Scotland's Census
Shaping our future
A' dealbhadh ar n-àm ri teachd

Scotland's Census 2022

Estimation Areas - Geographical grouping for stratification of population estimates

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National Records of Scotland

Contents

1. Plain English Summary

National Records of Scotland counts Scotland's population using the Census. To make sure that the count is correct, we must correct for people who do not respond or respond more than once. We achieve this through a process called Dual System Estimation (DSE). We must carry out DSE on people with similar response levels to get the population counts right. To do this we run DSE on areas of Scotland where we think people are equally likely to respond. This paper looks at how we decide these groups, called estimation areas (EA).

In 2011 we used groups of Local Authorities that are next to each other as estimation areas (EA). These worked well. However, there were some problems when our groups included LAs where different numbers of people responded.

Some of the ways we work have changed since the last Census, which makes EA groupings less important. We have ways of making people in different areas respond in similar ways. We also don't need to use the EA groups for other parts of our processing. However, we recommend that area based EA groups should be used for DSE. Dividing up the country like this will make it easier for us to make people in the groups respond the same way. The EAs groups we use in 2022 should made up of Local Authorities (LAs) and we should group LAs which are we think will respond the same based on their features. The LAs making up estimation areas do not have to be next to each other.

We also recommend that the EAs should be reviewed before DSE once we have all the returns. We can regroup the EAs at that point if the people in the LAs making up EAs do not respond in a similar way.

We considered four different EA groupings methods in this paper. Two of the groupings were made manually, while two semi-automatically using a computer program. One of the automatic approaches has seven groups and the rest have eight. Based on analysis, the automatic grouping with seven EA groups is the best approach. Since the Census is now scheduled for 2022, this chosen method should be re-run with the final Hard to Count and geographies data in 2021 to determine the EA groupings for 2022.

Note: On 17 July 2020 Scottish Government announced the decision to move Scotland's Census to 2022 following the impact of the COVID-19 pandemic.

2. Executive Summary

Scotland's population is assessed, accounting for people who are missed or counted more than once in the Census, using Dual System Estimation (DSE). This method requires that the population it is run on is homogenous; otherwise, there will be additional error in the estimates and bias in the lower level estimates for the Local Authorities (LAs) that make up the population. To make this more likely, DSE is run on geographical strata, which should encompass regions with similar response rate. This paper looks at how these geographic strata, called estimation areas (EA), should be decided on.

In 2011, geographically contiguous groupings, based on groups of LAs, were used as estimation areas (EA). While these were reasonably effective, there were issues in some EAs with the LAs underlying them having differing response rates (for example, the grouping of Aberdeen with Aberdeenshire and Shetland).

The EA groupings were reviewed in 2017 and a recommendation made to regroup the EAs using non-contiguous LAs to pair those that are expected to be similar in terms of response. A proposed grouping was put forward, with a recommendation to re-evaluate this when more details of the 2022 Census method and geography is known. The purpose of this paper is to carry this out re-evaluation.

EAs are now less necessary due to response rate equalisation and the absence of batching in downstream processing. However, the recommendation is to continue to use geographical EA groups as strata for DSE. Stratifying in this way should reduce the heterogeneity of response rates in the estimation strata during Census through response rate equalisation. The EAs in 2022 should be based on Local Authorities

(LAs) grouped based on the similarity of demographics related to the expected response rate. The LAs making up estimation areas will not necessarily be geographically contiguous.

It is also recommended that, after collection, return rates are examined and the levels of heterogeneity assessed. If there is a large amount of within EA heterogeneity, then post-stratification should be considered, regrouping LAs into more homogenous strata.

Four different EA grouping methods were evaluated. Three of these judged the similarity of the EAs by comparison of the Hard to Count (HtC) score, while the fourth, proposed in the 2017 review, used the HtC index. Two are based on cluster analysis while the other two utilise a manual approach. The evaluation indicates that one of the cluster analysis based groupings, with seven EA groups, is the most advantageous. With the Census now moved to 2022, the recommendation is that this is re-run with the new HtC and geographies in 2022.

3. Introduction

Scotland's Census aims to gather information from everyone in Scotland. However, it is possible that some people will be missed from the Census or their information will be collected more than once. Dual System Estimation (DSE)[1] is the process that is used to account for people who are missed or counted more than once in the population totals. This allows the final population estimates for Scotland to be as accurate and reliable as possible. DSE is not run on the whole country in one go. Instead the country is stratified into estimation areas before this process is run.

3.1 Overview of EA Groups

Estimation area (EA) groupings serve two purposes: to increase the speed of processing by creating more manageable dataset sizes; and, importantly, to

[1] More information on DSE can be found in the Estimation and Adjustment methodology paper https://www.scotlandscensus.gov.uk/documents/Scotlands%20Census%202021%20-%20SMDP%20-%20Estimation%20and%20Adjustment%20Methodology%20paper%20(pdf).pdf

decrease the risk of heterogeneity errors in our estimates by estimating the level of undercount for smaller areas with similar levels of non-response. In 2022 changes to collection methodologies make batching of data for processing less necessary, but there remains a need to conduct DSE on estimation areas with homogenous response rates.

