The use of Scottish sheep movements to inform sheep scab control activities: a descriptive analysis

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Summary

We have analysed Scottish sheep movement data to describe when and where sheep, from the isles of Lewis & Harris, are recorded as having moved to in 2021.

We have visually compared these movements with publicly available sheep scab notification data to give a preliminary indication of potential gaps in surveillance and a preliminary assessment of whether the impact of sheep scab control measures, if implemented in the isles of Lewis & Harris, could have a wider geographic effect on the occurrence of sheep scab in the Scottish sheep population.

We present the initial descriptive findings in this report, while we continue with further impact assessments and modelling.

Main points

Approximately 20,000 sheep are recorded as having moved off Lewis & Harris in 2021, in over 3,500 batches. The majority of all moves are non-slaughter moves i.e. to holdings other than slaughterhouses.

Just over a tenth of the sheep moved went to slaughterhouses in the last five months of the year (August to December). Almost all went to Stornoway without passing through a market.

Most sheep movement is to the agricultural region of Grampian (35%), with approximately 19% going to "Highland", 15% across the Western Isles and 15% outside of Scotland.

These moves occur seasonally with more than 80% occurring in August and September.

The most popular markets used are Dingwall and Stornoway.

When maps of the frequency of sheep movements are placed alongside maps of sheep scab notification data, visually most sheep movements from Lewis & Harris are to the Highland, North and North-East of Scotland in the quarterly periods July to September and October to December. Meanwhile sheep scab notifications occur in the North and NE of Scotland in the period January to March.

It is possible that this observation is associated with infested animals being moved from Lewis & Harris at the end of the summer (Aug-Sept) into areas in the North and NE of Scotland, with the disease then manifesting in the autumn/winter, when we start to see increased scab notifications.

If that is the case, then sheep scab control measures implemented in Lewis & Harris could be expected to have an impact on the frequency of occurrence of sheep scab in these areas.

In addition, if the movement of infested animals from Lewis & Harris is a factor in the occurrence of sheep scab, and subsequent notification, in areas of Scotland receiving these sheep then there are apparent 'gaps' in the notification data i.e. an apparent lack of sheep scab notifications from Nairnshire, Moray and Banffshire, and Fife and Dumfries-shire.

Movements of sheep from Lewis & Harris are not the only reason that sheep scab may exist in the sheep in an area and there are multiple factors that may influence and lead to a notification of sheep scab being made, or not.

It should be noted that this is only a preliminary report; the analysis remains 'in progress'. Up to date, more in-depth notifications data has been requested from the Animal and Plant Health Agency (APHA) to facilitate impact assessments and modelling.

It would be useful for the future impact assessments to discuss and identify with Lewis & Harris sheep keepers the types of sheep that are leaving, when and why, as this can not be determined from the sheep movements data.

The current and subsequent analyses will help to identify areas of the country that could be used (via serological screening) to determine the effect of the implementation of targeted control of scab on Lewis & Harris.

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Background and Context.

Sheep scab[1], or psoroptic mange, is an allergic dermatitis caused by infestation with an external mite (*Psoroptes ovis*). Control of this contagious endemic ectoparasitic disease continues to be a significant challenge to the United Kingdom (UK) sheep industry.

In Scotland, sheep scab is a notifiable disease (Sheep Scab (Scotland) Order 2010[2]). This means that there is a legal obligation on any person who has reason to believe that sheep in their possession or care have sheep scab to notify their local Animal & Plant Health Agency (APHA) office as soon as possible.

A blood test has been developed to assist with diagnosis of affected flocks. The use of this blood test has been trialled on a small-scale in some areas in Scotland and is currently being piloted in several geographic 'hotspots' in England. A similar 'hotspot' Scottish pilot has been proposed for the control of sheep scab in Scotland via the use of serological testing to guide targeted treatments on the isles of Lewis & Harris, in the second part of 2022 and in 2023.

The isles of Lewis & Harris have been identified (in a modelling study[3]) as an area where: sheep scab represents a significant issue; notification data demonstrates an increase in the prevalence of sheep scab in recent years[4], and properties with sheep are inter-connected, often with shared common grazing, due to the predominance of crofting systems.

An island-based setting provides a defined geographical area in which to apply control measures. However, sheep move across, within and out of Scotland for a variety of reasons at different times in the sheep production year, both for slaughter and for other management reasons[5].

It is possible - as sheep scab mites can, and do, move with sheep and vehicles - that the implementation of control measures on the isles of Lewis & Harris could
have a wider effect on sheep scab transmission events and the frequency of new infestations seen in other geographic areas of Scotland.

The statutory recording of sheep movements that originate, or terminate, in Scotland[6] is collated by the Scottish Animal Movement Unit. The data are held in ScotEID. Descriptive analyses of these data can be used to provide an empirical understanding of past sheep movements from the isles of Lewis & Harris, which could provide information about potential indirect effects of the proposed sheep scab control pilot project.

We have used the sheep movement data from ScotEID provided to the Scottish Government's Centre of Expertise on Animal Disease Outbreaks (EPIC), where they are managed and curated to sheep movements from the isles of Lewis & Harris, in the context of available Scottish sheep scab notifications data.

[1] Sheep Scab | Moredun
[2] Sheep scab: how to spot and report the disease - gov.scot (www.gov.scot)
[3] Sheep scab transmission: a spatially explicit dynamic metapopulation model (biomedcentral.com)
[4] Spatial and temporal analysis of sheep scab notifications in Scotland, 2014–2019 (wiley.com)
[5] Frontiers | The Use of Sheep Movement Data to Inform Design and Interpretation of Slaughterhouse-Based Surveillance Activities (frontiersin.org)
[6] Sheep and goats - Livestock identification and traceability: guidance - gov.scot (www.gov.scot)

The aim:

The aim, in this report[7], is to describe sheep movements from the isles of Lewis & Harris, and to examine them in the context of Scottish sheep scab notifications data to

- identify areas potentially at high-risk of transmission events, in the absence of a pilot sheep scab control project
- identify any potential gaps in the existing knowledge of disease status

A subsequent aim will be to complete an indicative impact assessment and to identify areas to target either with other impact assessment methodologies, or for surveillance purposes[8].

