Regional variation in livestock management in feeding habitat areas of red-billed chough in Great Britain and the Isle of Man

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Abstract

In Great Britain, red billed chough (*Pyrrhocorax pyrrhocorax*) breed in discrete populations along the west coast: on Islay and Colonsay, in the Inner Hebrides of Scotland; on the Isle of Man; in Wales; and in Cornwall. Chough are dependent on pastures grazed by cattle and sheep, and their survival is therefore dependent on sympathetic management of grassland. The Scottish population is in decline and all other populations are growing or stable. Sixty-three farmers in these locations whose farms were known to support feeding chough were asked questions about their farm management using a structured, questionnaire-based personal interview. Islay farms were significantly larger and had more grazing area, with the lowest stocking densities. Welsh farms had the least cropping area and the smallest number of cattle. Cornwall had the smallest number of sheep per farm. Welsh farms were more likely not to house cattle during winter. Liver fluke in sheep and ticks and tick-borne disease were a higher concern on Islay than other locations and abortion in sheep was of highest concern on the Isle of Man. Islay farmers used between four and 13 times as many treatments per year as farmers at other locations and the application rate of triclabendazole (TCBZ) was higher on Islay. The rate of application of other products, including macrocyclic lactones ML, did not differ among locations. The study described here shows clear differences in the farm grazing management, in the priority given to animal health problems and in the frequency of application of veterinary parasiticides among four locations that provide feeding habitat for chough in the UK. These differences suggest that the viability of chough populations might be favoured by higher intensity grazing, and by low rates of application of veterinary parasiticides of either the TCBZ or synthetic pyrethroid SP, or both classes of parasiticides.

Key words

Anthelmintic; acaricide; coleoptera; diptera; synthetic pyrethroids; triclabendazole

Introduction

Red billed chough (*Pyrrhocorax pyrrhocorax,* hereafter referred to as chough) breed in four small, discrete populations along the west coast of Great Britain: on Islay and Colonsay, in the Inner Hebrides of Scotland; on the Isle of Man; in Wales; and in Cornwall, England. Chough are dependent on pastures grazed by cattle and sheep, and their survival is therefore dependent on sympathetic management of grassland. These populations are relatively isolated, with infrequent gene flow (Wenzel et al. 2012) and are localised to (but do not completely fill) a climatic zone which is comparatively warm and humid with a reduced annual temperature range due to oceanic influence (Monaghan et al. 1989). Scottish chough have declined by 35%, whereas the GB and Isle of Man population overall has increased by 60% since 1992 (Hayhow et al., 2018). Unprecedentedly low first year survival from 2007, during the post-fledging period threatens the viability of Scottish chough (Reid et al.

2008, 2011). Supplementary feeding led to increased survival, suggesting that food availability was limiting (Bignal & Bignal 2011). Chough have a greater reliance on invertebrate prey than other corvids, with evidence of chough on Islay having more dung-associated insects in their diet than those elsewhere in Great Britain (Warnes 1982, Warnes & Stroud 1989, McKay 1996, MacGillivray et al. 2018). Observations during the post-fledging period on Islay showed dung to be an important source of food, significantly more so for young birds (Gilbert et al. 2019a). Dung invertebrates formed the majority of the biomass of chough diets from dune pastures on Islay during this period, and tipulid larvae the majority of chough dietary biomass on other pastures (MacGillivray et al. 2018). Aphodius (dung beetle) larvae were scarce in the diet, despite having been a major component in the 1980s, suggesting that their availability had declined (MacGillivray et al. 2018).

Macrocyclic lactones (ML), predominantly ivermectins, have long been known to affect the abundance of dung-associated insects (Wall & Strong, 1987; Suarez et al. 2003; McCracken 1992; McCracken & Foster 1993; Adler et al., 2016; Bai et al. 2016), and organisations that promote conservation-friendly farming often recommend its avoidance in animals on pasture (ECRDP, 2016). However, there are reports in the literature that other veterinary parasiticides from distinct classes can adversely affect dung-associated insect species (eg Beynon et al., 2012; 2015) and these reports have not been translated into recommendations for avoidance or reduction of use. We recently conducted a large scale field study in which we compared invertebrate abundance in dung from cattle that had been treated with deltamethrin (a synthetic pyrethroid, SP, used to treat fly and tick infestations), with triclabendazole (TCBZ, a product used to control liver fluke infestations), and with control, untreated dung, in two successive years. We recorded relatively few adult dung invertebrates overall, and found that numbers of larvae, particularly Dipteran larvae, were significantly reduced in both years by as much as 86% when the two treatments were combined (Gilbert et al. 2019b).

The present study was conducted to identify the priority areas of concern in relation to animal health in the areas of chough habitat in mainland Great Britain and to quantify their use in sheep and cattle. We also wished to determine the extent to which livestock grazed pasture continuously through the year and the stocking densities in each of the areas.

