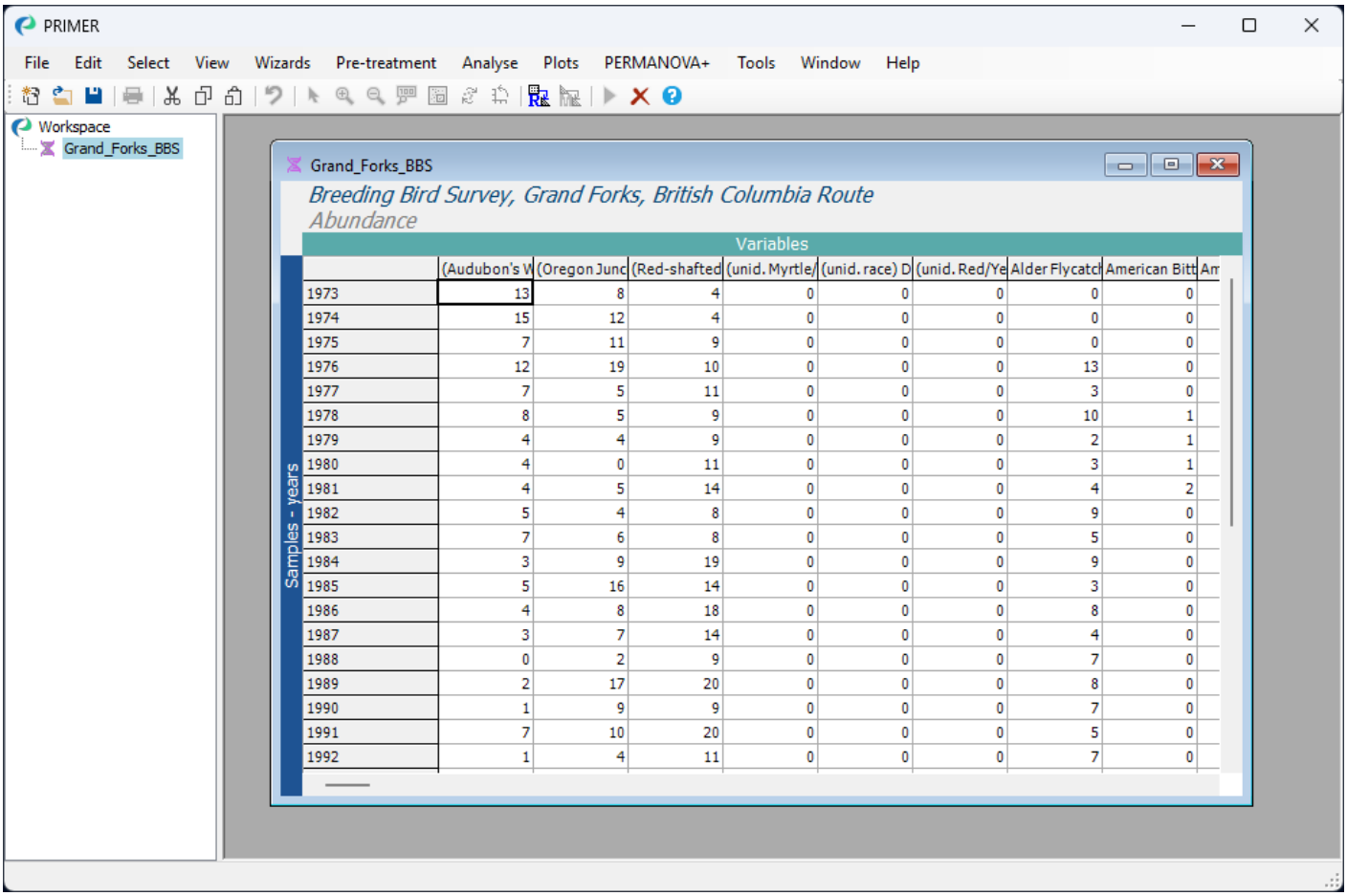
12.7 Example: Birds from Grand Forks

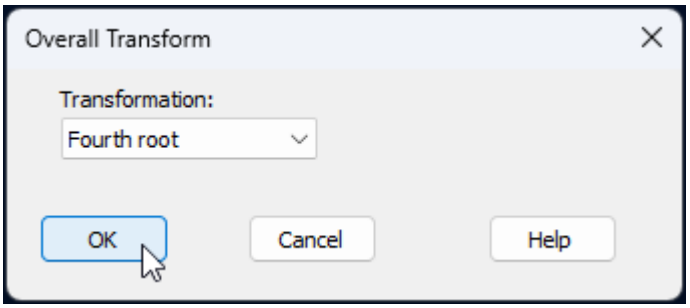
We shall implement a control chart on data from the North American Breeding Bird Survey (BBS) (Sauer *et al.* (2019)). We will specifically look at abundances of p = 156 breeding birds from a single route in Grand Forks, British Columbia, Canada in a time series that includes 38 years of observation (annual surveys done between 1973 and 2016, but with a few years missing). Data are in the file 'Grand_Forks_BBS.pri' found in the 'Examples_P8' > 'Grand_Forks_birds' folder.

Input data, transform and calculate resemblances

1. Bring the data in to a PRIMER 8 workspace (click **File** > **Open...**). It will look like this:



2. Transform the data to fourth-roots. From the 'Grand_Forks_BBS' sheet, click **Pre-treatment** > **Transform(overall)...** and in the 'Overall Transform' dialog choose 'Fourth root', then click '**OK**'.



The resulting data sheet will be called 'Data1' in the Explorer tree.

3. Calculate Bray-Curtis resemblances. From the transformed data sheet, called 'Data1', click **Analyse** > **Resemblance...** and in the 'Resemblance' dialog window, choose (Measure: $\bullet$Bray-Curtis similarity) & (Analyse between: $\bullet$Samples), then click '**OK**'.