Estimates are conducted on EA subgroups made by combining each EA with the 5 Hard to Count strata (HtC)[2]. To increase the homogenous response rates within each EA subgroup, non-response follow up for the Census will be prioritised to areas which deviate furthest from the EA subgroup mean response rate.

3.2 Purpose of Document

This paper aims to re-evaluate the EA groupings with the finalised HtC/ planning area definitions and in the light of changes to Census collection and downstream processing. Consistent with the findings of the 2017 review, EA grouping is carried out based on grouping together existing Local Authorities (LAs). The method of manual grouping is refreshed based on up to date information and evaluated alongside the original 2017 proposal and two groupings using clustering algorithms to obtain groupings of similar LAs.

4. Summary of Methodology used in 2011

4.1 The 2011 EA groupings

4.1.1 How the data was grouped

During all stages in 2011, from capture to output preparation, data was grouped into the same ten Estimation Areas, also known as Processing Units. Each EA contained one or more LAs (see Table 1) with approximately equal estimated populations in each EA - around 500,000. Where possible, each EA contained geographically adjacent LAs, although one exception was made to allow for practical issues

[2] More information on HtC can be found in the Developing a Hard-to-count Index paper https://www.scotlandscensus.gov.uk/external-methodology-assurance-panels-emaps-0

associated with data collection (Shetland was grouped with Aberdeen). Contiguous groups were also used in 2001 (see Table 2) although these differed from those used in 2011. Maps showing the geographical distribution of processing groups for 2011 and 2001 can be found in Appendix B.

While the need for homogeneity for optimal estimation processing was acknowledged, the design of processing groups for 2011 focussed more on contiguity than homogeneity as it was felt to be the most appropriate approach to meet upstream and early downstream requirements. It was suggested that functionality could be provided within the data processing system to allow regrouping of EA in order to better meet the balance between contiguity and homogeneity. In particular it was noted that the most likely areas that would need revision for the purpose of homogeneity would be the divorcing of Dundee and Aberdeen from their surrounding areas. However, no changes to the EA were made during live 2011 processing.

4.1.2 Issues in 2011

LAs were grouped together to meet the needs of field operations and to obtain approximately equal numbers across all EAs. Review and analysis of Census 2011 suggests that these groupings potentially did not best meet the needs of the estimation process, particularly where LAs with markedly different demographics were grouped together. For example Aberdeen, Aberdeenshire and Shetland in EA I.

This issue was evident during estimation and adjustment; however no major issues relating to how the LAs had been grouped were reported during other parts of census processing.

Table 1: EA in 2011

EA	Council Area	Estimated % of total population
A	Scottish Borders, East Lothian, South Lanarkshire	10.0
B	Dumfries & Galloway, East Ayrshire, North Ayrshire, South Ayrshire	9.9
C	Edinburgh, Midlothian	10.6
D	North Lanarkshire, West Lothian	9.7
E	Clackmannanshire, Falkirk, Fife	10.8
F	Glasgow	11.2
G	West Dunbartonshire, East Dunbartonshire, East Renfrewshire, Inverclyde, Renfrewshire	10.2
H	Angus, Dundee, Perth & Kinross, Stirling	9.4
I	Aberdeen, Aberdeenshire, Shetland	9.4
J	Argyll & Bute, Highland, Moray, Orkney, Na h-Eileanan An Iar	8.7

Table 2: EA in 2001

EA	Council Area	Estimated % of total population
1	Dumfries & Galloway, North Ayrshire, South Ayrshire, East Ayrshire, Scottish Borders	12.3
2	East Lothian, Midlothian, Edinburgh, West Lothian	15.1
3	Falkirk, Stirling, Clackmannanshire, Fife	12.2
4	Aberdeen, Aberdeenshire, Moray	10.3
5	Dundee, Angus, Perth & Kinross, Highlands, Orkney, Shetland, Na h-Eileanan An Iar	13.1
6	South Lanarkshire, North Lanarkshire	12.4
7	Glasgow, East Renfrewshire, East Dunbartonshire, West Dunbartonshire	17.8
8	Inverclyde, Renfrewshire, Argyll & Bute	6.9

4.2 2017 Review

Due to these issues there was a review of estimation areas in 2017. It found that while 2011 EAs had been beneficial, there was room for improvement.

4.2.1 Findings regarding the 2011 groupings

The EAs used in the previous census worked well in terms of allowing processing to progress in batches and the size of each EA was manageable. Processing complete LAs together allowed statistical quality assurance (SQA) to be undertaken with minimal reworking of the comparator sources and effectively utilized existing staff knowledge of the council area.

However, the diversity of the response level within the EA had a noticeable impact on production of the estimates both in terms of the accuracy of the estimates and in the width of the confidence intervals around those estimates. Response levels varied considerably over age groups, tenure and data zone as well as across other sub groupings. Therefore, there is a need to consider alternative groupings which minimise the heterogeneity of response rates within the EA as part of the process of ensuring the best possible estimates are produced.

4.2.2 Options reviewed

The 2017 review examined three main options for grouping EAs in 2021: the 2011 groupings, new, non-contiguous groupings of LAs, and groupings based purely on the demographics of the planning areas.