Materials and Methods

Data collection

A questionnaire was designed for use in direct, personal interviews by trained staff and was pilot-tested on three sheep/cattle mixed farmers from south-west Scotland prior to minor modifications to improve the clarity of the questions. The questionnaire, and anonymous data are available from the University of Glasgow data repository (http://dx.doi.org/10.5525/gla.researchdata.839). Ethical approval was granted under the University of Glasgow MVLS Ethics Committee (Application 200150194, 2016). Farms on which chough were known to feed were identified by RSPB staff working in each of the areas and contacted by telephone or in person to arrange an interview. Figure 1 depicts 10 km squares in which chough are present, and which of those 10 km squares also had at least one farm for which questionnaire data was obtained. There was the following proportion of 10 km chough breeding squares, also with questionnaire data: Scotland 10/14, IoM 3/13, Wales 23/74 and Cornwall 6/8. Responses were recorded on printed record sheets, which were assigned a key and then transcribed in anonymised form, into an excel spreadsheet prior to analysis using R (R core team 2016). Veterinary products were recorded in the questionnaire by their trade name, which was subsequently referenced using the Veterinary Medicines Directorate (VMD) Product Information Database (https://www.vmd.defra.gov.uk/ProductInformationDatabase/Default.aspx) to determine the active compound. For analysis, active compounds were aggregated into the following groups: macrocyclic lactones, organophosphorous products, synthetic pyrethroids, closantel, benzimadazoles, triclabendazole, nitroxynil, dicyclanil.

Data analysis

All continuous data were initially checked for normality by plotting as histograms and application of the Shapiro-Wilk test. Almost all variables showed strong right-skewness and were not normally distributed, but their log-transformations were normal. The area of land allocated for cropping was not readily transformed, so it was converted to a categorical vector with three levels (“No Cropping”, “Cropping < 10 Ha”, “Cropping ≥ 10 Ha”). The level of concern by farmers for each of the animal health problems is a categorical variable and the statistical analysis was conducted using contingency tables, with Fisher’s exact test, but means are presented for ease of interpretation as if they were a continuous variable. This is justified on the basis that results of almost all rating systems in common use are (incorrectly) presented to the general public as if they were continuous variables. To determine whether prioritisation by location was biased by any location-specific tendency to be concerned about health issues in general, an index of concern was established for cattle and sheep farmers. This index was an unweighted arithmetic mean of each farmer’s priority scores for each of the health problems. These were then compared among regions using the Kruskal-Wallis rank sum test. The number of applications of products was treated as a discrete, continuous variable and contrasts were drawn among locations using the Kruskal-Wallis rank sum test with no attempt at transformation. Multivariate relationships were explored using nested generalized linear models with total grazing area, number of livestock, livestock density nested in location. However in all of the cases in which location was a significant factor in the univariate analysis, the addition of the other variables did not substantially improve the model fit. Hence, we present here only the results of univariate analysis, with location as the only factor that was tested.

Results

Farms and data: 63 observations were recorded on 63 variables. The survey covered 15 farms in Cornwall, 23 on Islay (including 3 on Colonsay and 1 on Oronsay), 3 on Isle of Man and 22 in Wales (Figure 1). Table 1 summarises the farm characteristics and shows that with the exception of months of housing for cattle (among those farms that did house cattle), each characteristic differed significantly by location. Islay farms were significantly larger and had more grazing area, with the lowest stocking densities (Figure 2). Welsh farms had the least cropping area and the smallest number of cattle (Figure 3). Cornwall had the smallest number of sheep per farm. Welsh farms were more likely not to house cattle during winter.

The priority given by farmers to health problems in cattle and sheep are summarised in Tables 2 and 3 respectively. The first line of each table is an index of overall priority, which did not differ significantly among locations for either sheep or cattle. Most health problems were given more or less equal priority in each of the locations, with the exceptions of fluke in sheep (highest on Islay, $P = 0.0099$), ticks and tick-borne disease (TTBD) in cattle (highest on Islay, $P = 0.050$), and abortion in sheep (highest on Isle of Man, $P = 0.047$). Islay farmers also tended to have the highest concern regarding TTBD in sheep ($P = 0.06$) and fluke in cattle ($P = 0.06$). Concern about diarrhoea in cattle and bovine viral diarrhea virus (BVDV) in cattle tended to be lower among Welsh farmers ($P = 0.06$ and 0.08 respectively).

Table 4 shows the median and mean numbers of TCBZ, SP and ML treatments applied to cattle and sheep, by location. The greatest difference among locations was noted for the application of SP products to cattle, of which Islay farmers used between four and 13 times as many treatments per year as farmers at other locations ($P = 0.00024$, see also Figure 4). The application rate of TCBZ was also significantly higher on Islay ($P = 0.0085$). The rate of application of other products, including ML did not differ among locations.

Discussion

The primary aim of the investigation was to draw contrasts among discrete regions that support feeding chough with respect to farm characteristics (primarily indices of grazing intensity), the priority areas of concern in relation to livestock health, and the frequency of application of veterinary parasiticides to sheep and cattle. It is clearly not possible to draw inferences of causality from a cross-sectional observational study such as this, but the study was intended to generate hypotheses to be tested by intervention studies. The main contrast of interest is between the Scottish farms of the Inner Hebrides (here identified as “Islay”, including Oronsay and Colonsay), on which the population of chough has been in steep decline in recent decades, and all other populations, which have been stable or growing (Hayhow et al., 2018). The study provides clear evidence that the Islay farms were larger, had lower overall grazing intensity and used a higher rate of application of SP and TCBZ products.

