), around 17.2 million chicks
326 would hatch from imported eggs. 3,299,780 live pheasants and 1,673,165 live partridges were
327 imported (Prentis 2020). From these figures, I estimate that up to ~22.2 million birds that had been
328 bred outside the UK could be released annually.

329

330 By combining the numbers of birds bred within and without the UK, I estimate that up to 44.1
331 million birds could be bred and released annually.

332

333 *c) Poultry Register Data reporting numbers of birds reared*

334 The APHA Poultry Register records do not consider a bird's origin, and so records of birds reared for
335 release could include both UK and international-bred birds. Records for 2019 show that: 11,196,463
336 pheasants, 4,607,688 partridges and 195,811 duck (species unspecified) were reported as reared for
337 shooting. This produces a total of 16 million birds (of all species) that were reared and might be
338 released annually.

339

340 **4) Estimates based on numbers of birds reported released on samples of shoots of differing sizes**

341 *a) Using GOPSOC2017*

342 This census reports a mean of 4,307 birds (with no error margins reported) being released on each of
343 the 652 shoots that completed their survey. Assuming that the distribution of the surveyed shoots
344 matches that in the general population (in reality it is likely that larger shoots are over represented
345 in this survey - see above) then I estimate that between 14.2 and 39.2 million birds are released
346 annually, depending on the number of shoots we assume to operate in the UK.

347

348 *b) Using GOPDB2019*

349 Release numbers from 22 shoots on the Guns on Pegs website indicated that, of the birds released
350 on an average shoot, 73% were pheasants, 12% were partridges and 14% were mallard. For
351 pheasants, the distribution of releases was very skewed with a mean of 3238 pheasants/shoot, but a
352 median release size of 1500 birds/shoot with an IQ range of 1100-2500. For red-legged partridges,
353 the distribution of releases was also very skewed with a mean of 1070 partridges/shoot, but a
354 median release size of 400 birds/shoot with an IQ range of 275-1850. For mallard the distribution of
355 releases was also very skewed with a mean of 1816 mallard/shoot, but a median release size of 300
356 birds/shoot with an IQ range of 150-575. Assuming that the distribution of the surveyed shoots
357 matches that in the general population then I estimate (by multiplying mean releases per species
358 and adding them together for each shoot) that between 20.2 and 55.7 million birds are released
359 annually depending on the number of shoots we assume to operate in the UK.

360

361 *c) Using APHAPR2019*

362 For pheasants, the distribution of releases was very skewed with 6/3307 shoots reporting releasing
363 >100,000 birds (111,000-200,000), a mean of 3036 pheasants/shoot, but a median release size of

364 850 birds/shoot with an IQ range of 400-2275. For red-legged partridges, the distribution of releases
365 was also very skewed with 2/1323 shoots reporting releasing >100,000 birds (180,000 & 250,000), a
366 mean of 2887 partridges/shoot, but a median release size of 500 birds/shoot with an IQ range of
367 200-2000. For mallard one record was for 150,000 birds released at a single shoot (of the 578
368 included). This was 25 times larger than the next largest value (6,000), so it could be a typo. If I
369 retain this value in the calculations, there was a mean of 754 mallard/shoot, but a median release
370 size of 200 with an IQ range of 100-500. Excluding the aberrant record reduces the mean to 495
371 mallard/shoot (but the median and IQ range are unchanged). Assuming that the distribution of the
372 surveyed shoots matches that in the general population and using the lower figure for mallard, then
373 I estimate (by multiplying mean releases per species and adding them together for each shoot) that
374 between 21.2 and 58.4 million birds are released annually depending on the number of shoots we
375 assume to operate in the UK.

376

377 *d) Using SSBS2017*

378 According to the SSBS2017, small shoots reported a mean release of 1,532 birds of all species; medium
379 shoots reported a mean release of 6,212 birds; and large shoots reported a mean release of 26,241
380 birds. Assuming that of the shoots in the UK, 63% were small, 21% were medium and 17% were large
381 (see above) then I estimate that between 22.2 and 61.2 million birds are released annually depending
382 on the number of shoots assumed to operate in the UK.

