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Interactive comment on "Survey of the terrestrial habitats and vegetation of Shetland, 1974 – a framework for long term ecological monitoring" *by* C. M. Wood and R. G. H. Bunce

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Response: Many thanks for all the constructive comments regarding our manuscript which we have endeavoured to address as follows in the following format: (1) comments from Referees, (2) author's response, (3) author's changes in manuscript.

Response to Anonymous Referee #1

(1) General comments . This paper describes and presents important baseline data on habitats and vegetation of a northern archipelago in Britain, which could serve as a basis for future evaluations of long-term changes in vegetation. The use of Shetland

has increased considerably in the last decades due to developments in the oil industry and tourism, which may have affected the habitats, therefore, a resurvey or repeating of the original surveillance is warranted. The overall quality of the paper is high, it is generally well written, although the non-consequential use of some terms (site, plot, square, sub- square) makes it difficult to follow at places. For the above reasons, the paper is important, but as currently presented I have the feeling it has somewhat of a local importance. Relative to other parts of the world, Shetland appears to have low levels of specialized species and habitats, and more should be given as justification for the importance of this dataset. One missing piece of justification is climate change, which is not mentioned in the paper. I know climate change rules the current literature maybe too much, but in this case I believe it is relevant to mention. Northern areas, specially those so much influenced by maritime effects (as the authors note) and ocean currents, as Shetland, are certainly interesting scientifically due to their high exposure to the ongoing or likely impacts of climate change. This line of thought should be mentioned as a rationale to resurvey Shetland and to providing the baseline data here.

(2) We agree that adding a discussion of the possible effects of climate change would enhance the text greatly and would widen the audience of the paper. (3) We have inserted a discussion along the lines of the following into the text:

It would be expected that the most significant drivers of changes in the vegetation and habitats would be largely the socio-economic factors described. However, there is also the possibility that climate change may have already had some effect on the Shetland vegetation, and may do so in the future. Changes in the climate since the 1970s have not been great, but from the climate data presented in the figure below, there appears to be a trend towards higher temperatures and wetter winters. In the next 50 years, average temperatures are predicted to rise by 0.5-1.5oC, with 6-13% more rainfall (Scottish Natural Heritage, 2002). In a European context, Shetland is located in the Atlantic North zone, as described by Metzger et al. (2008). The Atlantic environment is relatively stable compared to other regions, and is not expected to change dramatically in extent or location in comparison to other zones (Metzger et al., 2008). However, the effects of potential climate change are difficult to predict. The species and habitats most likely to be affected are those which are close to the limits of their range, such as arctic-alpine plants. In Shetland, due to the cool winds, arctic-alpine species are present at much lower altitudes than would be expected on the British mainland. These species include Carex bigelowii and Silene acaulis. A warmer climate would perhaps result in a loss of these arctic-alpines and an increase in more generalist species, such as Agrostis tenuis and Festuca rubra. The Global observation research initiative in alpine environments project (GLORIA) has yielded research from the Swiss, Austrian and Italian Alps showing that warming causes arctic-alpine species to retreat to elevations higher than those pre-warming (Grabherr et al., 2010). As Shetland doesn't have higher elevations, it is likely the arctic-alpine species there would be lost in the event of climate warming. Monitoring these species in the islands would provide an early warning of the effects of climate change. Additionally, as this survey covers a range of functional plant types, changes in these could also be analysed in the context of climate change.

(New figure 1, Met Office, 2015)

Specific comments (1) I find four specific issues (by page/line). 1. Please make sure terms are used consistently, e.g. 1-km2 squares are referred to as "sampling unit", "squares", "sites" etc. and there is potential confusion elsewhere regarding the non-consequential use of some terms (site, plot, square, sub-square, e.g. p. 834, lines 13-15.

(2) Edited as below (3) We have simplified the description in the introduction as described in comments for Referee #2. We have also modified lines 185+ to read: 'The sample survey sites were based on 1km2 units randomly selected from across Shetland, as shown in figure 1. Five of these square units were randomly chosen from each of the 16 strata (or land classes) for survey, giving a total of 80 1km2 units to be surveyed. Within each selected 1km2 unit (or survey site), 16 individual 200m2 plots

were chosen for detailed survey. In order to allocate the location of these, each of the 80 selected 1km2 units was split into 16 equal sub-squares using an overlay grid, and a point location for the 200m2 plot was then randomly selected from within each of the 16 sub-squares. If a sub-square contained no land, that sub-square (and hence plot) was omitted from the survey, therefore between 1 and 16 plots were surveyed for each of the 1km2 units. In total, 927 200m2 plots were selected, although only 911 200m2 plots were actually surveyed as occasionally it was not possible to record the plot due to inaccessibility of a particular piece of land, for example due to a dangerous cliff or cultivated land.'