Chough choose to feed in fields with higher livestock density as these have short grazed vegetation, opening up easier access to soil invertebrates, as well as providing a source of dung invertebrates (Gilbert et al. 2019). A high proportion of out-wintered cattle results in the continuous presence of fresh dung in fields throughout the year, which is favourable for a more diverse and abundant dung-associated insect population (Lane & Mann 2016), hence is more favourable for a reliable feed resource for chough. The SP and TCBZ product groups have both been shown to cause depletion of dung-associated insects in the Hebridean environment (Gilbert et al., 2019). Hence, our observations in relation to livestock management are consistent with the hypothesis that the relatively poor performance of chough populations in Scotland might be linked to the combination of high rates of application of TCBZ and SP products, together with overall low stocking densities and a high rate of housing of cattle over winter.

It is not surprising that there are differences in farm characteristics and health priorities among the areas studied. The mix of agricultural activities carried out in each of the locations, and how they are conducted, are at least partly determined by physical geography, which differs substantially among them. According to the Scottish Government, all of the Inner Hebrides of Scotland are classified as less favoured areas, in the category of “severely disadvantaged” (Scottish Government, 2019). In contrast, few of the other areas of chough habitat in which farms were surveyed were classified as less favoured areas and none as “severely disadvantaged” (DEFRA, 2019). The larger size and lower overall stocking rates on Islay probably reflect its lower potential for livestock production. Livestock farmers on the island are subject to financial disadvantages relative to those on the mainland. There is no market premium for island-produced store lambs or cattle, and the cost of transportation to finishing units on the mainland is a penalty. Regardless of the reasons for the difference, our survey showed that the average stocking density on Islay farms was significantly lower than in other locations (see Table 1 and Figure 2). Average stocking rate is not a good indicator of effective stocking rate from an ecological perspective because stocking density is not homogeneous across a farm, so some caution is required in interpretation. Nonetheless, the contrasts between Islay and Isle of Man or Islay and Cornwall stocking density are marked. Previous work on Islay has shown that chough did feed in fields in which the stocking density exceeded 4.2 livestock units/Ha and did not feed in fields in which the stocking density was 2.0 livestock units/Ha (Gilbert et al., 2019a). It may therefore be the case that only relatively small areas of the large Islay farms provide good feeding opportunities for chough.

The greater concerns about ticks and tick-borne diseases registered by farmers on Islay are possibly a consequence of high densities of deer, although we have no information on the relative densities of deer in the different locations. Red deer and roe deer are definitive hosts in the UK for *Ixodes ricinus*, the main tick species of concern to livestock owners in the UK, and a strong correlation between abundance of deer and of *I ricinus* has been shown previously (Gilbert et al., 2012, for example). Several farmers mentioned that the declining profitability of livestock production on the island had resulted in the relatively recent conversion of several large estates from predominantly livestock-grazing farms to sport-shooting estates, which was followed by noticeable increases in the frequency of deer sightings on their own farms. The economically important diseases known to be transmitted by this tick are louping-ill virus, tick-borne fever (*Anaplasma phagocytophilum*), red-water (*Babesia* spp) and tick pyaemia (*Staphylococcus aureus*). There is no recent, accessible information regarding the occurrence of deer, ticks, or tick-borne diseases on Islay in comparison with the other locations in the study, but the significantly higher level of concern about ticks expressed by farmers on Islay suggests that there is a relatively greater problem there with ticks and the diseases they transmit. The index of overall concern about disease did not differ significantly among locations for either sheep or cattle, however it should be noted that for both species, Islay had the numerically higher mean score. Hence the possibility of a Type-II error (accepting the null hypothesis when there is a true difference) must be considered. It is possible that generally poor economic conditions for farmers on the island resulted in greater sensitivity to health problems in general.

Islay farmers were more concerned with liver fluke (fasciolosis) in sheep than farmers in other areas. There is no immediately obvious possible explanation for this concern being higher in Islay than the other areas because historical data suggest that, broadly speaking, each of the locations has a similarly high risk of fasciolosis (Fox et al., 2011). *Fasciola hepatica*, the parasite that causes the disease, passes one stage of its life-cycle in a snail intermediate host (*Galba truncatula*), which is dependent on the presence of standing water in and around drains, streams, dams or ponds or on generally wet conditions in fields. Predictions for the years 2020-2070 under climate change conditions suggest that the risk of fasciolosis will increase more or less equally in each of the four areas where chough are currently found (Fox et al., 2011). It is possible that the perceived higher risk of disease on Islay derives from different management practices or from alternative hosts. French et al. (2016) demonstrated a prevalence of liver fluke infection of red deer ranging from 9 to 53% in the Scottish highlands. Hares have also been shown to be a reservoir of infection with sometimes high prevalence, and to have the same genotypes of flukes as cattle that were grazing in the same pasture (Walker et al., 2011). Wildlife hosts will act as refugia for a parasite, enabling them to complete their life-cycle without exposure to anthelmintic drugs that are applied to domestic livestock. The extent to which the density of wildlife reservoirs varies among the locations in our study is not known.