The advantage of grouping by council area is that it would minimise the additional work required to enable effective SQA. However, these groupings would not need to be the same as those used for 2011. Instead, the 2017 review suggested a better approach would be to group together LAs with similar demographics and therefore similar expected levels of response. The proposed grouping used hard to count (HtC) levels generated for 2011 and splits LAs according to the percentage of their data zones at each HtC level.

Another option considered was forming EA groups on the basis of the demographics of the population. Data zones were used as a basic unit of geography and then grouped depending on demographics in a similar way to the generation of HtC levels.

4.2.3 Conclusions and Recommendations

The 2017 review recommended grouping LAs together based on similarity of demographics/ expected response rate, using the percentage of data zones at each Hard to Count level to achieve this. Eight groupings were proposed, rather than ten which were used for the 2011 census. The review recommended that these groupings should be reviewed once the final Hard to Count (HtC) levels had been generated and the distribution of data zones across the levels in each council area had been reviewed.

5. Proposal for 2022 Methodology

5.1 Changes to Data processing and the Census

There have been a number of changes to the planned approach for the 2022 Census since both 2011 and the 2017 review that are important for the chosen EA groups. These can broadly be grouped into changes to Census collection and changes to downstream processing.

5.1.1 Changes to Census Collection

The first major change to Census collection is the move to digital first. This should mean that the majority of returns are via the digital capture channel. This will reduce the capture and coding lead times meaning that processing will start on return data earlier. In addition there is no batching of returns by suppliers as in 2011, instead the data will be provided in a constant drip feed as soon as it is available.

There have also been changes to the prioritisation of follow-up enumeration methodology for field force. An algorithm will be used to equalise response rates across EA-HtC subgroups by prioritising follow up to the Planning Area (PA) with the response rate furthest from the subgroup mean. This should increase the homogeneity within EAs significantly.

Finally, the low level geography used by Census collection and the Census Coverage Survey (CCS)[3] has changed from data zones to planning areas since the 2017 review. This further reinforces the need to update the EA groupings recommended in the review with the final PA-HtC definitions.

[3] More information on the CCS sample methodology can be found in the CCS Sample Methodology and the CCS Sample Allocation and Reserve Sample papers https://www.scotlandscensus.gov.uk/external-methodology-assurance-panels-emaps-0

5.1.2 Changes to downstream processing

Due to the availability of quickly available, drip-fed, returns, cleansing in the 2022 Census will operate with a more on demand approach. Cleansing processes will be run regularly as data comes in, rather than on large batches of data at once. Some processes, such as Resolve Multiple Responses (RMR), require all returns in that area to be present in order to be finalised. In this case, processing will be run iteratively until a complete dataset is available, allowing clerical checks to be spread over a larger time period.

There are also changes to the way Edit and Imputation (E&I) is conducted. More computational resources mean that E&I can be conducted on larger data sets. At the same time it seems likely that conducting E&I on several batches will increase QA times as the same checks would need to be replicated on each batch. Finally, E&I works best on geographically close areas, as imputation from distant records can cause issues. Given that current plans are to have non-contiguous EA groups, these would not make optimal batches for E&I. For these reasons E&I will be conducted on the whole population together rather than in batches.

5.2 Proposal

The proposal is to stratify the estimates by geographical area, called Estimation Areas (EA). Stratifying in this way should reduce heterogeneity of response rates in the groups that estimates are created for, reducing bias and error. The EAs in 2022 should be made up of LAs grouped together based on similarity of demographics related to expected response rate. The LAs making up an estimation area will not necessarily be geographically contiguous.

In addition, it is recommended that after collection, return rates are examined and the levels of heterogeneity assessed. If there is a large amount of within EA heterogeneity then post stratification should be considered, regrouping LAs into more homogenous strata.

Four different EA groupings were evaluated (below) based on their likely within group variability, likely level of collapsing of strata and size. All three judge similarity of the EAs by the comparison of Hard to Count (HtC) score[4]. Two are based on cluster analysis while another utilises a manual approach:

1. 2017 Proposal – Highest variation across the EA-HtC groups, high levels of collapsing. Relatively equal grouping in terms of number of households.
2. Manual approach – This produced a fairly equal division of the household population and a lower variation that the 2017 proposal.
3. Cluster analysis algorithm with eight groups – This approach has less risk of collapsing (particularly HtC 3) compared to the manual approach. It also produced groupings with the lowest variation in HtC score. The grouping by similarity of the whole HtC score range, rather than on the basis of one HtC index group and a time, might also reduce the heterogeneity - for example if areas that neighbour other HtC index areas respond differently to those who do not.
4. Cluster analysis algorithm with seven groups – This grouping also has less risk of HtC collapsing (again HtC 3) than the manual approach, and lower collapsing risk than the eight group cluster analysis. It also has less risk of collapsing non-white groups in island LAs as they are grouped with other LAs. As with (3) it benefits from grouping by similarity of the whole HtC score range. It also has a fairly equal division of the household population.

Based on this evaluation the seven group algorithm (number 4) was chosen as the most optimal grouping. This algorithm should be re-run on the final HtC index and geographies in 2021 to produce the final grouping.

6. EA grouping method

6.1 Considerations around Grouping Approach

[4] The HtC score is based on a number of demographic features of areas and is intended to predict response rates.