383

384 **5) Estimates of birds released on shoots given the available keepers to manage them**

385 *a) Assuming constant efforts across gamekeepers*

386 The SSBS2017 reports that the mean number of birds released per full-time keeper is 10,204.

387 Assuming that each full time gamekeeper can and does manage 10,000 released birds and that each

388 part-time or amateur keeper can and does manage 5000 released birds, I calculate that with 3000 FT
389 and 3000 PT gamekeepers [see section above], a total of 45 million birds could be released and
390 managed.

391

392 *b) Assuming scaling effects of gamekeeper efficiency*

393 This assumption of constant efforts across keepers may be generous. The SSBS2017 reports that
394 there are significant differences in the numbers of birds released per keeper depending on the shoot
395 size, with full-time keepers on large shoots managing 11,478 each whereas those on medium shoots
396 manage only 5,892 birds. Assuming that small shoots are all run by part-time and/or amateur
397 keepers who are again half as efficient as a full time keeper on a medium shoot (thus managing 3000
398 birds each) and that the remaining full time keepers are equally split between medium and large
399 shoots (see above), then I calculate that a total of 35.1 million birds could be released and managed.

400

401 **6) Estimates based on harvests from shoots**

402 Harvest levels depend on both the number of birds shot per day and the numbers of days shot per
403 season. I obtained three estimates across all shoots for daily bag size. These ranged from 98/day
404 (GOPSOC2017), through 112/day (GOPGS2017) to 165/day (GOPDB2019) in which 120 shoots
405 offered for sale days with bags of < 100, 157 shoots offered days of 100-200 and 206 shoots offered
406 days of >200. The GOPSOC2017 provided the only estimate of the mean number of days shot
407 reporting 13 days/shoot which appeared to be stable over time with shoots anticipating the same
408 number of shoot days in the following year. This approximates to shooting on one day per week
409 during the three months of the main shooting season. I accounted for the harvest rate as described
410 above to estimate release sizes. Therefore, I made a series of estimates of bird releases based on
411 total harvest figures that included: harvest rate (33% or 40%) * mean bag size/day (98, 112 or 165) *

412 number of days shot/season (13) * number of shoots in the UK (3300, 5000, 7300 or 9100). This
413 approach produced estimates of between 10.5 and 58.6 million birds.

414

415 In addition to these estimates across all shoots, I obtained estimates for shoots of different
416 sizes which differed in both the number of birds that they shoot per day and the number of days shot
417 per season. Typically, larger commercial shoots both harvest larger bags per day and offer more days
418 shooting per season. The SSBS2017 described small shoots as offering 9 days/season with a bag of 80
419 birds; medium shoots offering 16 days/season with a bag of 148 birds; and large shoots offering 41
420 days/season with a bag of 232 birds. Assuming that of the shoots operating in the UK (ranging between
421 3300 and 9100), 63% were small, 21% were medium and 17% were large (see above) and that harvest
422 efficiency lies between 33% and 40% (as above), then I estimate that between 21.2 and 70.1 million
423 birds are released annually.

424

425 **7) Estimates based on harvests by individual guns**

426 *a) Based on the total number of guns in the UK*

427 According to PACEC2006, 480,000 people shoot live quarry, with 80% of those shooting pheasant &
428 partridges, suggesting that 384,000 people might shoot released birds annually. According to
429 PACEC2014, 260,000 shoot driven game. The numbers of birds shot per gun varies and this variation
430 is captured by the GOPGS2017. The survey identified three classes of gun from 6,510 individuals (of
431 the 12,143 surveyed) who reported spend data. Like the shoots themselves, the number of birds
432 shot per day typically increased with the number of days shot per year. Those described as 'Low
433 Spend' comprised 2031 guns (17%) and shot a mean of 8 days/year with a mean bag size of 73
434 birds/shoot. Those described as 'Medium Spend' comprised 3759 guns (31%) and shot a mean of 12
435 days/year with a mean bag size of 123 birds/shoot. Those described as 'High Spend' comprised 730