The frequency of veterinary parasiticide application varied among the regions, but there was also considerable variation within region. On Islay, where SP application to cattle and TCBZ application to sheep were higher than in other areas, some farms used no product or infrequent treatments, whereas others used very high rates of application. It is not known whether this reflects true differences in the parasite challenge or disease occurrence among farms, or is a result of different levels of risk aversion among the farmers. For tick-borne diseases and liver fluke, there is no simple method of safely and reliably assessing the risk of disease occurring in an individual animal until it is too late. There are very few reports in the peer-reviewed literature on the reasons why farmers are motivated to treat when they do. Anthelmintic applications for sheep flocks in the UK have been reported to be predominantly “blue-print” based, with treatments administered according to pre-determined plans (Taylor, 2012), so treatments are usually prophylactic and treatment frequency relates to risk-averseness of the farmer. On many farms, for both problems, this can result in high frequency, suppressive treatments, as seen in the present study. In the UK, the most widely accepted recommendations for parasite control of sheep and cattle are provided by consortia of government and non-government organisations from within the livestock industries (Taylor, 2012). For sheep the consortium is SCOPS (Sustainable Control of Parasites in Sheep - https://www.scops.org.uk/) and for cattle it is COWS (Control of Worms Sustainably - https://www.cattleparasites.org.uk/). Both consortia make recommendations for the control of fasciolosis, however they are not prescriptive and revolve around local and seasonal knowledge of likely fluke challenge. The use of faecal egg-counts (counts of the eggs of parasites in the faeces of the host) and faecal immunoassays to indicate infection status are advocated, although the interpretation of both tests is challenging. Sustainable control in the context of SCOPS and COWS relates to the preservation of effective anthelmintic products by delaying drug resistance, and whereas a major tenet of management of drug resistance is the reduction in anthelmintic use, the emphasis in SCOPS and COWS is on correct treatment to prevent under-dosing, according to 5 elements ("The five R's - The RIGHT product for the type of worm, the RIGHT animal, the RIGHT time, the RIGHT dose rate, administered in the RIGHT way"). Recommendations relating to the environment in SCOPS technical manual for sheep (Abbott et al., 2014) are restricted to the following statement.

> "Where fluke infection is present, identification and exclusion of snail habitats from livestock offers some measure of control. Drainage eliminates the snail and offers an effective means of control, but the proliferation of environmental schemes to protect wetland areas has reduced the opportunities for this to be implemented. Simply keeping stock off the wettest fields in the autumn and the winter, when the incidence of disease is at its highest, can reduce the risk from fluke."

SCOPS and COWS are relatively silent regarding ticks. SCOPS makes no recommendations for tick control in sheep. COWS states only the following (COWS, 2019).

> “A range of pour on pyrethroids or MLs may give protection, although none in the UK have a label claim for cattle against ticks at present, so must be used under the cascade system. Products will need to be reapplied at regular intervals during the tick season to achieve sustained protection.”

In practice, as elucidated from the survey and from personal experience of one of the authors (NNJ), producers who are concerned about the risk of ticks in sheep and cattle try to exclude susceptible younger stock from fields in which they know the risk of tick infestation is very high (usually those with poorest quality grazing and high densities of bracken, gorse and heather). In addition to this they use prophylactic treatments during the times of year when they consider the risk of infestation to be high. The rate of application of TCBZ and SP on farms on Islay was higher than on farms in all other locations. Both compounds have been shown to significantly and substantially reduce the abundance of dung-associated insects (Gilbert et al., 2019b). The wide range in frequency of applications used in a relatively small location suggests that a) there is very large inter-farm variation in parasite challenge, b) some farmers are using more treatments than necessary, or c) some farmers are using fewer treatments than necessary. At present, in the absence of any reliable quantitative information on parasite challenge or on the true effect of commonly used treatment strategies, each of the three possibilities seems to be quite likely true.

Cross-sectional, observational studies are subject to bias due to unbalanced sample selection. Thus, although the coverage of all farms on which chough were known to feed differed among areas (Scotland 10/14, IoM 3/13, Wales 23/74 and Cornwall 6/8), in selecting farms known to RSPB staff to be used by feeding chough, and which were believed to provide proportional representation of the types of habitat encountered in each area, we have attempted to minimise bias. However it is possible that a) RSPB staff were more inclined to contact farmers with whom there is already a relationship, and that this differential approach rate differed among locations, or b) the participation refusal-rate by farmers who were contacted by RSPB differed by location. It is not possible to definitively verify equivalence of these factors among locations although there is no immediately obvious reason why location-specific differences would be expected. The limited size of the dataset, its unbalanced design and the diversity of product use ensured that multivariate analysis would be relatively uninformative. This was not considered to be a problem in light of the objectives of the study. It is expected that the effect of location on animal health priority and on the frequency of parasiticide application is a consequence of location-specific geo-climatic and socio-economic factors interacting with farm management factors, including the stocking density and the propensity to housing of livestock. Identifying these factors and their interactions, and quantifying their importance with a view to designing effective interventions is the focus of our on-going work in this area.

The study described here shows clear differences in the farm grazing management, in the priority given to animal health problems and in the frequency of application of veterinary parasiticides among four locations that are occupied by chough in the UK. These differences are consistent with the hypothesis that the viability of chough populations is favoured by higher intensity grazing, and by low rates of application of veterinary parasiticides of either the TCBZ, SP, or both classes of parasiticides.

Competing interests

The authors declare that they have no competing interests.