The changes to Census processing have a number of consequences for the creation of EA groups. The move away from batching means that EA groups are solely for the purpose of estimation, rather than serving a purpose for consistent end to end batching through processing. This means that the restrictions on EA groupings are reduced.

As the response equalisation algorithm used during collection aims to remove the issue of response rate heterogeneity, one possibility is to not use any EA groups and simply use the five HtC index areas as strata. This would, however, be very optimistic about the extent to which the algorithm will be able to equalise response across distant geographic areas, particularly given that it was not tested in the Census 2019 rehearsal. Also, using large EA areas might make the process more difficult, as the range of field workers would increase.

Another possibility would be to treat the whole country as one area for the response rate equalisation mechanism, but once collection is finished, post stratify by the response rates that are observed (from return rates). This would mean EA groups could be chosen based on a much better metric to reduce heterogeneity than using HtC composition or some other demographic feature as a proxy. However, this would still have the previously mentioned issue of hindering the equalisation mechanism. It therefore is better to select EA groups in advance that are likely to have similar response rates, then post stratify these groups for Estimation if necessary.

A final possibility is to not use LAs as the basis for EA groupings, instead grouping planning areas according to their demographics. This option was rejected in the past as LAs are useful for SQA, which is still the case. Any groupings would also likely be very similar to HtC index groups, as this is attempting to do a similar thing (group planning areas by likely response rate). In addition, such groupings might cause complications for the response rate equalisation algorithm which is set up under the assumption of LA groups.

A number of approaches have been considered for grouping EAs out of LAs. As a baseline there are the 2017 proposed groupings. These could be improved by, instead of using their breakdown into HtC index groups by proportion, instead making use of the raw HtC score underlying this which would add granularity. The process of finding LAs that are similar across a wide range of scores is complex and there are a huge number of possible combinations, therefore the use of a clustering algorithm may provide a better approach to finding the optimal combination.

6.2 Proposed 2017 method

The three island LAs where grouped together as they have very similar HtC distributions and are likely to share similar factors affecting response rate. The remaining 29 LAs were split based on the proportions of data zones within the council area at each HtC level. As the four cities have a very high proportion (>5%) of the hardest to count HtC (5), they should be in separate EAs. They were split into two separate EAs to manage the size. Glasgow, as the largest, on its own and the other three together.

After this, the easiest to count (HtC1) LAs were put into a group. A minimum of 60% in HtC 1 was selected as the criteria for this group. The remaining 20 LAs were then ranked according to the percentage of data zones in the two easiest to count categories (HtC 1 and 2). Determining where to split these was a bit more subjective - for example East Lothian could have been the last council area in EA 6 or the first in EA 7. The final suggested groupings were made taking into account estimated population sizes and trying to have a reasonably even split of the population across EA.

Table 3: 2017 EA proposal

EA	Council Area	Estimated % of household population
1	Na h-Eileanan An Iar, Orkney Islands, Shetland Islands	1.36%
2	Glasgow	12.04%
3	Aberdeen City, Dundee City, City of Edinburgh	16.67%
4	Fife, Inverclyde, North Ayrshire, Renfrewshire, Stirling	15.99%
5	Falkirk, North Lanarkshire, Perth and Kinross, South Lanarkshire	17.65%
6	Angus, Argyll and Bute, East Lothian, Highland, Scottish Borders, West Dunbartonshire	13.97%
7	Clackmannanshire, East Ayrshire, East Dunbartonshire, East Renfrewshire, South Ayrshire, West Lothian	11.89%
8	Aberdeenshire, Dumfries and Galloway, Midlothian, Moray	10.44%

6.3 Manual EA grouping method

Use of the HtC score allows a more fine grained way of comparing LA-HtC index subgroups. This was used to supplement the 2017 method. Firstly, the island LAs, Glasgow, and the three cities (as the next three areas with the highest proportion of HtC 5), were grouped. The remaining LAs were divided in to two based on whether HtC 1 and 2 planning areas made up greater than or less than a 95% proportion of them. Those with proportion less than 95% were ordered by average HtC 2 score, dividing them in to groups of around 300,000 households. Those with a proportion higher than 95% were grouped using the average HtC 1 score instead, to similarly break them up in to groups.

Table 4: EA derived from manual approach

EA	Council Area	Estimated % of household population
1	Na h-Eileanan an Iar, Orkney Islands, Shetland Islands	1.36%
2	Glasgow	12.04%
3	Aberdeen City, Dundee City, City of Edinburgh	16.67%
4	Aberdeenshire, Argyll and Bute, East Lothian, Highland, Scottish Borders	14.43%
5	Dumfries and Galloway, East Dunbartonshire, Midlothian, Moray	7.86%
6	East Renfrewshire, North Ayrshire, South Lanarkshire, West Lothian	13.16%
7	Clackmannanshire, East Ayrshire, Falkirk, North Lanarkshire, Perth and Kinross, South Ayrshire	17.17%
8	Angus, Fife, Inverclyde, Renfrewshire, Stirling, West Dunbartonshire	17.31%

6.4 Cluster analysis

An alternative method to a manual approach is to use a machine learning cluster algorithm to quickly create optimal groupings. The first step is to define a feature to maximise. The best approach to achieve groups with similar numbers of planning areas across the whole HtC range is to maximise similarity of the HtC score distribution. To do this, a density profile was estimated and numerically integrated over. Intersections of each LA's HtC score distributions were calculated as proportions – a score of 1 indicates a perfect overlap, zero indicated no overlap. With this method we have a score for how similar two LAs are by how much overlap there is in their HTC score profiles. Figure 1 illustrates this with a density plot of Aberdeen City and West Dunbartonshire, showing the proportion of overlap.