436 guns (6%) and shot a mean of 21 days/year with a mean bag size of 212 birds/shoot. A further 5623
437 guns (46%) provided no spend data but reported that they shot a mean of 9 days/year with a mean
438 bag size of 99 birds. I assume that a day's bag was split equally between the typically eight guns in
439 attendance, meaning that over one shooting season, a mean Low Spend gun shot 73 birds, a
440 Medium Spend gun shot 184.5 birds, a High Spend gun shot 556.5 birds, and a No Spend gun shot
441 111.4 birds. I assumed that all those people reported as shooting birds in the PACEC survey fell into
442 one of the four classes (Low, Medium, High, No spend data) and derived a series of estimates based
443 on the total shooting population (384,000 or 260,000) * the proportions of each class (17%, 31%, 6%,
444 46%) * the mean season bag total of each class (73, 184.5, 556.5, 111.4) * harvest efficiency (see
445 above: 33%, 40%). This approach produced estimates of between 100.3 and 177.7 million birds
446 being released.

447

448 *b) Based on the number of gun-days*

449 An alternative approach to the total number of people shooting live quarry is to calculate the
450 number of days that people shoot per season. Because the four different classes of guns described
451 above shot different numbers of days/season as well as shooting different numbers of birds on each
452 day, I calculated the percentage of shooting days that were taken by people of the four classes (Low
453 = 13%, Medium = 35%, High = 12%, No spend data = 40%) and calculated the mean number of birds
454 that the gun was likely to shoot on that day (Low = 9.13, Medium = 15.4, High = 26.5, No spend data
455 = 12.4). The PACEC2006 reports 1.5 million gun days/season targeting driven lowland game and a
456 further 820,000 days/season targeting walked up lowland game which may include released birds.
457 This is a total of 2.32 million gun days/season with a conservative estimate of 1.5 million days if only
458 shooting at driven and therefore presumed released birds is considered. Therefore, I calculated
459 estimates of harvests based on these reported gun days (2.32 million, 1.5 million) being shared

460 among the gun classes as described above and accounting for harvest efficiency (see above:
461 33%,40%). This approach produced estimates of between 55.1 and 102.3 million birds.

462

463 The reported figures from the PACEC survey seem high when considering the numbers of
464 shoots likely to operate in the UK. Assuming that each shoot day involves 8 guns, then an average
465 shoot would be expected to host between 21 days/season (with 9100 shoots in the country and a
466 total of 1.5 million gun days) and 58 days/season (with 5000 shoots in the country and a total of 2.32
467 million gun days). These figures do not correspond to any other survey data and at the high end of
468 the estimate require that every shoot be operating on almost 4 days a week throughout the main
469 three months of the shooting season. Therefore, I also estimated more realistic numbers of gun days
470 based on the mean numbers of days reported as being shot on each shoot (13 days/season) with 8
471 guns per day multiplied by the range of numbers of shoots in the UK (3300-9100). I then calculated
472 estimates of harvests based on these estimated gun days (total gun days = 343200, 520000, 759000,
473 946400) being shared among the gun classes as described above and accounting for harvest
474 efficiency (see above: 33%,40%). This approach produced estimates of between 12.6 and 41.7
475 million birds.