Acknowledgements

We would like to thank all of the anonymous farmers who subjected themselves to interview. We are very appreciative of the efforts of RSPB staff to conduct interviews. Interviews were conducted by Rhian Pierce, Claire Mucklow, the authors and Sarah Mellor of the National Trust. Thanks also to Ian Johnstone for his knowledge and support and Helen Robertson for data collation.

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Table 1. Summary of median and mean of farm characteristics by location, with estimate of p-value and significance from analysis of variance using log-transformed data, with the exception of cropping area, which is derived from a contingency table of three levels of grazing area (“No Cropping”, “Cropping < 10 Ha”, “Cropping ≥ 10 Ha”).

	Location					
	Islay	Cornwall	Isle of Man	Wales		
Characteristic	n=24	n=15	n=3	n=22	p-value	sig
Median Farm Area (Ha)	**500**	105	101	162	0.00063	**
Mean Farm Area (Ha)	**718**	167	158	225		
Median Grazing Area (Ha)	**445**	100	101	142	0.00019	***
Mean Grazing Area (Ha)	**668**	114	144	191		
Median Cropping Area (Ha)	10	7.0	6.0	**0.0**	7.1×10^{-6}	***
Mean Cropping Area (Ha)	26.4	37.5	12.8	**1.9**		
Median Max N Sheep	550	**0**	720	360	0.0022	**
Mean Max N Sheep	805	**82**	557	460		
Median Max N Cattle	170	100	200	**33**	0.016	*
Mean Max N Cattle	169	152	217	**68**		
Median Livestock Units/Ha	**0.44**	1.3	2.6	0.72	0.0020	**
Mean Livestock Units/Ha	**0.61**	1.3	2.5	1.0		
Median Months Housed (Cattle)[a]	6.0	4.5	6.0	5.0	0.14	NS
Mean Months Housed (Cattle)[a]	5.50	4.42	5.33	4.91		
House Cattle?						
Yes	7/23	1/15	3/3	6/22	0.004	**
Some	9/23	11/15	0/3	5/22		
No	7/23	3/15	0/3	11/22		

[a] Means and medians for the number of months that cattle were housed are derived only from farms that did house cattle.

Table 2. Mean score given to each health problem of cattle by location, with p-value and significance from Fisher's exact test of contingency tables. GIT -gastrointestinal tract, TBD – tick borne disease, BVDV - bovine viral diarrhea virus.

	Location					
Health Problem	Islay	Cornwall	Isle of Man	Wales	p-value	sig
Overall Index (mean)	2.30	2.08	2.02	1.75	0.10	NS
Minerals	3.1	3.0	3.0	2.2	0.42	NS
GIT Nematodes	3.2	2.6	2.7	2.1	0.13	NS
Fluke	4.0	2.2	3.0	3.0	0.06	.
TBD	3.0	1.8	1.7	1.5	0.05	*
Respiratory	2.0	2.1	1.0	1.6	0.67	NS
Johnes disease	2.5	2.0	2.3	1.8	0.59	NS
Diarrhoea	2.2	2.2	2.0	1.2	0.06	.
Abortion	1.5	1.7	1.7	1.3	0.04	NS
Lameness	2.0	2.1	2.3	1.4	0.21	NS
Sudden Death	1.4	1.8	1.3	1.2	0.15	NS
Plant Poisoning	1.3	2.0	1.3	1.3	0.16	NS
Predation	1.3	1.4	1.0	1.3	0.36	NS
Flies	1.7	1.8	1.7	1.3	0.38	NS
BVDV	2.1	2.7	2.7	1.5	0.08	.

Table 3. Mean score given to each health problem of sheep by location, with p-value and significance from Fisher's exact test of contingency tables. GIT -gastrointestinal tract, TBD – tick borne disease,

	Location					
Health Problem	Islay	Cornwall	Isle of Man	Wales	p-value	sig
Overall Index (mean)	2.62	2.12	2.13	2.21	0.20	NS
Minerals	3.0	1.8	3.0	2.3	0.19	NS
GIT Nematodes	3.5	2.8	2.7	2.6	0.47	NS
Fluke	4.5	1.7	2.0	3.3	0.0099	*
TBD	3.7	1.7	1.7	2.9	0.06	.
Respiratory	1.7	1.3	1.3	1.4	0.75	NS
Diarrhoea	1.5	1.2	1.3	1.3	0.55	NS
Abortion	1.4	1.3	1.7	1.4	0.047	*
Lameness	2.3	2.3	2.3	2.4	0.78	NS
Sudden Death	1.8	2.0	2.0	1.7	0.26	NS
Plant Poisoning	1.4	1.6	1.0	1.1	0.25	NS
Predation	3.2	2.0	3.0	2.9	0.20	NS
Flies	3.1	3.2	3.0	3.5	0.44	NS

Table 4. Mean and median number of treatments with some major parasiticides (SP – synthetic pyrethroid; TCBZ - triclabendazole, ML – macrocyclic lactone) applied to sheep and cattle, by the location, with Kruskal-Wallis rank sum test *p*-value and significance.