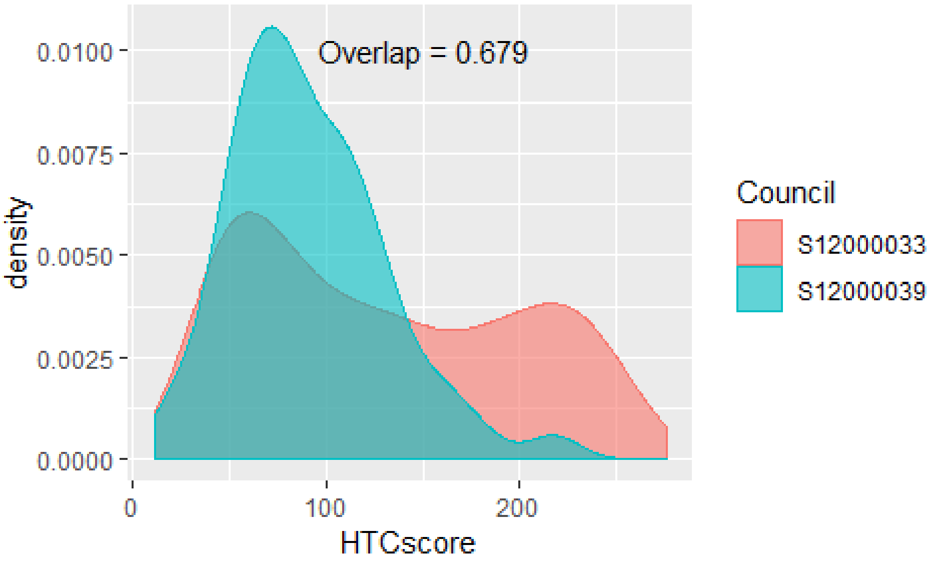


Figure 1: Density distribution of Aberdeen City compared to West Dunbartonshire

The best suited clustering methods for this format of data is a hierarchical algorithm. Under this method, LAs with good overlaps were grouped iteratively. Firstly, the two LAs with the most similar scores are grouped, then groups are combined on the basis of the similarity between each member of the two groups, the two groups being combined if their most dissimilar LAs are less dissimilar than in any other combination. In order to group them with a hierarchical clustering method the scores were inverted such that small scores indicate similarity. This is achieved by dividing 1 by the overlap score.

Table 5: EA grouping using cluster analysis - 8 groups

EA	Council Area	Estimated % of household population
1	Na h-Eileanan An Iar, Orkney Islands, Shetland Islands	1.36%
2	Glasgow	12.04%
3	Aberdeen City, Dundee City, City of Edinburgh	16.67%
4	Inverclyde, Renfrewshire	4.99%
5	North Lanarkshire, West Dunbartonshire, West Lothian, North Ayrshire, Clackmannanshire	14.62%
6	Angus, East Lothian, Fife, Perth and Kinross, Scottish Borders, South Ayrshire, Stirling	19.45%
7	East Ayrshire, Falkirk, Midlothian, South Lanarkshire	12.51%
8	Aberdeenshire, Argyll and Bute, Dumfries and Galloway, East Dunbartonshire, East Renfrewshire, Highland, Moray	18.36%

Hierarchical clustering allows the number of groups to be controlled. Two approaches for the number of groups were used. Firstly, an approach in which the algorithm is instructed to create six groups from the data, with the islands and Glasgow removed and treated as two additional groups, to make a total of eight groups. Secondly, an approach in which the algorithm is instructed to create eight groups, and Na h-Eileanan An Iar, which the algorithm grouped on its own, is merged with the other islands in group 1, to form seven groups.

Table 6: EA grouping using cluster analysis - 7 groups

EA	Council Area	Estimated % of household population
1	Aberdeenshire, Dumfries and Galloway, East Dunbartonshire, Highland, Orkney Islands, Shetland Islands, Na h-Eileanan An Iar	14.77%
2	Glasgow	12.04%
3	Aberdeen City, Dundee City, City of Edinburgh	16.67%
4	Argyll and Bute, East Renfrewshire, Moray	4.95%
5	Clackmannanshire, Inverclyde, North Ayrshire, North Lanarkshire, Renfrewshire, West Dunbartonshire, West Lothian	19.60%
6	Angus, East Lothian, Fife, Perth and Kinross, Scottish Borders, South Ayrshire, Stirling	19.45%
7	East Ayrshire, Falkirk, Midlothian, South Lanarkshire	12.51%

6.5 Evaluation

The results from the various grouping methodologies were compared using three criteria. Firstly, the variation (Standard Deviation) within each EA-HtC subgroup was found and averaged across each EA in each HtC. These scores were examined and compared for each method. Secondly, the likely level of collapsing was examined. To do this the number of planning areas (PAs) in each EA-HtC subgroup were compared. Small numbers of PAs could indicate an issue. Finally, the number of people from minority ethnic groups, based on the previous Census, was determined for each EA. Small numbers could again indicate a problem for estimation.