Data sources:

Two sources of data were used. These were:

1. ScotEID sheep movements data (batch data and individual animal data) for 2021 and the first half of 2022 (January-June, inclusive), as provided to the EPIC4 data repository.

   Please note that one of the limitations of these data are that we cannot reliably distinguish the age of all sheep that are moved.

2. Publicly available sheep scab notifications data[9]

Sheep movement types:

There are several different types of movements that can be identified within the sheep movement data. These are the movements that occur:

1. into a defined area (location) in Scotland, from any other defined area in Scotland
2. out of a defined area in Scotland, to any other defined area in Scotland
3. into a defined area in Scotland, from a location in England & Wales
4. out of a defined area in Scotland, to a location in England & Wales

These categories can be further classified into:

A. moves to slaughter - either direct, or via a market, or

B. all other moves (termed non-slaughter). These can also be direct from one livestock production enterprise to another, or via a market.

Our primary interest is in describing sheep movements **out** of the isles of Lewis & Harris to other locations (Movement types 2 & 4).

In terms of the categories of movements, our primary focus here is on **non-slaughter moves** between livestock production enterprises (holdings) where sheep are kept, as the risk of onwards transmission of the

[7] For EPIC4 Milestone (M) 3.1.8.1
[8] EPIC4 M3.1.8.2 due Dec 2022
[9] https://www.gov.scot/publications/sheep-scab-notifications/

sheep scab mite and subsequent infection and disease occurrence on these destination holdings is likely to be higher than for slaughter moves.

However, we have explored **slaughter moves** in the overall description, as we recognize that there may be potential for indirect transmission (vehicles, shared haulage).

We have looked at the **markets** that are involved as a step in holding-holding journeys, as they play a potential role in transmission events, via animal-animal direct transmission and, possibly, via in-direct transmission (e.g. vehicles, fencing etc).

Both **markets and slaughterhouses** are locations from which a notification of sheep scab can be made. In addition, they could be access points for monitoring, or surveillance, activities.

Results:

Question 1: How many sheep moved out of (i.e. left) Lewis & Harris in 2021?

In 2021, the total number of sheep recorded as having moved out of Lewis & Harris was 19,895, in 3,668 batches.

The majority (88% of animals, 83% of batches) of these sheep movements are non-slaughter movements.

Sheep movements out of Lewis & Harris are seasonal with 83% of sheep (76% of batches) leaving in August and September, 8.2% of sheep (11% of batches) in October and less than 5% of sheep numbers in any other individual month of the year (Figure 1).

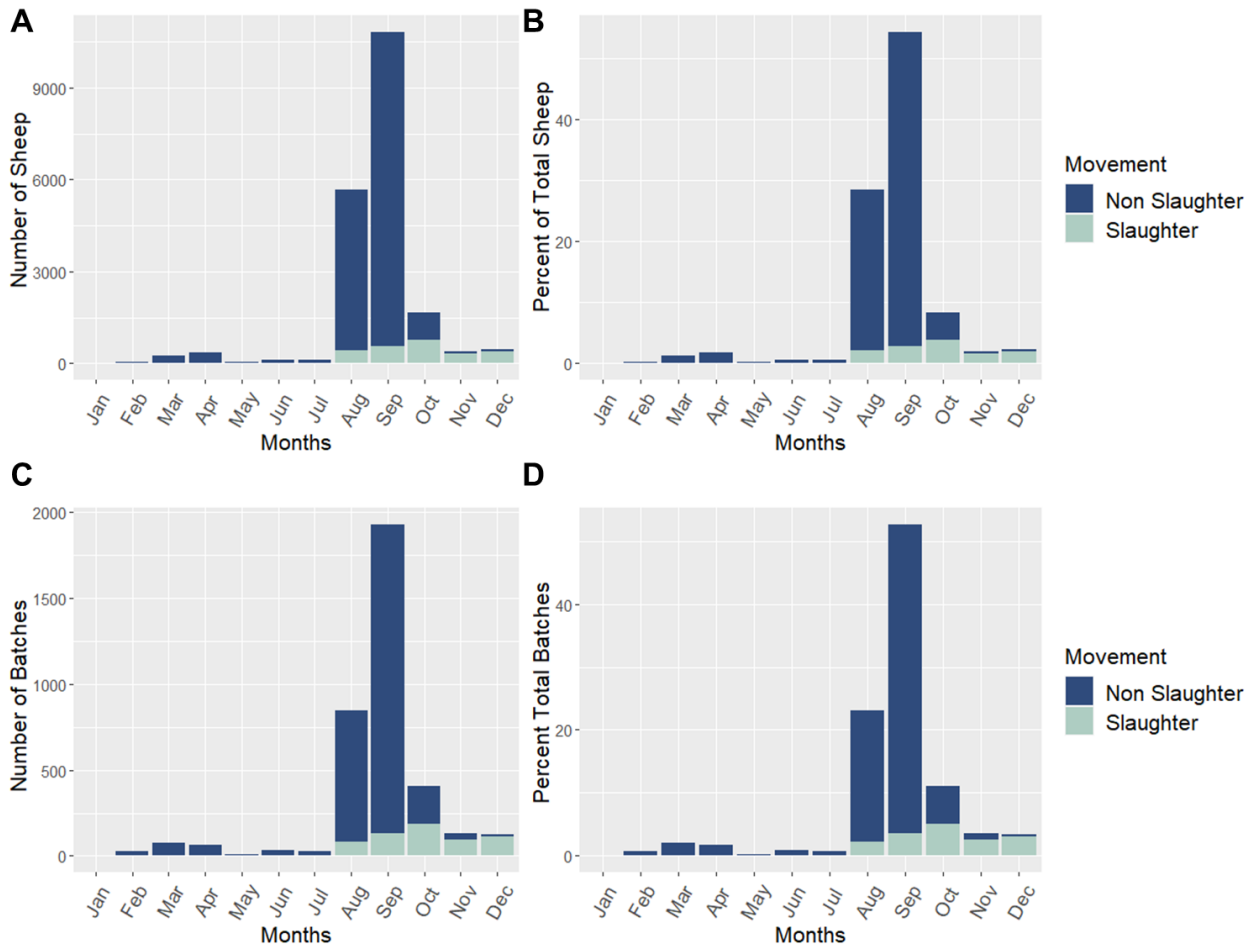

Figure 1 – The numbers and per cent of sheep recorded as having moved from Lewis & Harris in 2021, by month and movement type (non-slaughter/slaughter moves).