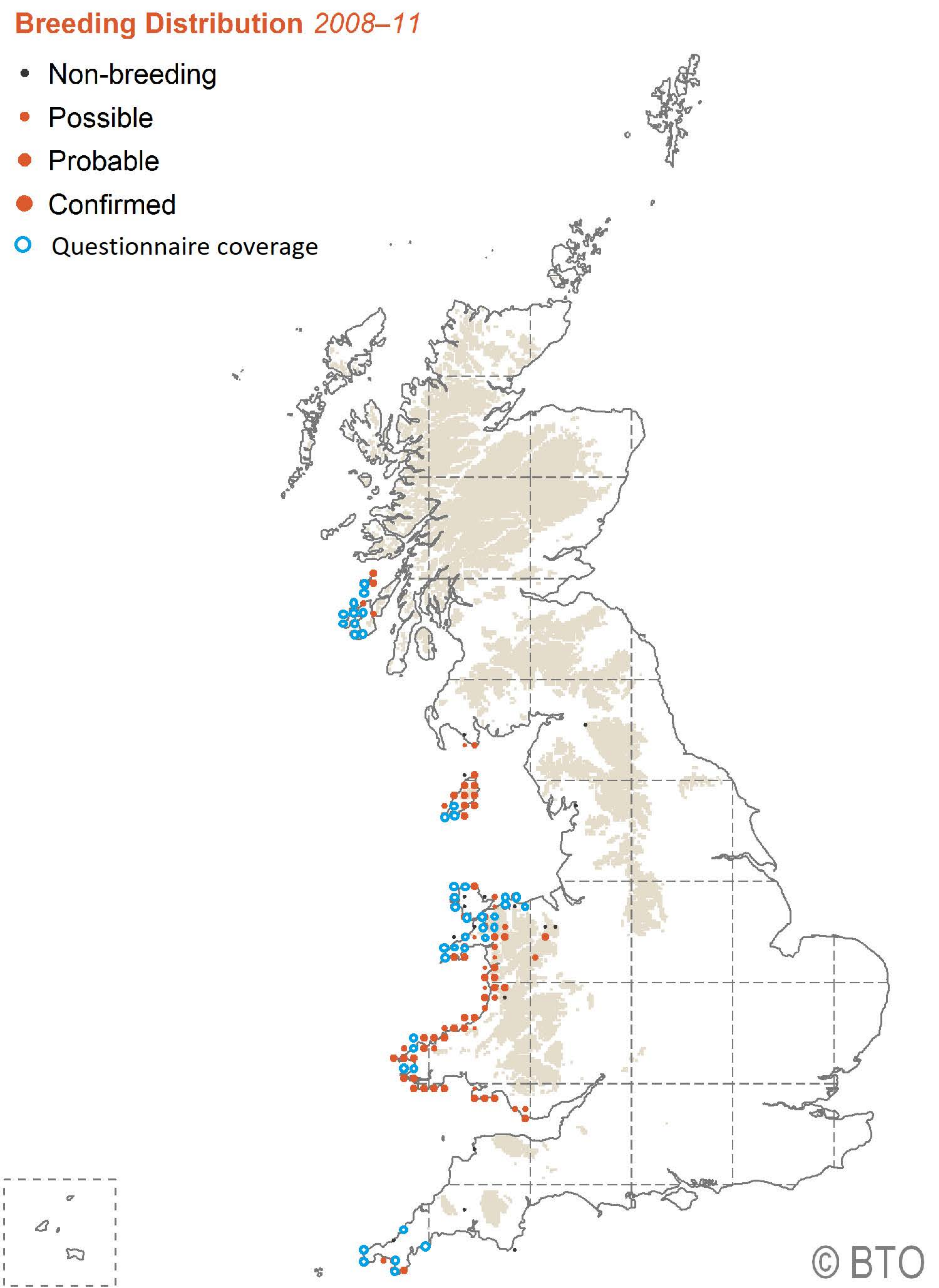
Location	Cornwall	Islay	Isle of Man	Wales	p-value	Significance
Cows SP Mean	0.20	**1.39**	0.33	0.13	0.00024	***
Med	0.00	1.00	0.00	0.00		
Sheep SP Mean	0.60	1.78	0.67	1.17	0.28	NS
Med	0.00	1.00	1.00	1.00		
Cows TCBZ Mean	0.33	0.83	1.33	0.00	0.14	NS
Med	0.00	0.00	2.00	0.00		
Sheep TCBZ Mean	0.60	**1.70**	1.00	0.44	0.0085	**
Med	0.00	2.00	1.00	0.00		
Cows ML Mean	0.73	0.96	1.33	1.06	0.88	NS
Med	0.00	1.00	1.00	1.00		
Sheep ML Mean	0.00	0.57	1.33	0.67	0.21	NS
Med	0.00	0.00	1.00	0.00		