6.5.1 Variation

Table 7 shows the standard deviations of the HtC-EA subgroups, averaged across HtC for the four EA groupings. The three HtC index based groupings all perform notably better than the 2017 proposed grouping. There is not a large amount of difference between the three new proposals in terms of variation however. The eight group cluster algorithm approach has the lowest, followed by the seven group algorithm and finally the manual approach.

Table 7: Average SD of HtC subgroup across each HtC index for the various EA groupings

Grouping	*HtC1 SD*	*HtC2 SD*	*HtC3 SD*	*HtC4 SD*	*HtC5 SD*	***Total SD***
EA 2017 proposed	11.1	22	13.7	16	10.7	*73.5*
Manual Grouping	11	22	13.8	14.3	10.7	*71.8*
Clustering 8 Groups	10.9	22.2	13.7	14.5	9.6	*70.9*
Clustering 7 Groups	11.1	22	12.9	14.6	10.7	*71.1*

6.5.2 Collapsing

The amount of strata collapsing likely to be needed was examined for the four EA groupings. When there are less than five PAs available for DSE in an EA-HtC strata, they are collapsed together for the purposes of DSE to increase statistical power and decrease error. The number of PAs available is constrained by the number sampled in the Census Coverage Survey (CCS). There is uncertainty around which areas will be sampled in the CCS, but it will be around 9% of Census PAs, meaning that subgroups with less than 50 PAs are at risk for collapsing.

Based on this threshold of 50 PAs for collapsing, the two EA groupings generated by cluster analysis have the lowest level of collapsing: the seven group method has eight subgroups in danger of collapsing while the eight group method has 10 subgroups. With the two manual methods showing higher collapsing - both manual methods have 11 subgroups in danger of collapsing.

The differences in collapsing levels are due to two HtC 3 groups requiring collapsing for both the 2017 and manual methods. For both the cluster analysis based approaches there was no HtC 3 collapsing. Collapsing in the HtC 4 and 5 groups was relatively consistent across the four methods, with collapsing being likely for these HtCs across all groups apart from the cities in all the methods.

The non-white population was also examined to see if there were any concerns around collapsing for this group in any of the groupings. This was only found to be an issue in the island grouping. For this reason the seven group cluster grouping which did not include an island EA performed best in this evaluation.

7. Strengths and limitations of methodology

All the new approaches performed well, markedly better than the 2017 proposal.

Both the cluster analysis algorithms have good performance in the evaluation, with the lowest variation in HtC score within groups. Importantly, they avoid collapsing HtC 3 groups with HtC 2 as much. In addition it seems possible that the approach of judging similarity across the whole HtC score range distribution might cause them to have more homogenous response rates than analysis of HtC score variation would suggest. This might be the case if neighbouring other HtC levels influence response rate for instance.

The main differences between the two approaches are the inclusion of the islands as a separate group and the equality of the groups in terms of number of households. The island group is small and may cause collapsing issues, particularly for non-white ethnic groups. However, it is possible that the response patterns for island communities will be similar, beyond what is suggested by the HtC score. The seven group approach also has more even group sizes.

The manual method also performs well. It shows slightly higher HtC subgroups than the cluster approaches. It also has a more even split of households across the EA groups than the eight group cluster analysis approach which should mean that the variation of the estimates is more consistent across EA groups for this method as well as the seven group cluster analysis method.

7.1 Potential Concerns

With the delay in the Census to 2022, the data set that was used to create these groups is now not the final version. Therefore, the groupings will need to be updated in 2021 when the final HtC and geographies are created. The recommendation is that an algorithm is chosen now, and re run on the final data set to create the groupings.

All the proposed methods decrease the number of EA groups from the 10 that were used in 2011. The advantage of this is that they will have less collapsing and likely lower estimate variance. The reduction in groups is due to the low level of geographic variation in response rates expected across many rural LAs away from the large cities. If these LAs instead have more variation in response rates, then a higher number of groups to divide into those with similar response would be a better approach.

The methods used rely heavily on the HtC index groups and HtC score being a good predictor of response rates. If there is another source of response rate variation not captured in the HtC model (for example, digital exclusion), the groupings described may not adequately divide the county into groups with similar response rate. In this case, however, post stratification would allow regrouping along different lines.

8. Conclusion

This review of the EA groupings method examines the approach that should be adopted for 2022 and suggests that with minor modifications the approach proposed in 2017 is appropriate. While there have been a number of changes to the working of the Census that effect EA groups, such as response rate equalisation during collect and no batching outside of estimation and adjustment for data processing, there still seems to be a good rational for creating estimates stratified by geographical groupings. Given the benefits to SQA, the geographical areas created should be groupings of LAs, although unlike in 2011, they do not have to be geographically contiguous.

8.1.1 Post-stratification

Designating these EA groups before collection starts will be likely to improve their homogeneity via response rate equalisation. However, it seems sensible to re-examine how well this has worked after collection has finished using the return rate. If EA subgroups within EAs have high variation in the return rate, then this could be improved by post stratification. LAs could be re-grouped on the basis of the return rate, that should provide a more exact estimate of the response rate than the HtC score.