(A) Numbers of sheep moved, (B) Percentage of total annual number of sheep moved,

(C) Numbers of Batches moved, (D) Percentage of total annual number of batches moved.

While the movements in August and September are predominantly non-slaughter movements, 47% of October's sheep movements are to slaughter, as are the majority of those in November and December 2021, (82% & 82%, respectively) (Figure 1)

Question 2: How many sheep left Lewis & Harris in the first half of 2022?

The seasonality is reflected in the number of sheep (868) that are recorded as having left Lewis & Harris in the first half of 2022. This is similar numbers to the same period in 2021 (779). However, there are some apparent variations between the two years (Figure 2).

We will explore the August-October 2022 period and formally compare the two periods when the data become available, i.e. for the next milestone[10].

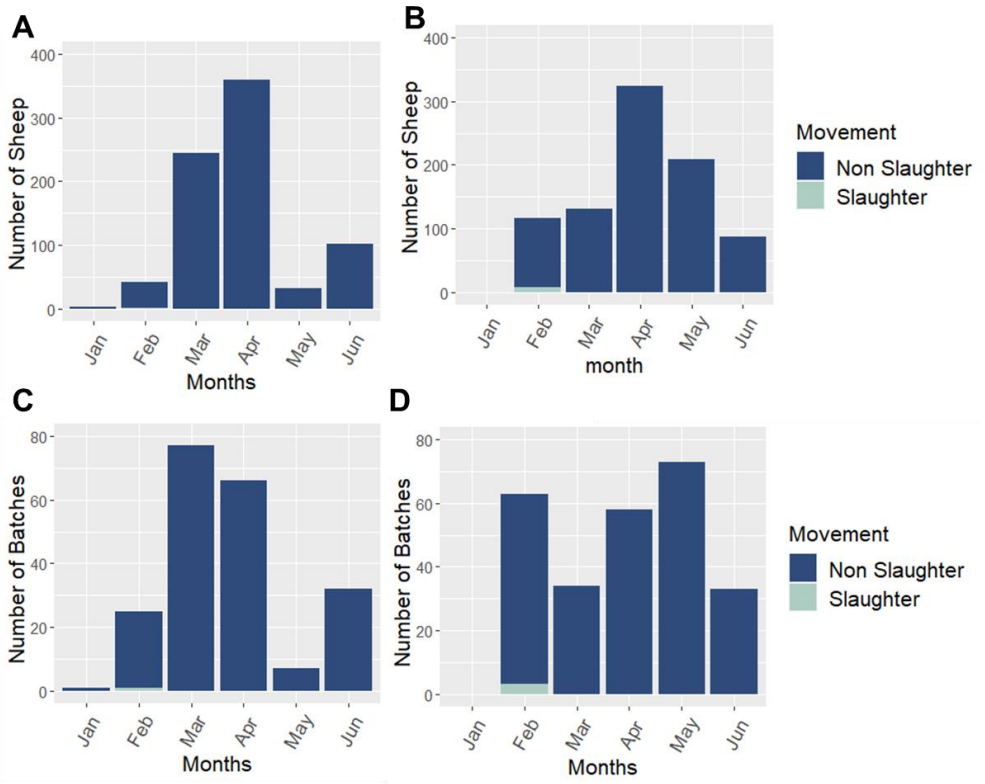

Figure 2 – The numbers of sheep and batches of sheep recorded as having been moved from Lewis & Harris in the first 6 months of 2021 compared to 2022, by month and movement type.

(A) Numbers of sheep 2021, (B) Numbers of sheep 2022,

(C) Numbers of Batches 2021, (D) Numbers of Batches 2022.

[10] EPIC4 M3.1.8.2 due Dec 2022

Question 3: What management types and ages of sheep leave Lewis & Harris?

As previously stated, from the data that are available to EPIC, we cannot reliably distinguish the age, age category (lamb/adult), or type for all the sheep that are moved.

We can distinguish the moves that go direct to slaughter. In 2021, 2453 sheep/ 609 batches went from Lewis & Harris directly to slaughter. Almost all of these were slaughtered in Stornoway (99.9%) in the latter half of the year and did not pass through a market. It could be assumed that these were most likely to be new season lambs. We have explored the possibility of looking at slaughter tags as a classification method; however, these data are not currently available to EPIC.

Previously, in discussions with industry sector representatives, it has been suggested that it might be possible to use batch size to provide an indication of the type of sheep within the batch, and that this could be used as a proxy (Appendix 1: Table A1).

This method has the potential for misclassification and has not been validated. While it may be applicable to general commercial sheep enterprise movements, it is unlikely to apply to the smaller-scale island and crofting enterprises. This would appear to be the case given the frequency distribution of batch sizes recorded in these data as having moved out of Lewis & Harris (Appendix 1: Table A2).

It would be useful for future impact assessments to discuss and identify with Lewis & Harris sheep keepers the types of sheep that are leaving, when and why.

For example:

- to confirm if the August- October non-slaughter moves are predominantly the current season lambs intended for the food chain;

- to identify if, when and why adult sheep are moved off-island (culls/breeding stock etc).

Question 4: Where did the sheep that left Lewis & Harris go to in 2021?

In 2021, the sheep that are recorded as having left Lewis & Harris went to holdings in 19 geographic areas of Great Britain (GB).