476

477 **8) Estimates assuming that BTO Breeding Bird Survey Data is a remnant of the release population**

478 An alternative to calculating release numbers from birds being shot, is to extrapolate backwards
479 from the numbers of birds recorded as surviving following the shooting season and before the next
480 year's cohort has been released. 2,300,000 female pheasants were calculated to be present in GB
481 during the 2016 breeding season (Woodward et al. 2020). Assuming that each hen has a single
482 partner (generous, because pheasants are a polygynous breeding species with single males holding
483 harems of several females, although other males may be classed as non-reproductive satellites),

484 there are 4.6 million pheasants present in the breeding season. If these are the all the remnant
485 survivors of the released birds and between 9 and 15% of released birds survive to the start of
486 following breeding season (Madden et al. 2018), I estimate a release of 29-51 million pheasants.
487 72,500 red-legged partridge territories were calculated to be present in GB during 2016 breeding
488 season (Woodward et al. 2020). Assuming that each territory comprises a single male and female,
489 and that survival of released partridges to the end of January is 15% (Hesford 2012), I estimate a
490 release of at least 0.96 million partridges. Wintering mallard in the UK include migrants so it is not
491 possible to reliably attempt to calculate the size of mallard releases based on breeding populations.
492 It was estimated that there were 665,000 mallard individuals present during winter 2012/13-
493 2016/17 (Woodward et al. 2020), but these could include both wild and released birds. By combining
494 values for pheasants and partridges (but excluding mallards due to unreliable data), I estimate that
495 between 30 and 52 million birds could be released annually.

496

497 **Examination and Refinement of Estimate Data**

498 Several of these estimates were clearly incompatible with one another. The minimum number of
499 birds being released should be taken as the numbers reported in the APHAPR2019 (14.3 million) as it
500 is highly unlikely that game managers would report releasing birds when they are not doing so. Five
501 estimations fell below that value. Estimates that included data from the PACEC2006 and PACEC2014
502 that referred to the numbers of guns thought to partake in game shooting in the UK each year and
503 the number of days that they shot each season led to some extremely high values. If 177 million
504 birds were released annually then, if we assume that the average shoot releases 4307 birds, there
505 would have to be 41,000 shoots operating in the country. Given that there are around 6,000 full and
506 part-time keepers in the country, this seems unlikely. If we assume that there are 9100 shoots in the
507 country (the maximum value used in my estimates) then each shoot would release 19,450 birds,
508 which would provide 43 shooting days, each with a bag of 150 birds/day. The PACEC data regarding

509 gun days also leads to high values. Assuming that each shoot day involves 8 guns, then, according to
510 PACEC data, each shoot would be expected to host between 21 days/season (with 9100 shoots in
511 the country and a total of 1.5 million gun days) and 58 days/season (with 5000 shoots in the country
512 and a total of 2.32 million gun days). These figures do not correspond to any other survey data and
513 at the high end of the estimate require that every shoot be operating on almost 4 days a week
514 throughout the main three months of the shooting season. Consequently, I distrust the estimates
515 based on PACEC2006 and PACEC2014 data and recommend excluding them.

516

517 When estimates falling below the APHAPR2019 values and those involving data from PACEC
518 are excluded, there are 59 remaining estimates varying from 14.3 to 70.1 million birds released
519 annually across all species. These had a mean value of 34.5 million birds (95%CI 30.9-38.1 million)
520 and a median value of 32.1 million (IQR 22.0-44.9 million). These values have been estimated by
521 combining across all species because data are often not provided per species. Therefore, to calculate
522 the estimated numbers of each species being released, I took the proportions of each species
523 reported as being released in the GOPDB2019 (73% pheasants, 12% partridges, 14% mallard) and
524 the APHAPR2019 (70% pheasants, 27% partridges, 3% mallard) and multiplied them mean total bird
525 values. This suggests that 24.3-25.3 million pheasants, 4.2-9.4 million partridges and 1.0-4.9 million
526 mallard are released annually in the UK.