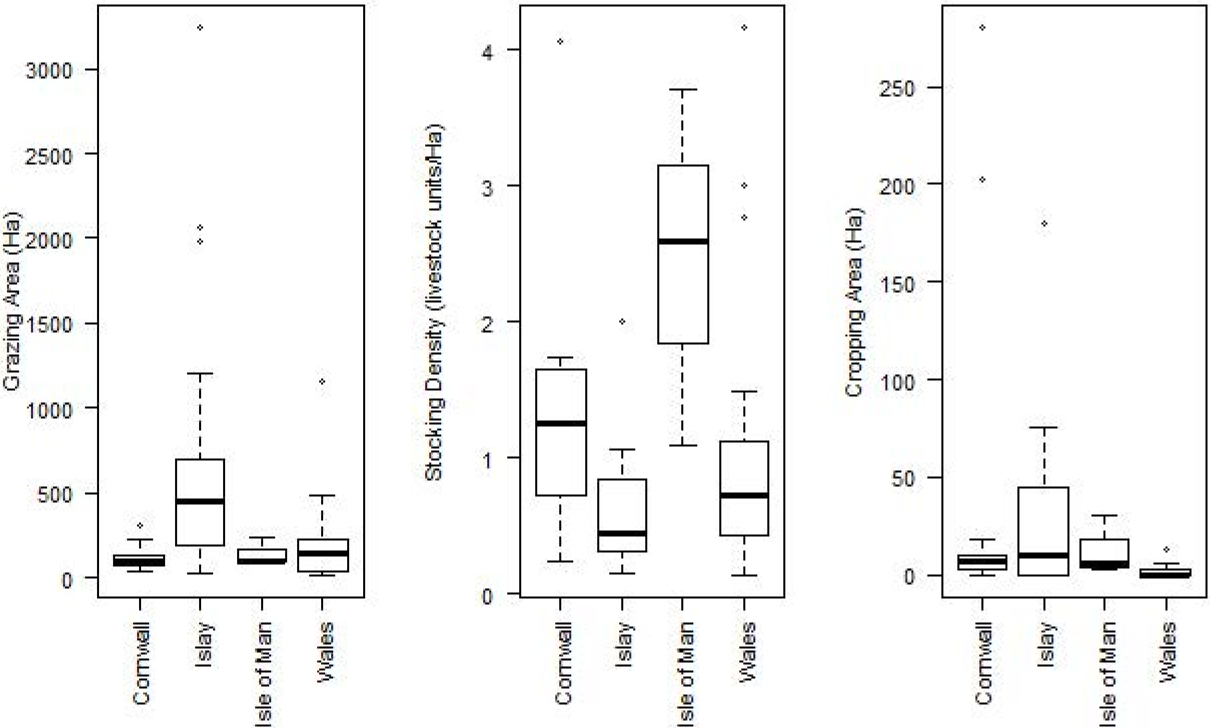
Figure 1. Map of distribution of chough in mainland Great Britain and the Isle of Man, showing 10 km squares in which there are confirmed and possible breeding or non-breeding sites (red or black circles) and 10 km squares were chough are known to feed and which contained at least one farm for which questionnaire data were obtained. (Distribution map is from *Bird Atlas 2007-11*, a joint project of BTO, BirdWatch Ireland and the Scottish Ornithologists' Club. Maps reproduced with permission from the BTO.)

Figure 2. Box and whisker plots showing the grazing area (left), the stocking density (centre) and the area reserved for cropping (right) by location.

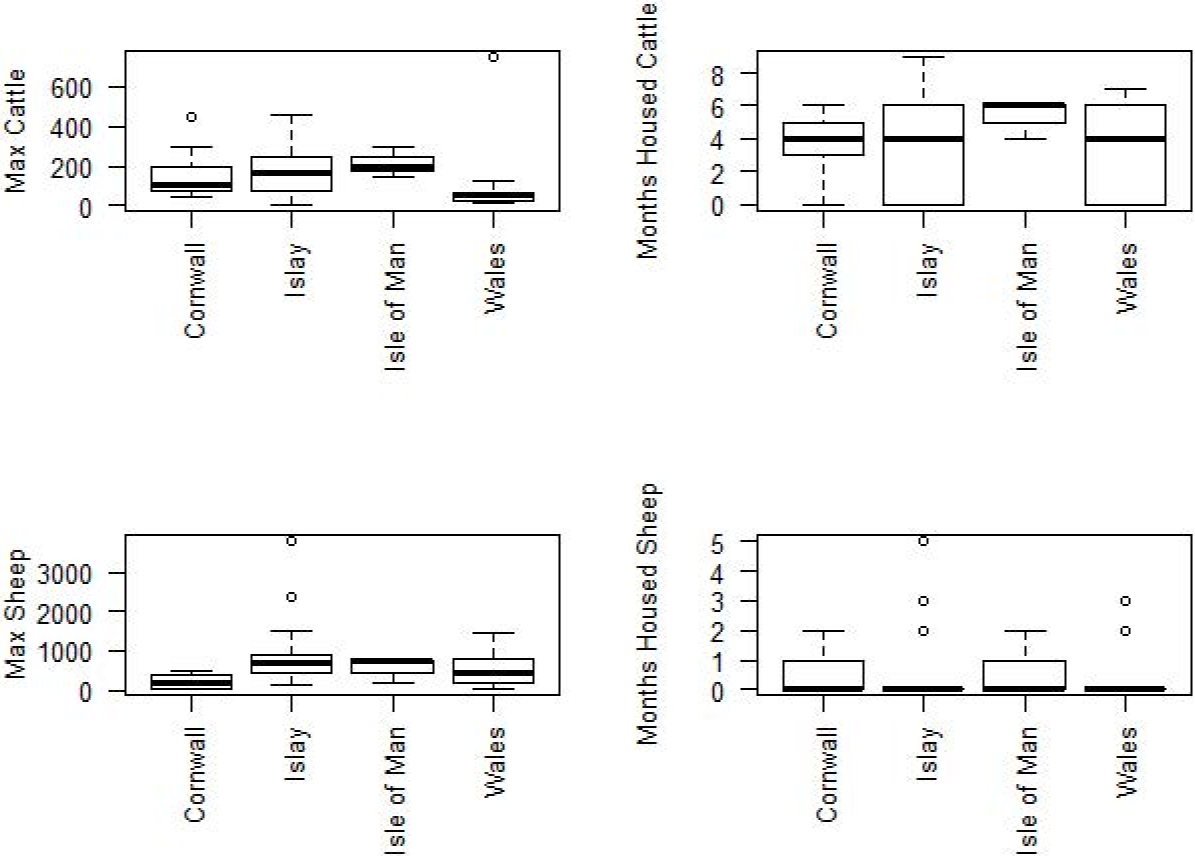
Figure 3. Box and whisker plots showing the livestock densities (maximum total number on farm at any time) and periods of housing (months per year) by location.