The resulting resemblance matrix will be called 'Resem1', and will look like this:

Resem1

Breeding Bird Survey, Grand Forks, British Columbia Route
Similarity (0 to 100)

Samples - years	1973	1974	1975	1976	1977	1978	1979	1980
1973								
1974	78.25							
1975	75.411	73.946						
1976	75.313	73.523	78.319					
1977	72.667	72.686	77.016	80.836				
1978	72.395	71.333	74.607	77.801	82.893			
1979	64.522	68.267	74.087	76.423	81.499	80.649		
1980	66.581	69.275	74.493	77.347	79.225	80.029	84.254	
1981	71.075	72.027	71.62	76.895	81.325	81.664	82.082	
1982	65.75	69.056	73.078	75.091	79.583	81.558	80.993	
1983	69.445	67.683	71.793	79.528	78.585	81.601	83.677	
1984	68.988	69.11	72.013	77.691	80.459	83.251	79.984	
1985	68.623	67.681	75.898	79.106	76.925	77.324	80.454	
1986	68.78	69.588	76.005	80.135	80.342	82.337	80.411	
1987	68.283	65.957	71.155	75.571	72.867	74.814	76.775	
1988	64.287	64.188	65.531	73.263	72.721	72.221	74.859	
1989	68.989	69.824	75.171	77.73	74.466	76.333	77.444	
1990	71.905	70.995	73.471	75.635	74.989	78.292	77.894	
1991	68.791	65.118	69.556	73.782	74.69	77.192	76.619	