527

528 **DISCUSSION**

529

530 The estimates of numbers of gamebirds being released for shooting in the UK that I derived were
531 markedly lower than the most recent published estimate. The average value of my estimates of
532 around 35 million birds of all three species is just 61% of the estimate of 57 million proposed by
533 Aebischer (2019). That estimate falls outside either the IQR or 95%CI of my estimates, and my mean

534 and median estimate falls outside his 95%CI. Just 5/57 (9%) of the credible estimates exceeded his
535 estimate. They are also in stark contrast with estimates derived from the current formal means by
536 which we might to obtain the measure, via the APHA Poultry Register. The 14.3 million birds
537 recorded in the register are just 40% of my mean estimate and falls outside either the IQR or 95%CI
538 of my estimates. They are just 25% of Aebischer's (2019) estimate.

539

540 My estimates are highly variable. This is because the data on which they are based is sparse,
541 often collected in an ad hoc fashion with little attempt to ensure that it is representative, and
542 commonly relies on indirect modifiers such as measures of egg production or numbers of shoots that
543 are themselves based on small and potentially biased samples. Some of the variation is due to the
544 uncertainty over the numbers of shoots operating in the UK. With credible values ranging from 3,300
545 to 9,100 shoots, this introduces an almost three-fold variation in many estimates. Like bird releases,
546 shoots are currently not required to register their existence. An accurate value is critical because
547 many other values are derived at the level of the shoot including mean numbers of birds released
548 and shot. Is it possible to increase our certainty about the number of shoots? I explained above how
549 a consideration of the numbers and distributions of gamekeepers that work on the shoots might be
550 used to refine estimates and that supports the value of around 5,000 shoots. An alternative
551 approach is to consider the density of shoots in the UK and relate it to local observations on the
552 ground. If we assume that gamebird release is concentrated in the lowlands and that of the
553 244,000km² of the UK (World Bank 2020), 40% of UK is uplands (RSPB, no date), then there might be
554 around 146,400km² of land suitable to host released bird shoots. With 9,100 shoots, we might
555 expect there to be one shoot every 16km², with 5,000 shoots, one per 29km² and with 3300 shoots,
556 one per 44km². Either use of remote sensing data or direct sampling on the ground in a stratified
557 random sampling method is required to test which of these densities is most credible.

558

559 It is not simply the number of shoots that is likely to be critical, but also their size and
560 activities. The distribution of releases across shoots appears to be very skewed. Both the
561 APHAPR2019 data and the GOPDB2019 data reveal that there are many small shoots that operate
562 over a relatively small area, shoot relatively few birds either on each shoot day or across the season
563 as a whole because they only shoot on a few days, and consequently release few birds. There are
564 also a small number of very large shoots that shoot large bags on many days, typically over much
565 larger areas of land, and consequently release many birds. From the SSBS2017 classification of shoot
566 sizes and based on APHAPR2019 release data, large shoots make up only 17% of UK shoots, yet they
567 appear to shoot 63% of the birds. In the GOPSOC2017 it is reported of the distribution of their data
568 that “just over 7% of shoots accounted for half of the total number of birds put down and shot.” In
569 the APHAPR2019 data for pheasants, there were 6/3307 shoots reporting releasing >100,000 birds
570 (111,000-200,000), but a median release size of 850 birds/shoot. For red-legged partridges, the
571 distribution of releases was also very skewed with 2/1323 shoots reporting releasing >100,000 birds
572 (180,000 & 250,000), but a median release size of 500 birds/shoot. Therefore, my estimates may not
573 be especially sensitive to the total number of shoots in the country, but rather to the number of
574 these especially large shoots. Given that such shoots are more likely to be commercial, they are also
575 more likely to have advertised on Guns on Pegs website and hence have been included in the three
576 datasets based on that website that I considered.