We have also included a new figure to clarify the sampling locations:

(New figure 2)

(1) 2. (834/17): How representative is one 200-m2 plot surveyed for a 1-km2 square? This should be discussed. Sampling effort appears to have varied greatly across the 1-km2 squares, thus the precision of cover/abundance estimates also varies across squares. Was there any effort to control for this in the analyses? What advice can be given to potential users of this data regarding the varying intensity of sampling?

(2) The target number of 200m2 plots within each 1km2 unit was 16 plots. This only varied if a plot was inaccessible due to being in water, in a location such as a dangerous cliff edge, or perhaps in an arable field, therefore sampling effort did not vary greatly across the 1km squares. The sampling intensity of 16 plots per site was originally used in a previous survey, the Woodland Survey of Great Britain in 1971 (Wood et al., 2015), and was chosen on the basis of previous experiences in surveying a wide variety of sites in the north of England and Wales. It also coincided with the time and manpower available (Bunce and Shaw, 1973). In terms of the species frequencies, these confirm much of what has been written about the phyto-geography of the islands, in that the majority of the species are wide-ranging members of heath and bog communities throughout Scotland, the arctic-alpine species present are of restricted

distribution but in Shetland, extend to sea level in many cases. In the survey report (Bunce, 1975), analysis was done to compare the results gained from the plot information against information from aerial photographs, thus testing the representativeness of the plot information across a wider area. The correspondence between the different values was found to be reasonably close at a broad category level.

Group Plot estimate of cover % Aerial photo estimate of cover %

Calluna/Eriophorum 29.5 39.0

Calluna/Nardus 23.0 25.0

Nardus 14.9 17.0

Juncus effusus 10.1 3.0

Calluna/Rhacomitrum 5.4 10.0

Festuca rubra 4.7 3.0

Agrostis/Holcus 11.4 6.0

The methodology has subsequently been developed further (for example in the Countryside Survey (Maskell et al., 2008)) to include a habitat mapping component to capture the variation in habitats across 1km squares. This could perhaps be incorporated into a repeat survey of Shetland. Overall, individual plots are not intended to be analysed at the 1km square level (even in comparable surveys such as the national Countryside Survey), but rather at the strata (or 'land class') level only.

(1) 3. (834/26): How is it possible to find these plots for someone other than the people originally surveying the sites? This is important, e.g. were the positions of the plots measured by GPS since 1974? If so, it would be a great help in potential future resurveys. If not, it should be done very fast.

(2) Detailed maps are held by the Centre for Ecology and Hydrology (CEH) showing the

locations of each plot. Similar maps have been used in subsequent surveys, such as the Great Britain Woodland Survey, and have been proven to be sufficiently accurate to allow a repeat of the survey (see comment below). To help preserve their representativeness of the wider countryside, and to protect the privacy of landowners, these precise locations are held in confidence by CEH. Again, we point out that the plots are intended to be representative of the strata (or 'land class') in which they are located, and intended to be analysed thus. Unfortunately, the plots have not yet been marked by GPS, and we agree very strongly that this is highly desirable, and should be done as soon as possible.

(1) 4. (840/19 and on): Repeatability is certainly much more than simply being able to find the plots and carry out the survey again. Please provide some quantitative assessments regarding the repeatability of the measurements made (correlation or correspondence etc. between two or more successive measurements, if available, maybe from the report).

(2) It is certainly the case that statistical analyses of temporal vegetation change are more powerful when based on records from plots located in the same place rather than randomised to new locations at each survey. As the Shetland survey has not yet been repeated, we cannot provide repeated values from this particular survey. However, surveys using exactly the same methodology have been proven to be highly repeatable. One such example is the Woodland Survey of Great Britain, carried out in 1971 and again in 2001. In the repeat survey, the field surveyor relied only on the marked point on a map as the sole aid to relocating the 1971 plot location, as would be the case in a repeat survey of Shetland. Consequently, there is the potential for considerable relocation error. The expectation is that having made an effort to move near to the mapped point, the plot records from the repeat survey will, on average, be more similar to the respective 1971 plot record than if a completely new, random set of locations were chosen. Even if vegetation change occurs, species compositional data recorded from the same point at times 1 and 2, will tend to be more similar than data recorded