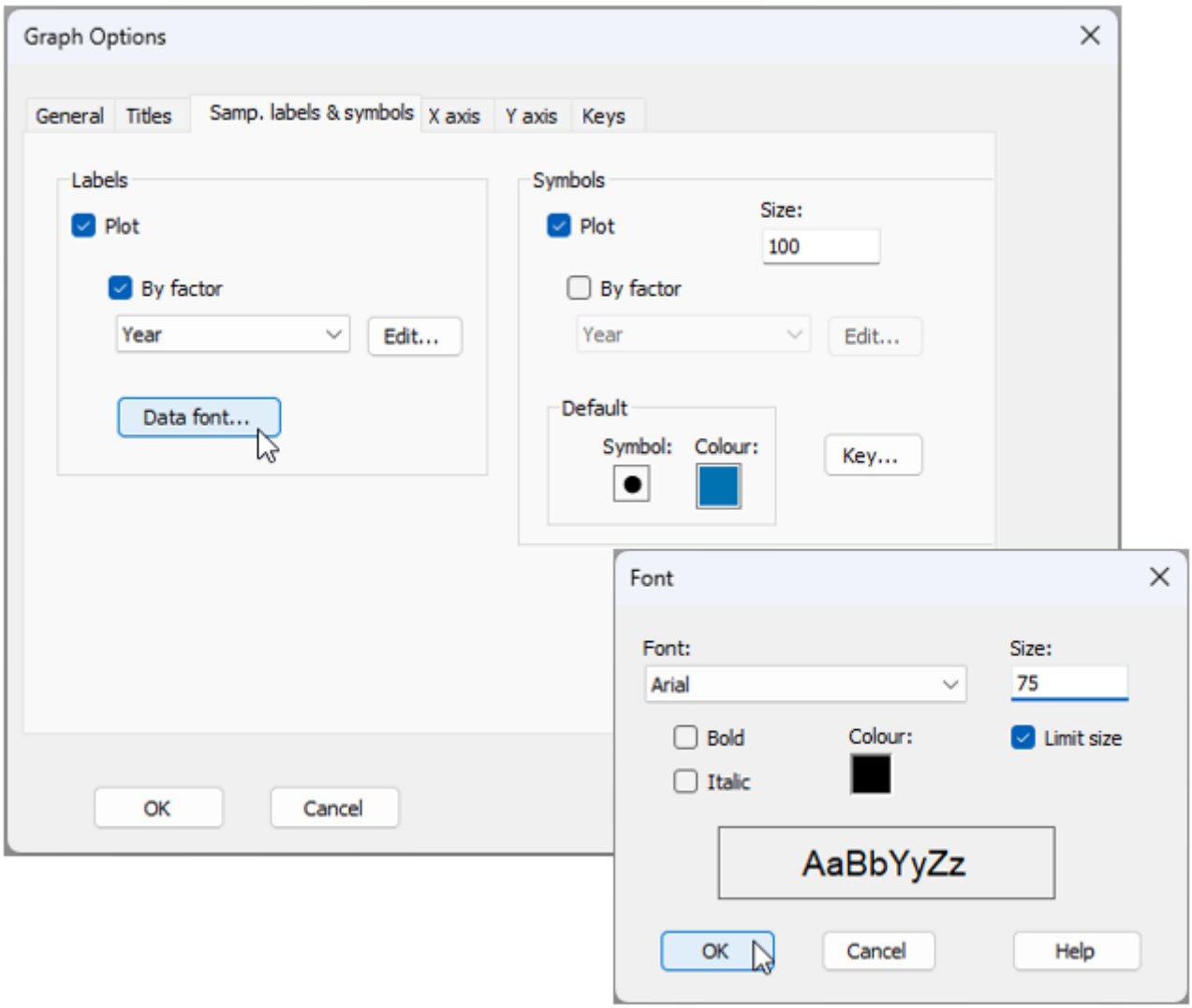
Visualise the trajectory over time *via* ordination

We will create a non-metric MDS ordination of the samples through time, to visualise how the bird assemblages may have changed at Grand Forks over this 38-year period.