These geographic areas included 13 of the 14 Scottish agricultural regions (Appendix 1: Figure A1). The Shetland Isles were the single region that did not receive sheep from Lewis & Harris in 2021.

The sheep recorded as having moved to England & Wales went to six of the Nomenclature of Territorial Units for Statistics[11] 1 areas (NUTS1). The six NUTS1 areas are not individually represented in the figures below; they are combined and represented by the 'Across Border' category.

The most common destinations were (Figure 3):

- Grampian (35%),
- Highland (19%)
- the Western Isles (15%). and
- the 15% that moved out of Scotland across the border to areas of England & Wales.

[11] Eurostat - Office for National Statistics (ons.gov.uk)

We have also used a finer spatial scale (counties; Appendix 1: Figure A2), so that we can compare movements with the publicly available sheep scab notifications data.

The Scottish local authority areas that received more than 5% of the non-slaughter sheep from Lewis & Harris that stayed within Scotland in 2021 were (Question 7, Figure 6):

- Aberdeenshire (28%),
- Ross-shire (21%),
- Banffshire (11%),
- Nairnshire (8%),
- Inverness-shire (8%),
- Caithness (5%), and
- Kincardineshire (5%).

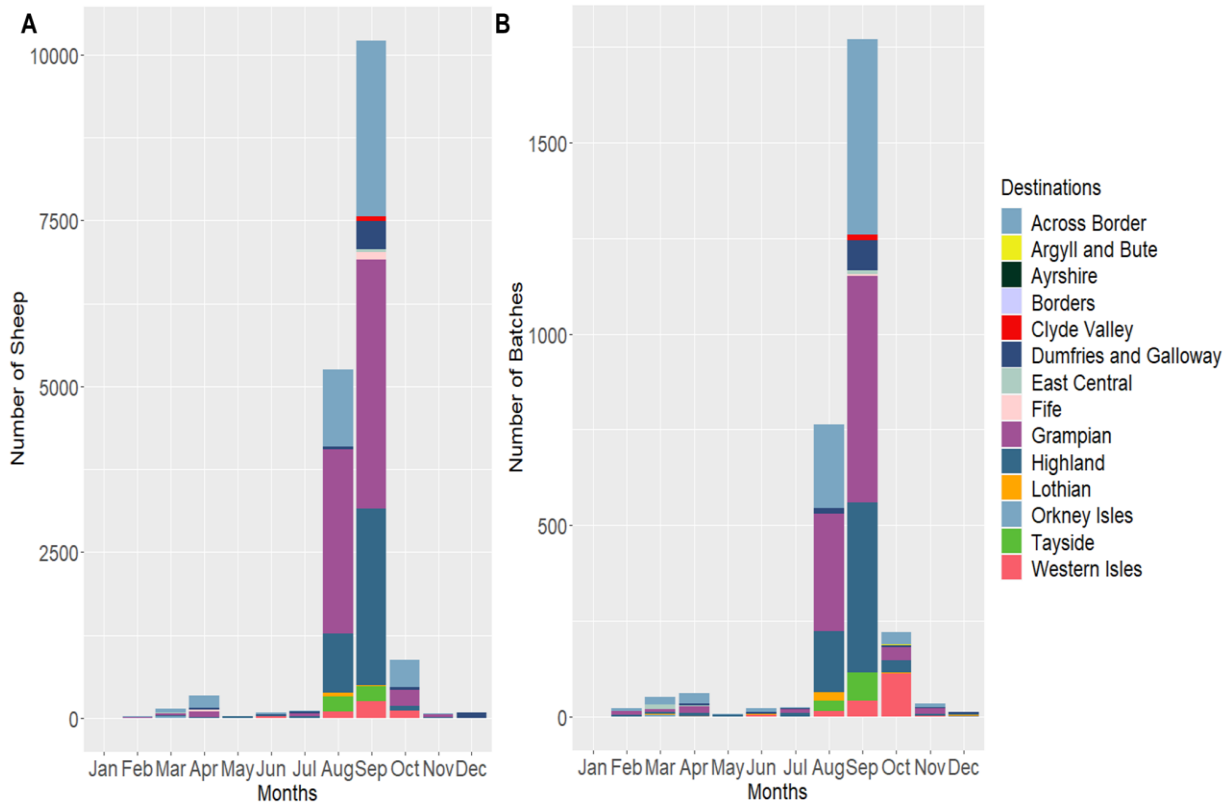

Figure 3 – Non-slaughter moves: the numbers of sheep (A) and batches (B) received from Lewis & Harris in 2021, by month and region.

Question 5: Where do the sheep that left Lewis & Harris go to in 2022?

As with the differences seen between the first half of 2021 and the first half of 2022 in the numbers recorded as having moved monthly from Lewis & Harris, there was some apparent variation in the destinations of these moves (Figure 4).

As before, we will explore this for the August-October 2022 period and formally compare the two periods when the data become available, i.e. for the next milestone[12].