from two random points at times 1 and 2. In attempting to measure the amount of relocation error, one cannot of course exploit a ‘true’ set of temporal pairs known to have been recorded in exactly the same position. What can be done is to compare the average species compositional similarity between the ostensibly true temporal pairs with the average similarity for a random pairing of the 1971 data with the 2001 data. If, on average, attempts to relocate the true 1971 position had been successful then the similarity between the true pairs should be greater than the random pairs. Overall at 97 of the woodland sites (out of 103) mean similarity was greater between ‘relocated’ plot pairs compared to random-pair comparison; for 59 sites the difference was significantly greater, therefore we were satisfied that the relocation error was not significant when interpreting any results. A full account of this is given in Appendix 3 of Kirby et al. (2005). (3) We have updated the text with a description of the above.

(1) Technical corrections (page/line) 830/8: please use metric units (km2) throughout, same in line 10 and elsewhere (2) Corrected

(1) 832/6: this is out of the world here, consider using an introductory sentence to the paragraph or restructuring the paragraph (2) Agreed, this has been modified as below. (3) ‘In order to obtain a general comparison with the environment and land cover of Shetland with the rest of Britain, data from Britain’s national monitoring programme, the Countryside Survey (Brown et al., 2014) may be used. The overall land cover, described by the CS survey data, is dominated by bogs and acid grassland habitats and provides an independent comparison with the results from the vegetation survey described below.’

(1) 832/16: replace “even although” with “even though” (2) Corrected

(1) 834/14: what is a "square” - please be consistent in term use (2) We have clarified this at various points in the text, as described in a comment above.

(1) 835/10: probably should be "physical” or maybe "physiognomic” but certainly not "physiological” (2) Changed to ‘physical’

(1) 840/12-18: give this justification in Methods when describing plot size, not here (2) Agreed. (3) Paragraph moved to Section 4.2.

(1) 841/14: You could cite more recent and more comprehensive work in this topic, e.g. Lengyel et al. 2008 on description of habitat monitoring in Europe if you want to make this more relevant for people outside the UK.

(2) Thank you for the suggestion – we have expanded the text as below. (3) More recently, a consideration of habitat monitoring in Europe by Lengyel et al. (2008b) highlights several factors that would be desirable when planning monitoring schemes, but are factors often lacking. In particular, spatial variations are barely monitored in over half of the monitoring schemes in Europe, schemes pre-1990 are rare, and few schemes use advanced statistical methods to present the data. In terms of the Shetland survey, spatial variation is a key factor in the design of the survey, the survey is historically significant, being first undertaken in 1974, and the data has been collected in such a way that advanced statistical methods can be applied effectively. The integration of surveys across Europe is discussed in Lengyel et al. (2008a). Lengyel et al. (2008a) recommend methodology such as the Biohab methodology (Bunce et al., 2005) in order to increase the potential for integration. By using the General Habitat Categories described in Bunce et al. (2005) and Bunce et al. (2008), data from this Shetland survey could be analysed in a European context and enhance the understanding of landscape ecological change, in terms of a range of drivers.

Response to Anonymous Referee #2

(1) General comments This well written manuscript data on a 40-years old vegetation survey shows an impressive example of vegetation data recorded by using a repeatable standard procedure based on stratified random plot design attempting to capture the vegetation of the entire Shetland Islands. All plots appear to be properly repeatable at the same locations as in the 1970s. The data set, consisting of over 900 plots records, contain all plant species found in each 200m2 plot including cover/abundance esti-

mates. Especially noteworthy is the full consideration of both bryophytes and macro-lichens (growing on soil) on a species level – a laborious effort where only few experts are usually available. Further, data are complemented with detailed soil samples and information of the directly neighbouring area. As such, the 40 years old data set is already of much interest for a resurvey. A re-survey project, however, should target on clearly defined objectives and hypotheses. For this purpose, more information on developments during the past 40 years, such as on settlements, e.g. through the oil industry, changes in crofting practices and the intensity of pastoralism would be desirable. I think there is no need for an exhaustive search for literature and archive sources, but to provide general information on dimension the above factors were changing.