8.1.2 EA grouping method

Four EA grouping methods were examined, three utilising HtC score to judge similarity, and the 2017 approach, updated with new data, which uses the HtC index proportion. The three new approaches all performed better than the 2017 method using HtC index, but there are some variations between them. All four options are presented below:

1. 2017 Proposal – Highest variation across the EA-HTC groups, high levels of collapsing. Relatively equal grouping in terms of number of households.
2. Manual approach – This produced a fairly equal division of the household population and a lower variation that the 2017 proposal.
3. Cluster analysis algorithm with eight groups – This approach has less risk of collapsing (particularly HtC 3) compared to the manual approach. It also produced groupings with the lowest variation in HtC score. The grouping by similarity of the whole HtC score range, rather than on the basis of one HtC index group and a time, might also reduce the heterogeneity - for example if

areas that neighbour other HtC index areas respond differently to those who do not.

4. Cluster analysis algorithm with seven groups – This grouping also has less risk of HtC collapsing (again HtC 3) than the manual approach, and lower collapsing risk than the eight group cluster analysis. It also has less risk of collapsing non-white groups in island LAs as they are grouped with other LAs. As with (3) it benefits from grouping by similarity of the whole HtC score range. It also has a fairly equal division of the household population.

Based on both the low level of collapsing and the equality of the groups in terms of household size, number 4, the seven group cluster analysis algorithm is the recommended approach.

Due to the delay in the Census to 2022, the HtC index and geographies have not yet been finalised and will be next year. Therefore the recommendation is to choose the algorithm now, and run it again on the final data in 2021 to choose the finalised grouping.

9. References

Estimation and Adjustment Methodology
https://www.scotlandscensus.gov.uk/documents/Scotlands%20Census%202021%20-%20SMDP%20-%20Estimation%20and%20Adjustment%20Methodology%20paper%20(pdf).pdf

Developing a Hard-to-count Index
https://www.scotlandscensus.gov.uk/external-methodology-assurance-panels-emaps-0

CCS Sample Methodology
https://www.scotlandscensus.gov.uk/external-methodology-assurance-panels-emaps-0

CCS Sample Allocation and Reserve Sample
https://www.scotlandscensus.gov.uk/external-methodology-assurance-panels-emaps-0

10. Appendix

10.1 Appendix A – Definitions

10.1.1 List of Acronyms

CCS	Census Coverage Survey
DSE	Dual System Estimation
EA	Estimation Area
E&I	Edit and Imputation
HtC	Hard to Count Index
LA	Local Authority
PA	Planning Area
RMR	Resolve Multiple Responses
SQA	Statistical Quality Assurance

10.1.2 Geography Definitions

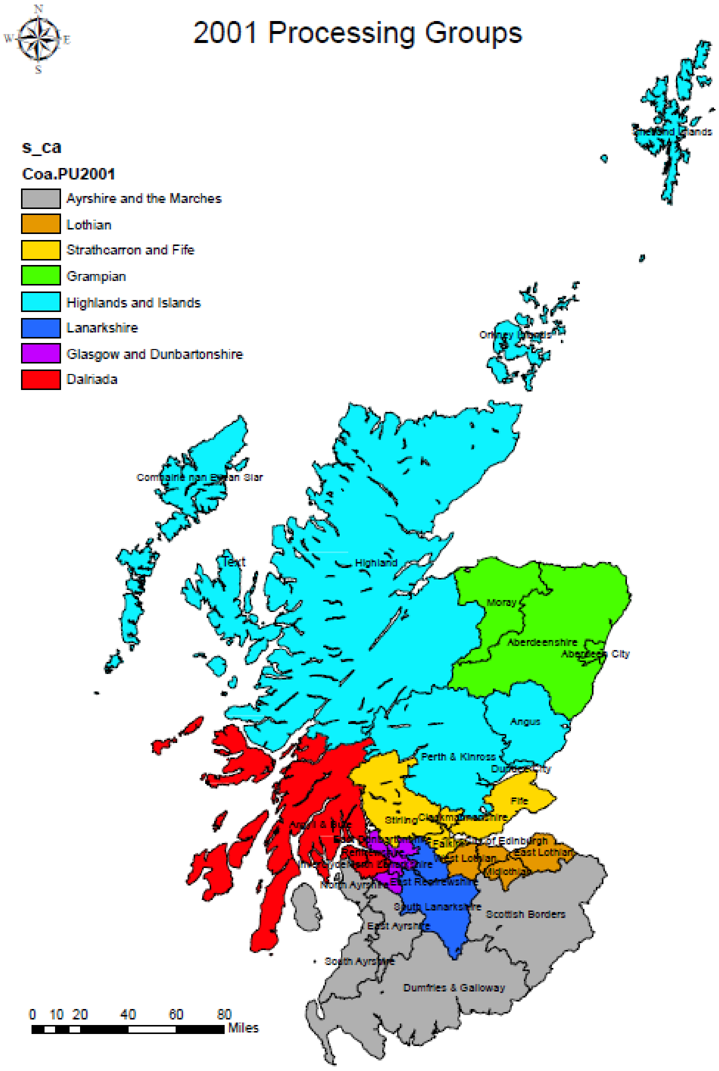
Data Zone	The data zone geography covers the whole of Scotland and nests within local authority boundaries.
Estimation Areas	The estimation areas are made up of council areas grouped together based on similarity of demographics related to expected response rate. The council areas making up an estimation areas will not necessarily be geographically contiguous
Hard to Count Index	The Hard to Count index is a scale of 1 (easiest to count) to 5 (hardest to count) which was created to indicate how difficult it may be to enumerate a particular geographical area based on certain demographic features.
Local Authority	Local Authorities are the 32 council areas within Scotland.
Planning Areas	Planning Areas are geographic areas built from groups of postcodes and averaging between 200-400 residential addresses. They nest within Local Authorities.