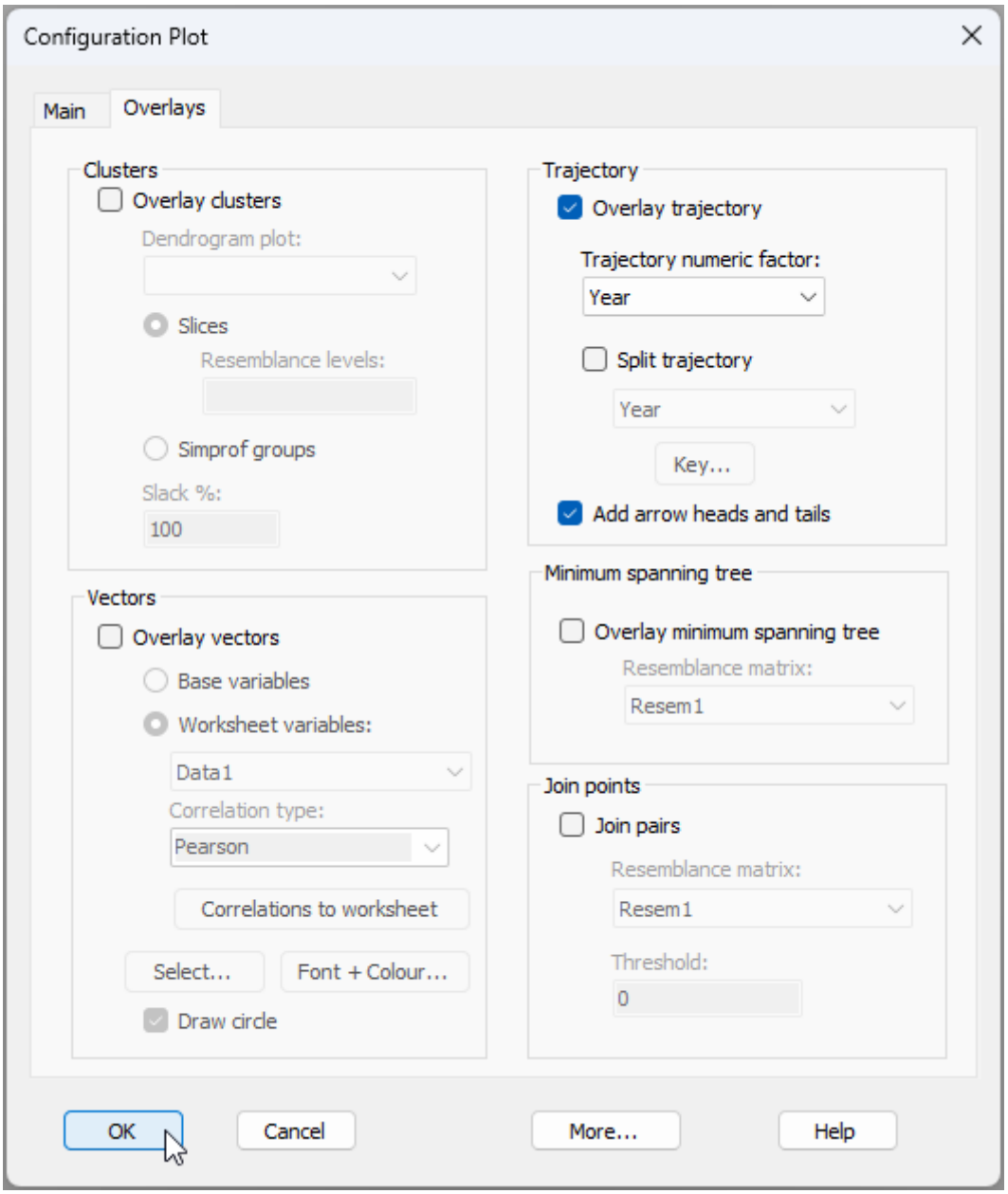
4. From the 'Resem1' matrix, click **Analyse** > **MDS** > **Non-metric MDS (nMDS)...**, take all of the defaults in the 'Non Metric MDS' dialog and click **OK**.

The best 2D nMDS solution will be shown in the item called 'Graph1' (under 'MultiPlot1' in the Explorer tree. To clarify the patterns over time, we will make a few adjustments to the default output.