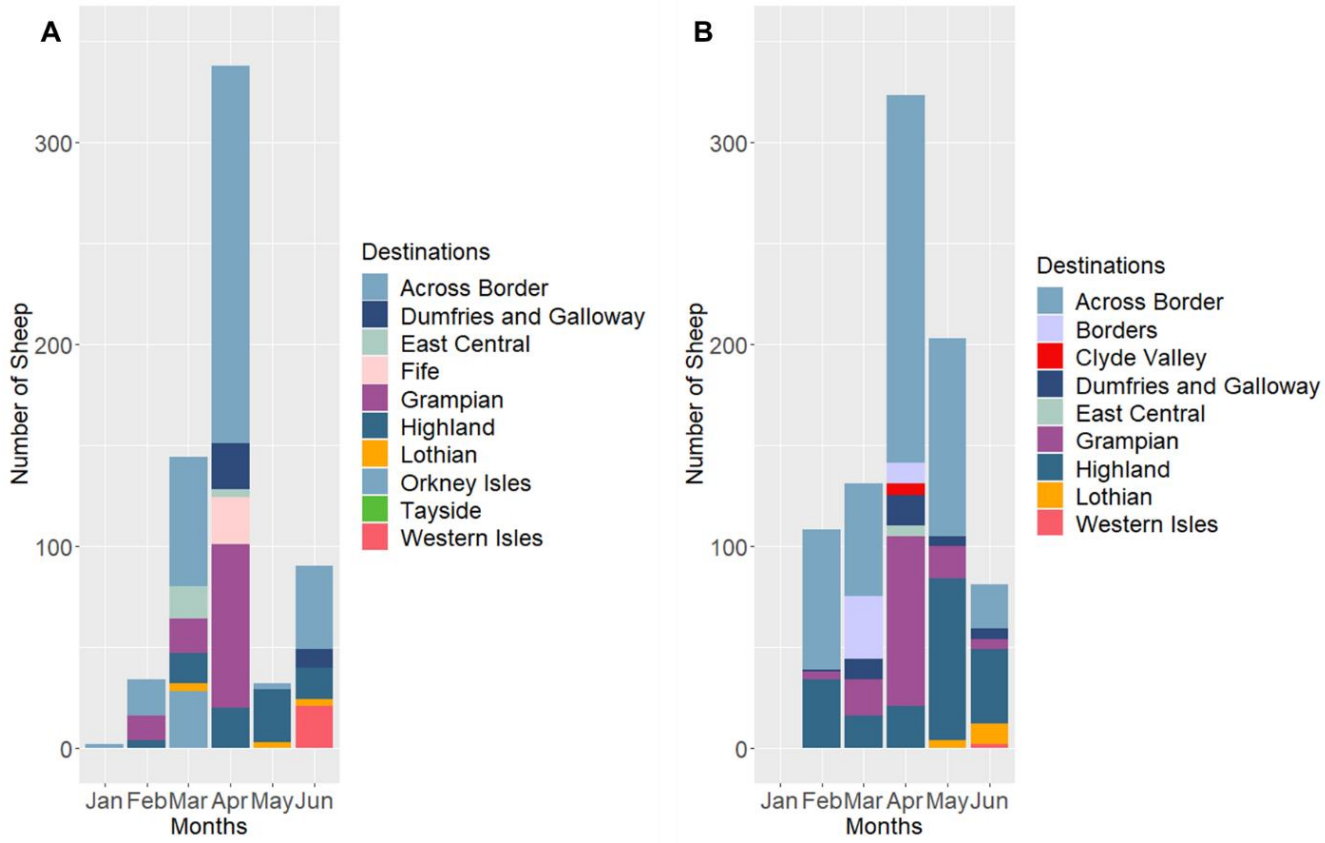

Figure 4 – Non-slaughter moves: the numbers of sheep (A) and batches (B) received from Lewis & Harris in the first half of 2021 (A) and 2022 (B, by month and region.

Question 6: Which markets did sheep recorded as moving from Lewis & Harris pass through in 2021?

The sheep that left Lewis & Harris via a market in 2021 went through one of 10 Scottish markets (Figure 5).

Given the previous finding (Question 3) that almost all the slaughter moves of sheep from Lewis & Harris did not pass through a market, the sheep that move via market are predominantly involved in non-slaughter moves.