577

578 A second notable source of potential imprecision is the sparsity of human data covering the
579 behaviour of those people rearing, releasing, managing and shooting the birds. The behaviour of
580 guns and game managers is not homogenous and mirrors the skew seen in the scale of shoots
581 described above, with the three groups of guns identified in the GOPGS2017 varying 7.5 fold in the
582 numbers of birds that they shot each season, ranging from 70-550 . Despite these values being
583 derived from a large sample of >6000 people, the fact that it drew on people who had joined a

584 website in order to purchase shooting suggests that they may be those individuals that shot more
585 birds than most guns in a year. To refine these numbers, we require a deliberate sampling method
586 that equally captures the behaviour of the occasional gun who is invited to walk around a friend's
587 farm twice a year, as well as that of the person for whom shooting is their main recreational hobby,
588 shooting large numbers of birds on many days of the year at multiple sites, and can provide a
589 reliable count of the numbers of such individuals.

590

591 The PACEC (2006 & 2014) reports did indeed attempt to collect such large and
592 representative samples of gun and game manager behaviour, including survey results from >16,000
593 people. Yet the authors of the 2014 report state that even this sample was likely to underrepresent
594 those with low levels of involvement or over represent larger providers of driven game shooting.
595 Further, the PACEC surveys were framed as investigating economic, environmental and social
596 benefits of shooting sports and as such, respondents may have been moved to over-report their
597 activities in order to support an idea that their actions had these benefits. Such over-reporting,
598 specifically in the numbers of people involved in shooting and of days that they shot each year may
599 explain why my estimates based on those PACEC values consistently resulted in figures that seem
600 incredible. Consequently, one explanation for the discrepancy between my own estimates and those
601 of Aebischer (2019) is that he drew on data from the PACEC surveys reporting the numbers of birds
602 (and other quarry) shot. If those data, like those regarding the shooting behaviour of respondents,
603 were also imprecise and over-reported, then they may lead to especially high estimates of numbers
604 of birds being released. However, even if I retain these estimates in my set, then my mean estimate
605 of released birds (~41 million) is still only 72% of that of Aebischer (2019).

606

607 A third indicator of likely imprecision in these measures are clear contradictions or
608 anomalies when comparing data sources. For example, the data on egg imports (Prentis 2020)

609 records ~28 million pheasant eggs and no partridge eggs being imported, whereas Canning (2005)
610 states that around 90% of red-legged partridges are hatched from imported eggs. One explanation is
611 that some of the eggs described as being from pheasants are actually partridge eggs. A second
612 example is that the APHAPR2019 records 15,999,962 birds being reared for released but 14,294,709
613 actually being held for release, a drop of 12% which is more than twice the reported mortality rate
614 at this stage of <5% (Đorđević *et al.* 2010). The fate of these missing birds is unknown. The
615 APHAPR2019 also reports that 195,811 duck were held for rearing whereas more than twice as many
616 (435,907) were held for releasing. It is unclear where these additional birds came from. These
617 anomalies are all seen in official DEFRA records (of imports, poultry registration or background
618 reports) which might usually be assumed to be the more reliable data sources. Consequently,
619 although it may be desirable to base estimates of releases on the most credible data sources, it is
620 unclear which these may be.

621

622 Because data reporting numbers of birds shot or their release and management did not
623 commonly separate by species, it is difficult to be confident in the exact numbers of each species
624 that are released. Pheasants are clearly the most commonly released bird, comprising >70% of the
625 release population. They are also released at the most sites. In contrast, the numbers of partridge
626 and mallard being released is less well known. This may be because some shoots specialise in these
627 two species and so a small number of shoots that release large numbers of these species, indicated
628 by the skewed APHAPR2019 and GOPDB2019 data, may mean that numbers of these species are
629 especially sensitive to records from a small number of sites. Generally, the release patterns and
630 broader ecology of partridge and mallard is less well understood compared to pheasants (Madden &
631 Sage 2020) and a better understanding of these species is desirable in future work.