(2) We have provided more detailed information on developments in the past 40 years, covering the following points:

There has been a general decline in traditional crofting agriculture, partly due to the availability of well-paid jobs in the oil industry, and factors such as EU subsidies. Key habitats and species of conservation value are often found in crofting communities, therefore these are under threat (Scottish Rural Development Programme, 2016). Additionally, the demography of the crofting community is changing and many common grazings now have insufficient active adults to undertake routine operations such as sheep round-ups. This has seen quite widespread apportionment (fencing of hill shares) which has broken up large hill units. Sheep numbers have fluctuated in response to headage subsidies from the EU, from around 265,000 in 1971 to nearly 400,000 in 2001, with the associated grazing pressures (Scottish Government, 2016). This figure reduced to around 280,000 in 2010 when subsidies switched to area payments in the early 2000s, and agri-environment schemes encouraged better stewardship of the land. Additionally, the amount of land put to silage has increased markedly since the 1970s whilst at the same time the amount of arable has dropped. The availability of grant aid from the Local Authority (as a result of oil income) meant that there was a considerable amount of re-seeding, surface seeding or liming of moor-

land/heathland, as well as large drainage schemes. Now that the economic situation is currently less favourable, there is no money available to crofters for these activities, much of this improved land is reverting back (Scottish Natural Heritage, 2002). Peat is frequently used a domestic fuel in Shetland. Peat cutting has declined, although there is a small resurgence at the moment in response to high oil prices. Mechanised cutting can seriously damage blanket bog by draining the peat and destroying large areas of surface vegetation. However, there are now only a few commercial peat cutting operators and the practice is currently viewed as unsustainable (Scottish Natural Heritage, 2002). The construction of the third largest windfarm in Scotland (Viking Energy, 2016), due to be built in the near future could also affect the vegetation of this islands, by altering the local micro-climate.

(3) A discussion regarding the above has been inserted into the text.

(1) Probably even more, this accounts for the climate development during the past 40 years, which was exactly the period ranging from the cooler period around the mid-20th century to about the 1970s to the decades of exceptionally warm decades – at least globally and in most parts of Europe. Therefore, I think, climate change – temperature and precipitation in particular – across the 4 decades on Shetland Islands should be briefly described. Tracing climate change impacts would be a further very interesting reason to use these data as a baseline. The position of the Shetland Islands quite in the area of direct influence of the Gulf Stream could make this baseline data set even more important. Noteworthy is the particular value of the data for this purpose as it includes species data across different organism groups vascular plants, bryophytes, lichens, and, as such, very different functional groups. A focus on climate change, therefore, could provide a strong incentive for resurvey studies.

(2) We have addressed these issues, as per comments for Referee #1.

(1) Specific comments

The description of the Shetlands briefly describes the climate and here a focus on climate change is much recommended. Means for winter and summer temperatures and precipitation (lines 83-87) are only the values from the 1974 report. (2) We have addressed this issue, as per comments for Referee #1.

(1) A detailed description for data users on how to relocation and setup of plots is important (lines 200 ff., 335 ff.). Are the indications based on the maps used in 1974 sufficient to find the midpoints of the 200m2 plots, are there precise enough geographical coordinates available to find the plots with GPS devices? (2) This has been addressed in a comment for Referee #1, above.

(1) In the conclusions I suggest to provide more information on land use changes and an account on climate change. (2,3) Thank you for the suggestion, we have expanded the conclusion accordingly.

(1) Further notes and minor corrections line 51: Details such as 911 plots distributed over 80 1-km2 and 16 environmental strata remains a bit unclear at this point of the paper. You may be more general here in the intro and refer to below where the design is described.

(2) We have modified the text in line 51 as below in order to clarify, and have made modifications as per a comment for Referee #1, above. (3) 'In order to randomly sample Shetland in a strategic way, the islands were stratified into a set of 16 relatively homogenous areas (strata, or 'land classes'). Sampling locations were randomly selected from within each of these strata, giving a total of 80 1km2 sampling units, each containing up to 16 200m2 sampling plots'.

(1) Please use metric units throughout, e.g. lines 72-74, (2) Corrected. (1) Table 1, (2) Corrected (kept the heights in feet, and added metric in brackets, otherwise the metric numbers seem strangely random). (1) Figure 2, scales in Figures 1, 5. (2) Corrected

(1) line 211: "data collected from the : : :" (2) Corrected 'form' to 'from'

(1) line 233-234: ": : :all vascular plants (gymnosperms, monocots, dicots, includ-

ing tree species, ferns), bryophytes and macro-lichens growing on soil." (in the 1974 handbook you speak of bryophytes and macrolichens growing on soil – i.e. excluding epilithic lichens and epiphytic cryptogams). (2,3) Corrected as suggested.