[12] EPIC4 M3.1.8.2 due Dec 2022

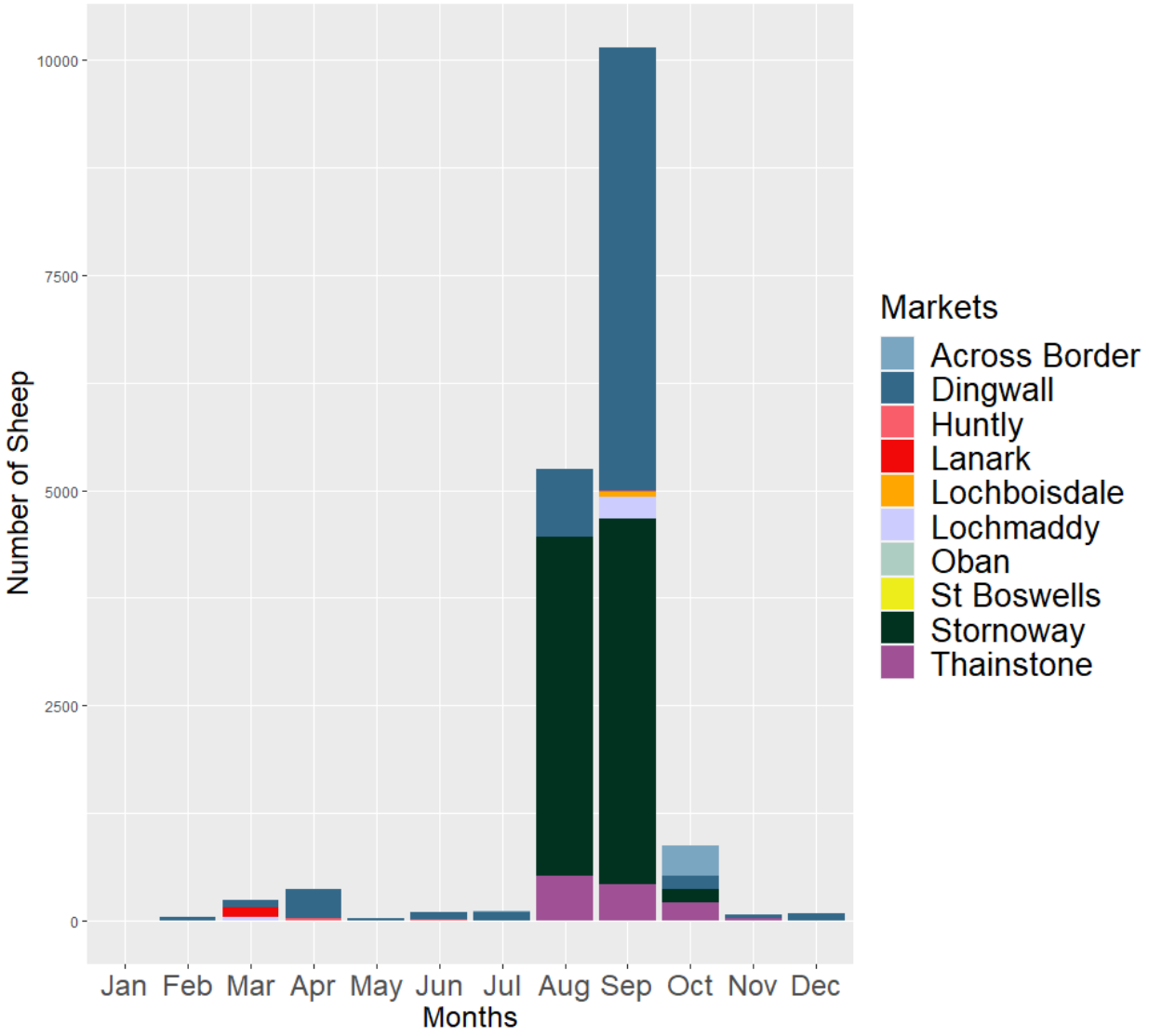

Figure 5 – The number of sheep recorded as moving from Lewis & Harris via a market in 2021, by month and market.

Stornoway market received the highest percentage of sheep (48%, n=8357 sheep / N=17314 total)that passed through a market when leaving Lewis & Harris. In 2021, they were received in three months of the year (August September, October) with the highest number (4255) passing through in September.

Dingwall also received a substantial percentage of the sheep (40%, n = 6902) that passed through a market when leaving Lewis & Harris, predominantly in September but also throughout the year.

Thainstone also featured in the busy late summer and autumn movement period (August - October, 7%, n=1177).

Question 7: How do the sheep scab notifications data compare with the movement of sheep from Lewis & Harris in 2021?

We have looked at this grossly at the spatial scale of Scottish counties for 2021 as a whole year (Figure 6), and by quarter of the calendar year (Figure 7).

The division of the year into quarters is due to the way that the notifications data are categorized. The cut-offs used for categories of time are artificial boundaries and may affect the visual pattern observed.

Movements of sheep from Lewis & Harris are not the only reason that sheep scab may exist in the sheep in an area and there are multiple factors that may influence and lead to a notification of sheep scab being made, or not.

Extreme care must therefore be made in when interpreting and attempting to draw conclusions from Figures 6 & 7.

We will be doing a more formal assessment of the relationship between sheep movements and Lewis & Harris and Scottish sheep scab notifications data as part of impact assessments in the next milestone[13] and the modelling milestone[14].

However, from a visual comparison of Figure 6 A & B, gaps of immediate interest for further exploration, in the context of the reporting of sheep scab and actions taken to control infection and disease are:

1. Given the numbers of Lewis & Harris sheep recorded as moving to these areas and the notification experience of neighbouring counties, there is an apparent dearth of sheep scab notifications in 2021 from
    a. Nairnshire, Moray and Banffshire, and
    b. Fife and Dumfries-shire.

2. If surveillance is to be targeted to assess the wider impact of control measures implemented in Lewis & Harris, then - depending on the surveillance question and subsequent design - it could be hypothesized that areas to target might be those that both receive most sheep from Lewis & Harris and currently have a high number of notifications e.g. Caithness, Inverness-shire, Aberdeenshire & Perthshire.

However, depending on timing it could then be difficult to tease out the effects of the implementation of control measures on Lewis & Harris from that of the implementation of the surveillance activities.