632

633 An attempt to verify these estimates is possible by setting the numbers of birds estimated to
634 be released within the context of the rearers, shoots and broader landscape where they are bred,
635 released, managed and shot. By considering how many birds we might expect to see being bred,
636 released, managed or shot on an either an average shoot or a shoot that we can place in a particular
637 class, future studies can judge whether an estimate is realistic. If large numbers of birds are believed
638 to be released, then we should expect to also see large numbers of shoots operating over many days
639 of a season with large harvests on each day. More detailed surveys of the numbers of shoots, their
640 frequency and harvest intensity could be conducted either directly by observing at shoots, or via
641 targeted surveys or even remotely by recording sounds of shooting, in order to establish how
642 accurate these and future estimates may be. Given the uncertainty about the credibility of many of
643 the components that contributed to my estimates, it is helpful to explore what these estimates may
644 mean in terms of ‘the average shoot’. If my mean estimate of ~35 million birds being released is
645 correct, then assuming a 33% harvest rate, there are probably around 12 million birds being shot
646 each year. If these are shared evenly across 9,100 shoots in the UK then an average shoot will
647 harvest ~1,300 birds per season. This could be achieved over 13 days of shooting per season with a
648 daily bag of 100 birds. If there are fewer shoots, say 5,000 (based on the numbers of gamekeepers
649 reported by the NGO), then an average shoot would harvest 2,400 birds per season, with either 24
650 days of shooting bags of 100 birds per day, equating to the shoot operating just under two days
651 every week during the height of the shooting season, or about 10 days of shooting bags of 250 birds
652 per day. If the estimate of Aebischer (2019) of 58.5 million birds (including mallard) being released is
653 correct with ~20 million being shot, then across 9100 shoots, an average shoot would harvest ~2,200
654 birds per season, perhaps over 22 days shooting bags of 100 birds, or across 5000 shoots, an average
655 shoot would harvest 4,000 birds. However, the data suggest that all shoots are not equal and instead
656 there are a few large shoots and many smaller ones. Following the definitions of shoots considering
657 their daily bag and numbers of days of shooting from SSBS2017, small shoots harvest 17.6% of the
658 total bag, medium shoots harvest 19.4%, and large shoots harvest 63.0%. If my estimate is correct

659 then a total annual harvest of 12 million birds, would suggest that there are 2,933 small shoots, 983
660 medium shoots and 794 large shoots, totalling 4710 shoots in the UK. If Aebischer's estimate is
661 correct then there should be 4,889 small shoots, 1,638 shoots and 1,325 large shoots, totalling 7,852
662 shoots in the UK.

663

664 Given such variability and uncertainty, is there any value in trying to make estimates? I
665 would argue that even if my mean or range of estimates are inaccurate, they highlight that the
666 existing measures derived from Aebischer (2019) or the official APHAPR2019 figures are also likely to
667 be highly suspect because they do not appear to correspond to either the numbers of birds being
668 bred, nor the activity patterns of game shoots, nor to the numbers of birds surveyed in the
669 countryside during the breeding season. This has two implications. First, my estimate being higher
670 than that of the APHA figures suggests that many game managers, perhaps most, are failing to
671 comply with the register regulations. Second, my estimate being lower than that of Aebischer (2019)
672 suggests that we are unlikely to have an accurate understanding of the ecological effects that the
673 released birds and their associated management exert on the country's wildlife and habitats
674 (Madden & Sage 2020; Sage et al. 2020). Currently, the figure of 57 million gamebirds being released
675 annually (excluding mallard) is one that is quoted by both advocates and opponents of gamebird
676 release. For both 'sides' there is an incentive to report high figures: for opponents, such as the
677 League Against Cruel Sports (LACS 2020), a large number of birds can be presented as both an
678 increased source of direct negative environmental effects and a large pool of individuals that might
679 be considered to suffer from poor husbandry or death; for advocates, high numbers can support
680 high figures of employment (including that directed at habitat conservation) and economic benefits
681 derived from game shooting. If my mean estimate is correct, being about 60% of the previously
682 published figure, then it suggests that neither the scale of negative ethical or ecological effects of
683 release, nor the positive economic benefits are as high as are currently assumed.