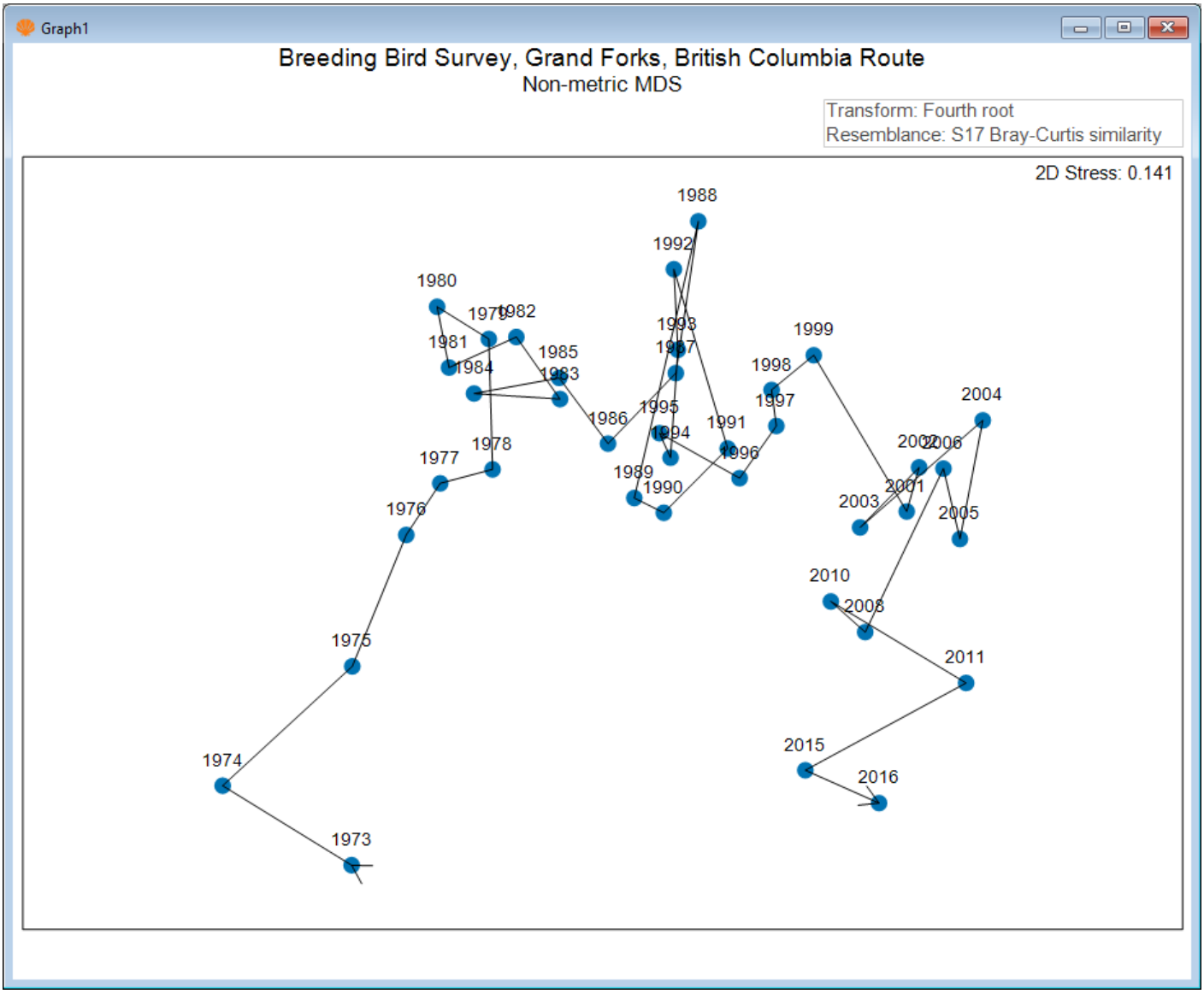
5. Put the years on the plot as labels, and put a common symbol onto all of the sample points. From 'Graph1', click **Graph** > **Sample Labels & Symbols...**, and in the resulting dialog, choose (Labels > $\checkmark$Plot > ($\checkmark$By factor: Year) & (Data font... > Size: 75)) & (Symbols > $\checkmark$Plot) & untick the box in front of ($\Box$ By factor)). With these choices, the dialog will look like this:



6. Add a trajectory through time to connect consecutive years. From 'Graph1', click **Graph** > **Special...**, click the '**Overlays**' tab, and under the word 'Trajectory', choose $\checkmark$Overlay trajectory > Trajectory numeric factor: Year, then click '**OK**'. The dialog looks like this:



After these modifications, the resulting MDS plot, showing changes in bird assemblages through time, looks like this:



Create a 'fixed baseline' control chart

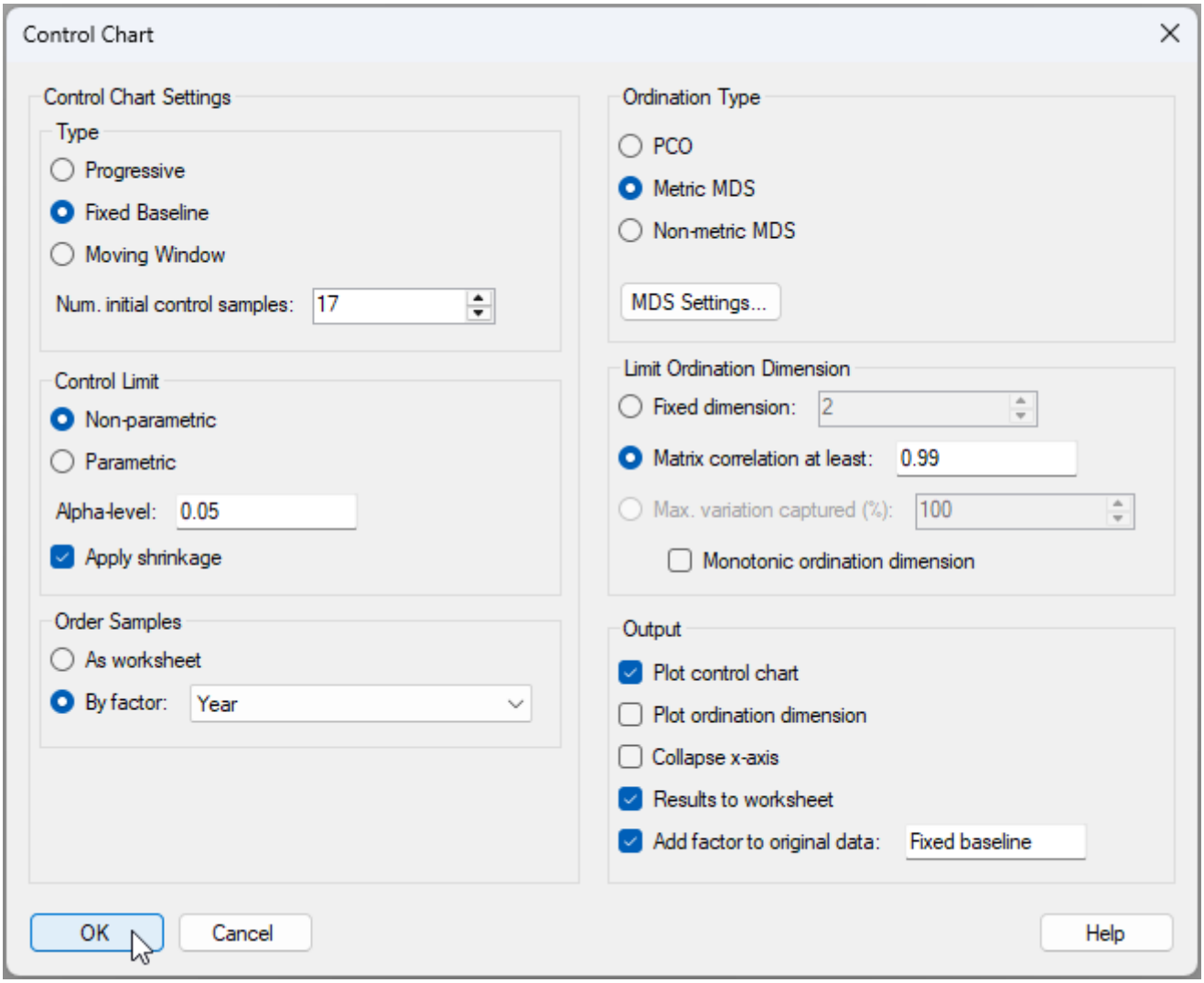
We will start by running a 'fixed baseline' type of control chart. In this case, we are comparing any individual time point at time t with the centroid obtained using a fixed set of initial points. For this example, we will consider the first 17 points (through the 70's and 80's, up until 1989) as being 'in control'. For this type of plot, the number of initial 'in-control' points never changes, and all subsequent individual points are looked at by reference to those initial ones (ignoring the rest).