[13] EPIC4 M3.1.8.2 due Dec 2022
[14] EPIC4 M2.4.1.4

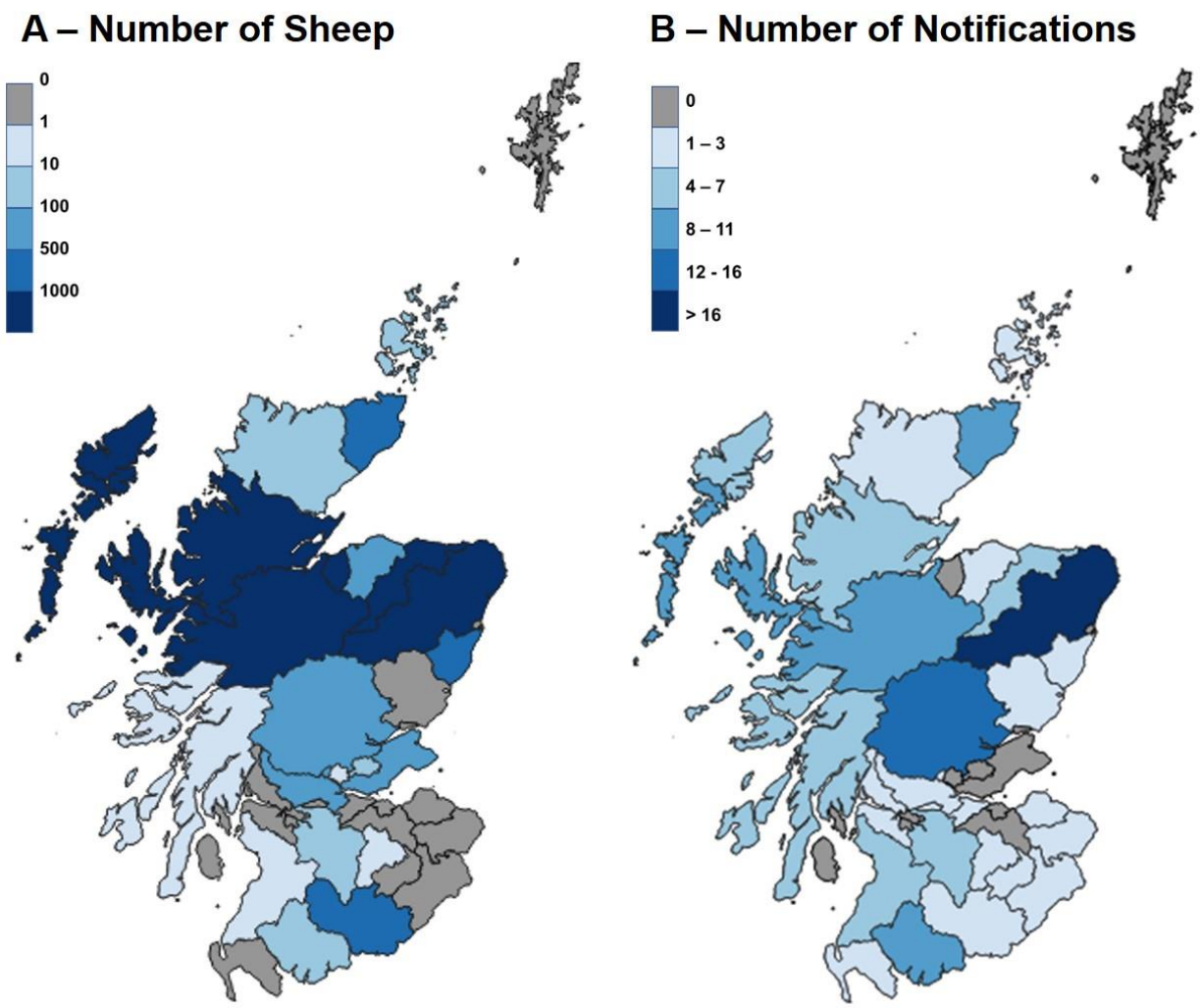

Figure 6 – For 2021, by Scottish counties, (A) the number of non-slaughter sheep recorded as moving from Lewis & Harris to a county and (B) the number of premises with a confirmed sheep scab notification.

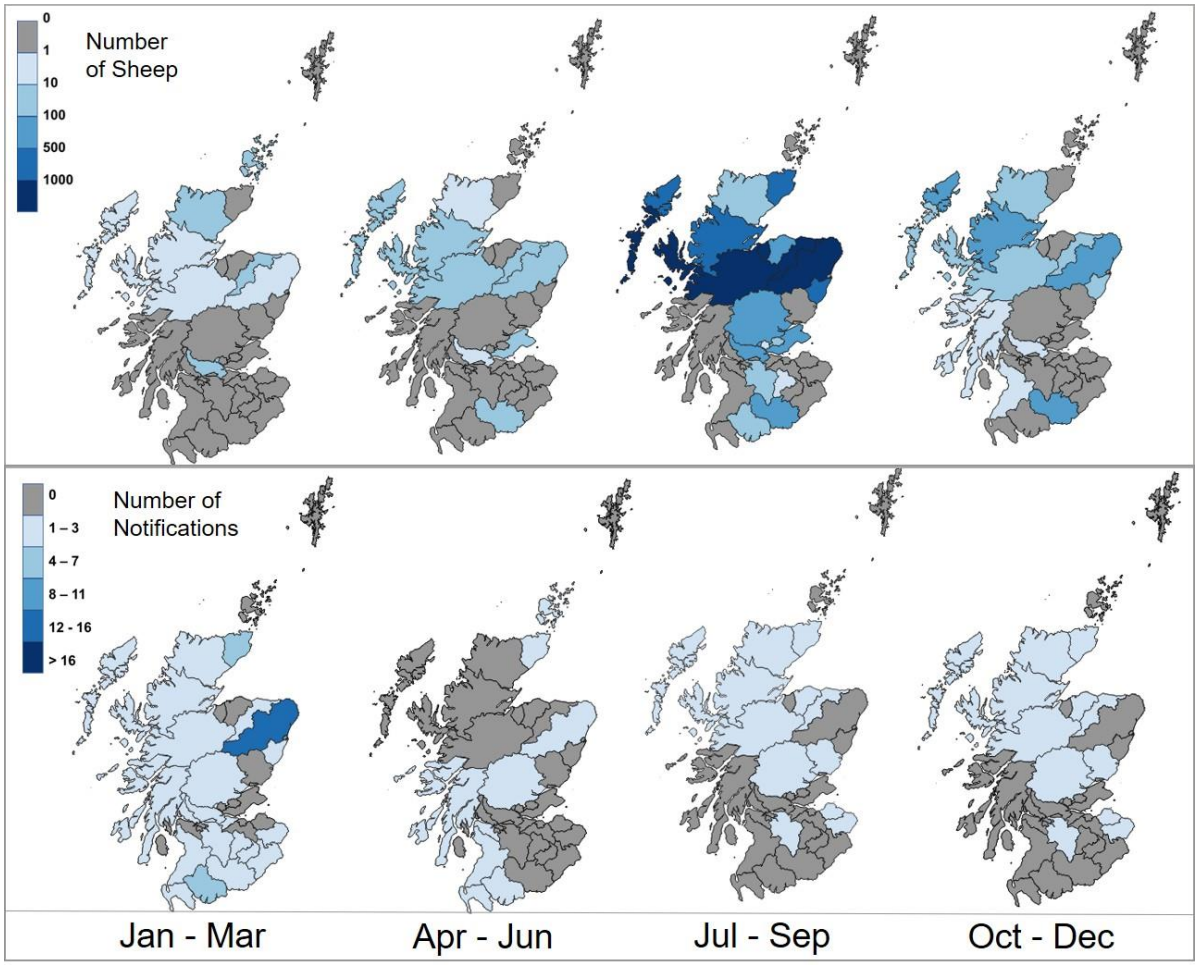

Figure 7 – For 2021, by Scottish counties, and quarter (Top panel) the number of non-slaughter sheep recorded as moving from Lewis & Harris to a county that quarter and (Bottom panel) the number of premises with a confirmed sheep scab notification in that quarter.

The numbers of sheep scab notifications are low when stratified by county and so there are even smaller numbers when looked at on a per quarter basis (Figure 7). Even so, from a visual comparison of the two panels in Figure 7 it appears that there may be a potential lag between the quarters (Q3 & 4, Jul-Sep & Oct-Dec) when sheep are recorded as arriving from Lewis & Harris and an apparent increase in sheep scab notifications in a county.