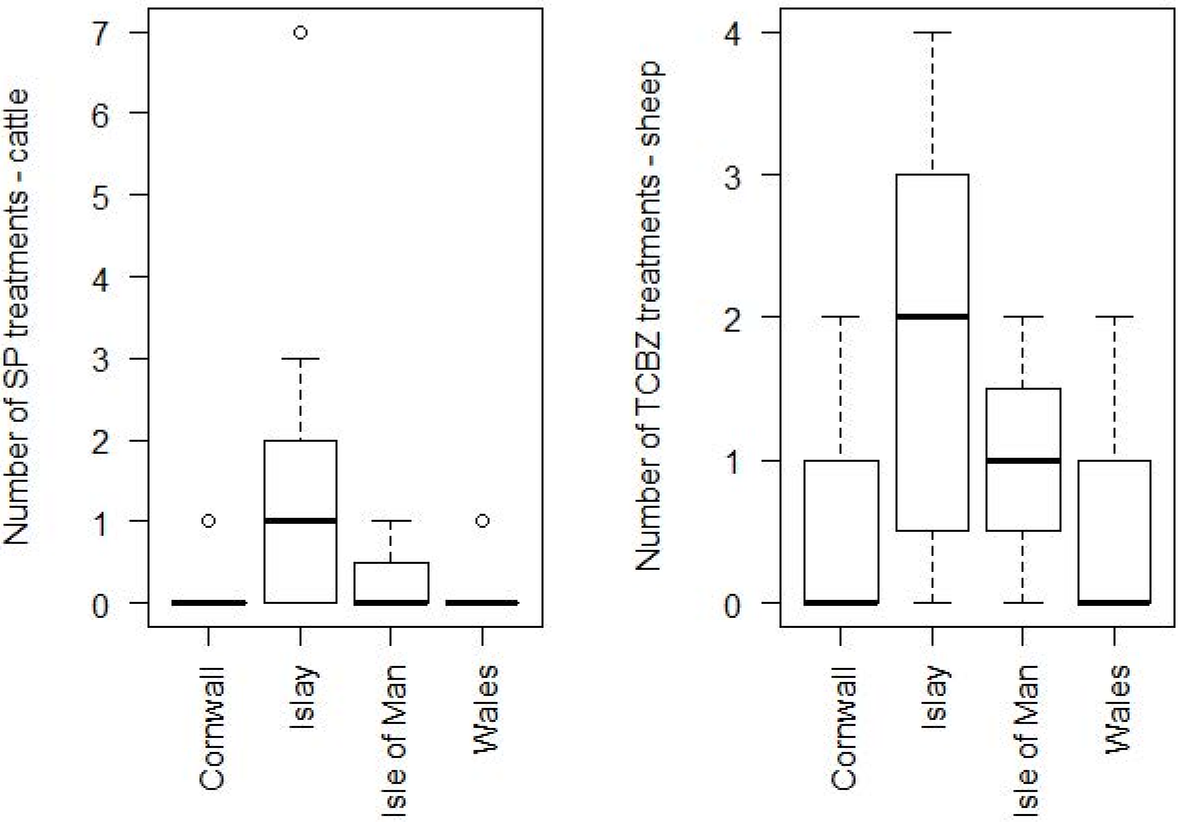
Figure 4. Box and whisker plots showing the number of synthetic pyrethroid (SP) treatments applied to individual cattle in each year (left) and of triclabendazole (TCBZ) treatments applied to individual sheep in each year (right) by location.


Breeding Distribution 2008–11
Non-breeding
Possible
Probable
Confirmed
Questionnaire coverage
© BTO



Grazing Area (Ha)
0
500
1000
1500
2000
2500
3000
Cornwall
Islay
Isle of Man
Wales
Stocking Density (livestock units/Ha)
0
1
2
3
4
Cornwall
Islay
Isle of Man
Wales
Cropping Area (Ha)
0
50
100
150
200
250
Cornwall
Islay
Isle of Man
Wales


Max Cattle
0
200
400
600
Months Housed Cattle
0
2
4
6
8
Max Sheep
0
1000
2000
3000
Months Housed Sheep
0
1
2
3
4
5
Cornwall
Islay
Isle of Man
Wales


Number of SP treatments - cattle
0
1
2
3
4
5
6
7
Cornwall
Islay
Isle of Man
Wales
Number of TCBZ treatments - sheep
0
1
2
3
4
Cornwall
Islay
Isle of Man
Wales