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686 **Ethics approval** N/A

687 **Consent to participate** N/A

688 **Consent for publication** N/A

689 **Availability of data and material** All data are provided in the text or in accompanying references

690 **Code availability** N/A

691

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814 **Figure Legends**

815

816 **Figure 1** The various ways that datasets may be combined in order to generate estimates of the
817 numbers of gamebirds released in the UK.

818

819 **Figure 2** The 72 size-ordered estimates of the total numbers of gamebirds released in the UK. The
820 diagonally hashed bar indicates the official figure derived from the APHA Poultry Register data for
821 gamebirds held for release for shooting in the UK. The chequered bar indicates the figure published
822 in Aebischer 2019. Grey bars indicate values that I consider to be uncredible, either because they fall
823 below the official APHA Poultry Register figures or because they include data from the PACEC 2006
824 /2014 surveys that appears to be susceptible to over-reporting and bias. The mean value based on
825 credible estimates is shown by the grey dashed line.

826

827 **Table 1** The set of the estimate calculations and the datasets used in them.

Method	Data sets used	Number of estimates
Published estimates	Aebischer 2019	1
Formal Release Records	APHAPR2019 data considering birds reported as 'held for release'	1
Estimates based on numbers bred and reared for release	a) APHAPR2019 data considering birds reported as 'held for breeding' b) APHAPR2019 data considering birds reports as 'held for rearing' c) DEFRA data on eggs/birds imported into the UK d) Egg production values e) Egg hatching proportions f) Chick survival values	2
Estimates based on numbers of birds reported released on samples of shoots of differing sizes	a) GOPSOC2018 (Mean number of birds of all species per shoot = 4307) b) PR data considering birds reported as 'held for releasing' (Mean number of birds per shoot = 3036 pheasants; 2887 red legged partridge; 754 mallard) c) GOPDB2019 (Mean number of birds per shoot = 3238 pheasants; 1070 red legged partridge; 1816 mallard) d) SSBS2017 (Mean number of birds per shoot with consideration of 3 shoot classes = 1532, 6212, 26241 birds/shoot) e) Estimated numbers of shoots in the UK = 3300, 5000, 7300, 9100 (see Methods)	16
Estimates based on numbers of game keepers	a) NGO published estimate of numbers of keepers in the UK b) SSBS2017 data on numbers of birds that each keeper can manage single handed and as part of a team	2
Estimates based on harvests from shoots	a) GOPSOC2018 (mean harvest/day = 98 birds) b) GOPGS2018 (mean harvest/day = 112 birds) c) GOPDB2019 (mean harvest/day = 165 birds) d) SSBS2017 (mean harvest/day corrected for shoot class = 80, 148, 232 birds) e) GOPSOC2018 (mean shoot days/season = 13) f) SSBS2017 (mean shoot days/season corrected for shoot class = 9, 16, 41) g) Estimated numbers of shoots in the UK = 3300, 5000, 7300, 9100 (see Methods) h) Harvest efficiency (Robertson et al. 2017 = 33%; GOPGS2018 = 40%)	32
Estimates based on harvests by individual guns	PACEC2006 (number of people shooting released birds = 384,000) PACEC2014 (number of people shooting driven game = 260,000) PACEC2006 (number of gun days/season = total lowland shooting 2.32 million days; driven game only 1.5 million days) GOPGS2018 (numbers of birds shot/gun/season corrected for spending group = 73, 185, 557, 111 birds/season) Estimates of total gun days based on mean number of shoot days, shoot numbers and the size of gun teams, corrected for spending group Harvest efficiency (Robertson et al. 2017 = 33%; GOPGS2018 = 40%)	16
Estimates based on BTO Breeding Bird Survey Data	BTO BBS data (Woodward 2020) Mortality data (Pheasants = Madden et al. 2018; Red legged partridge = Hesford 2012)	2

Figure 2