(1) line 275: Carex panicea Table 3; Sphagnum rubellum (2) Corrected

(1) Fig. 3: indication of diagonal distances better on the right side of the diagonal (currently, in the first glimpse, it look like of the quadrat sides. (2) The quadrat sides and diagonal lengths are given below the quadrat figure, hence we have removed the distances from the quadrat to remove any confusion.

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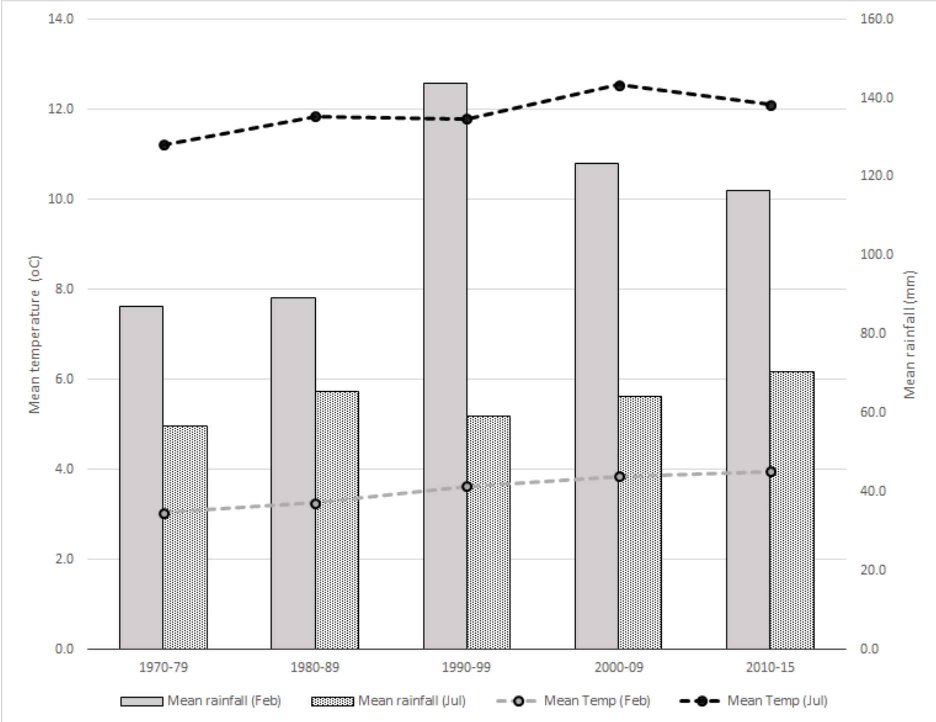
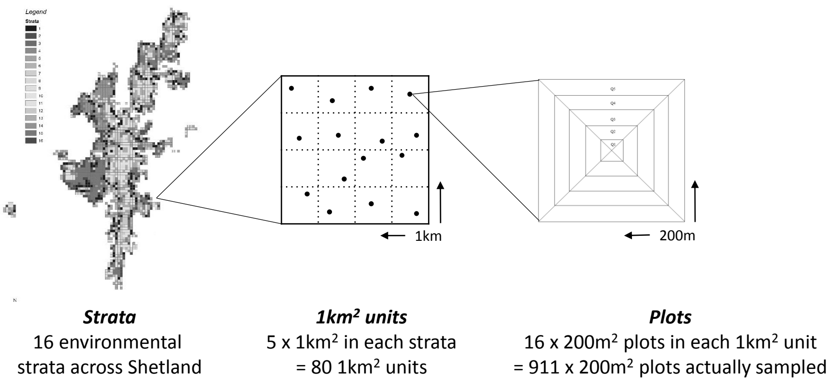


14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Mean temperature (oC)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Mean rainfall (mm)
1970-79
1980-89
1990-99
2000-09
2010-15
Mean rainfall (Feb)
Mean rainfall (Jul)
Mean Temp (Feb)
Mean Temp (Jul)

Fig. 1.



1km
200m
Strata
16 environmental
strata across Shetland
1km² units
5 x 1km² in each strata
= 80 1km² units
Plots
16 x 200m² plots in each 1km² unit
= 911 x 200m² plots actually sampled

Fig. 2.