To further explore this apparent lag effect, we will need to look at the sheep movements from Q3 & 4 of 2020 to compare with the Q1 (Jan-Mar) 2021 notifications data, and when available the Q1 & Q2 2022 sheep notifications data 2022, to compare with the Q3 & 4 sheep movements data of 2021.

APPENDIX 1

Table A1: A proposed allocation of the type of sheep in a batch, based on sheep numbers in the batch.

Numbers of sheep in a batch	Proposed likely type of sheep in
<=2	Rams
3 - 13	Rams and Ewes
14 - 61	Gimmers
62 - 1066	Fattening

Table A2: Frequency distribution of batch sizes of sheep recorded as having moved off Lewis & Harris in 2021 and the first half of 2022, by month and movement type.

	Non-Slaughter				Slaughter			
Batch Sizes	***1***	***2 - 3***	***4 - 7***	***> 7***	***1***	***2 - 3***	***4 - 7***	***> 7***
2021								
Jan	0	1	0	0	0	0	0	0
Feb	16	5	3	0	1	0	0	0
Mar	3	13	5	5	4	11	5	4
Apr	12	18	23	13	0	0	0	0
May	3	2	1	1	0	0	0	0
Jun	15	7	6	4	0	0	0	0
Jul	7	7	6	5	0	0	0	0
Aug	151	183	197	231	12	29	22	2
Sep	431	46	496	413	13	57	46	16
Oct	179	7	14	2	22	67	72	24
Nov	14	15	4	0	25	36	29	6
Dec	5	3	0	4	23	5	32	7
2022								
Jan	0	0	0	0	0	0	0	0
Feb	33	19	8	0	0	3	0	0
Mar	13	12	4	5	0	0	0	0
Apr	14	12	19	13	0	0	0	0
May	27	35	6	5	0	0	0	0
Jun	19	7	5	2	0	0	0	0

Figure A1; Key to the Scottish agricultural regions used in Figure 3 and 4

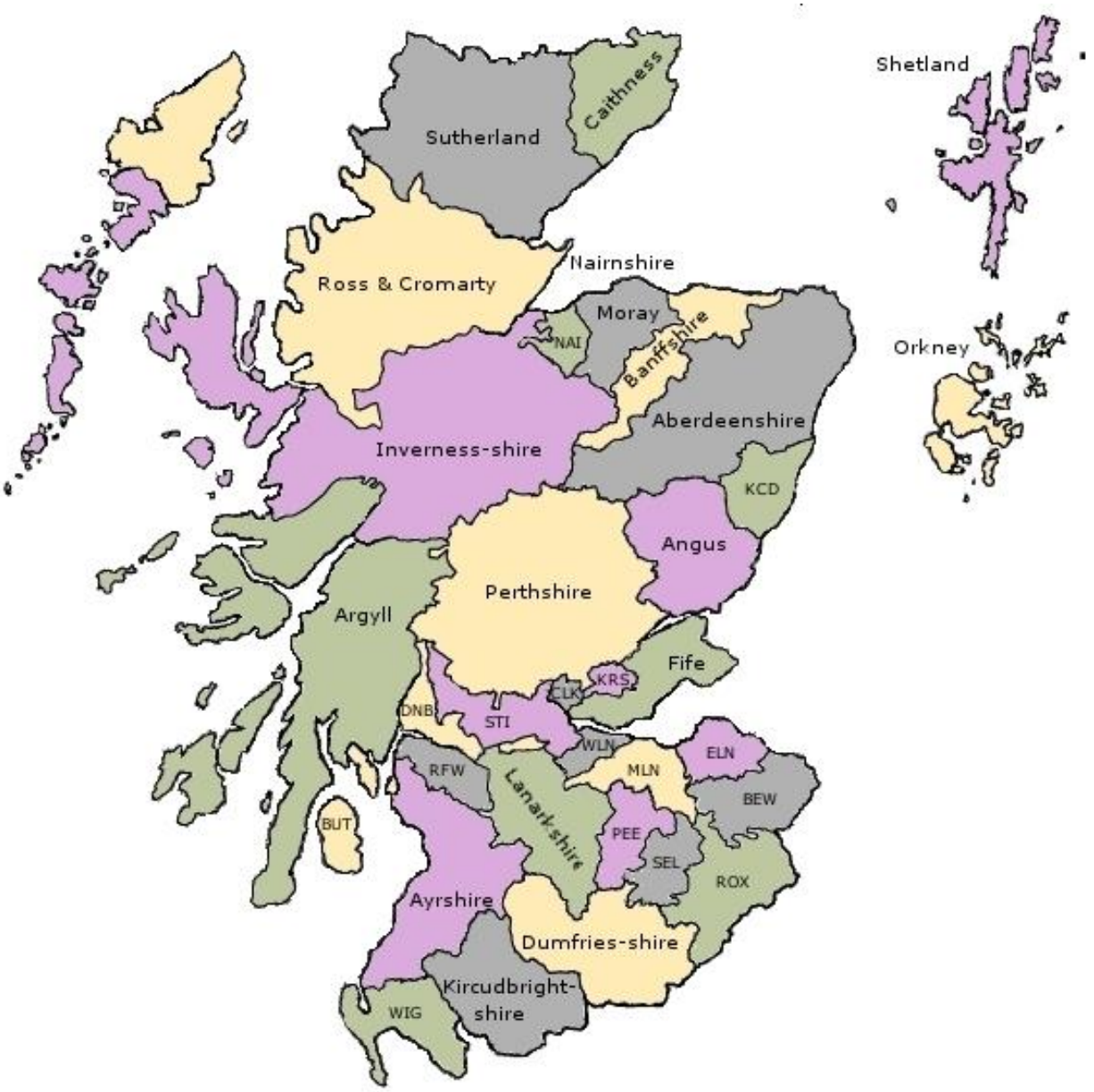

Figure A2: Key to the Scottish counties – boundaries and names - used for Figures 6 & 7