10.2 Appendix B - Measures of success for Scotland's Census 2022 objectives, as at November 2019.

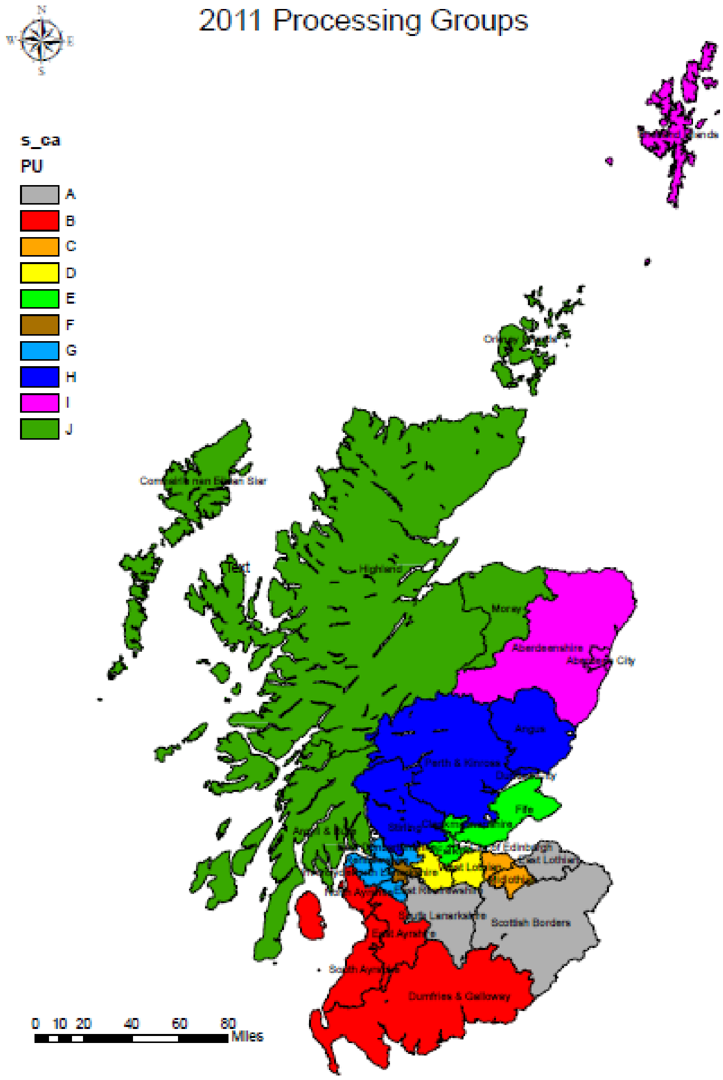
How we will achieve high quality results?	How will we measure success? (Level 1 Key Performance Indicators (KPIs)[1] and acceptance levels)
We will maximise our overall person response rate	Person response rate[2] of at least 94%
We will ensure a minimum level of response with every local authority in Scotland	Person response rate in every council area of at least 85%.
We will maximise the accuracy of our national population estimates	Variability[3]: national estimates will achieve 95% Confidence Intervals (CI) +/- 0.4%; Bias: < 0.5%
We will maximise the accuracy of our local authority population estimates	Variability[4]: council area estimates will achieve 95% CI +/- 3%
We will minimise the non-response to all mandatory questions	Achieve or exceed target non-response rates for all mandatory questions
Our data will demonstrate high agreement rates with post coverage quality surveys	Agreement rates of at least XX%[5] achieved for all questions
All national and local authority level results for each main release will be assessed by a quality assurance panel	Undertaken with no residual issues remaining
We will publish details of methods and full details of all our data quality indicators	Published on our website
We will publish the results of an independent methodology review	Positive review published.
We will maintain our National Statistics Accreditation	Accreditation maintained throughout

1. Lower-level KPIs may sit below individual Level 1 KPIs.
2. Precise measure for person response rate to be defined.
3. This target is under review.
4. This target is under review.
5. Precise measure for agreement rate to be defined.

10.3 Appendix C – Maps of EA Groupings



2011 Processing Groups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🟩 J
Shetland Islands
Orkney Islands
Comhairle nan Eilean Siar
Text
Highland
Moray
Aberdeenshire
Aberdeen City
Angus
Perth & Kinross
Dundee City
Fife
Stirling
Clackmannanshire
Argyll & Bute
Falkirk
City of Edinburgh
East Lothian
West Lothian
Midlothian
North Ayrshire
East Renfrewshire
South Lanarkshire
Scottish Borders
East Ayrshire
South Ayrshire
Dumfries & Galloway
0
10
20
40
60
80
Miles