7. From the 'Resem1' matrix, click **PERMANOVA+** > **Control Chart...**, and choose:

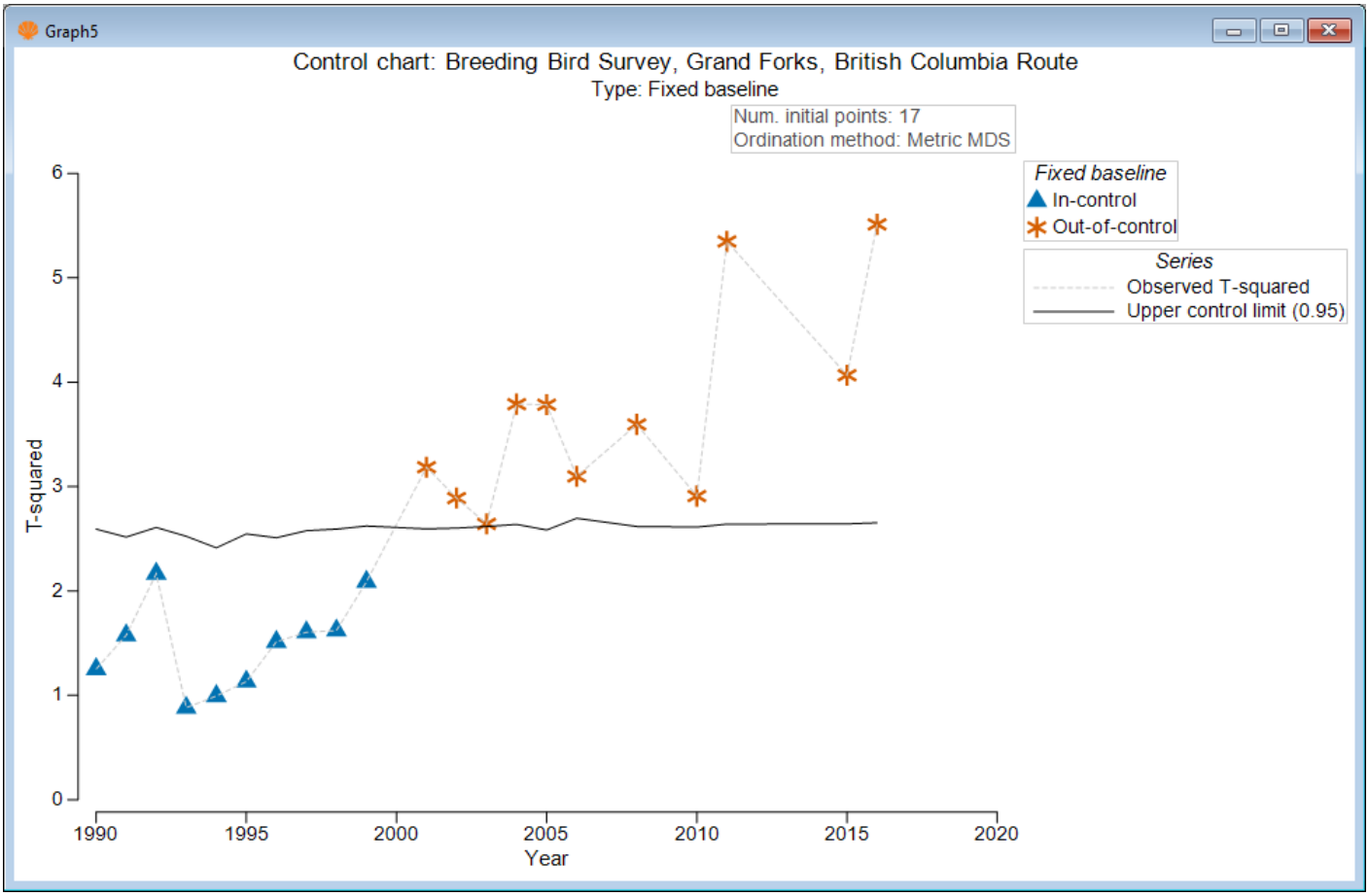
- Type: ($\bullet$ Fixed Baseline) & (Num. initial control samples: 17).
- Control Limit: ($\bullet$ Non-parametric) & (Alpha-level: 0.05) & ($\checkmark$Apply shrinkage)
- Order Samples: $\bullet$ By factor: Year
- Ordination type: $\bullet$ Metric MDS and click 'MDS Settings...' and choose: Choice of intercept > $\bullet$ Threshold metric MDS (non-zero intercept) and click '**OK**'
- Limit Ordination Dimension: $\bullet$ Matrix correlation at least: 0.99

- Output: ($\checkmark$Plot control chart) & ($\checkmark$Results to worksheet) & ($\checkmark$Add factor to original data: Fixed baseline).

The Control Chart dialog with these choices will look like this:



The resulting control chart looks like this:



From this graphic, we can see that the bird assemblages initially (through the 1990s) stayed effectively 'in control' (i.e., did not differ significantly from the baseline set of 17 years); however, from 2001 onwards, the bird assemblages shifted away from this baseline significantly in every year and did not 'return' to their former state. This accords well with the pattern of ongoing change we could see through time in the original MDS plot above.

Detailed results, including the choices made by the end-user, the value of the test-statistic ($T^2_{n_c}$) at each time-point, the value of the upper control-chart limit U_{CL}, identification of each time-point as being either 'in control' (where $T^2_{n_c} < U_{CL}$) or 'out of control' (where $T^2_{n_c} > U_{CL}$), the matrix correlation achieved ($r_{e,d}$) and the ordination dimension (m), are all given in the Control Chart output file (named 'Control Chart1' in the Explorer tree).

Results for each time-point are also given in a worksheet (if requested). In the present case, this worksheet is called 'Data2', which looks like this:

Data2

Control chart: Breeding Bird Survey, Grand Forks, British Columbia Route

Other

Variables

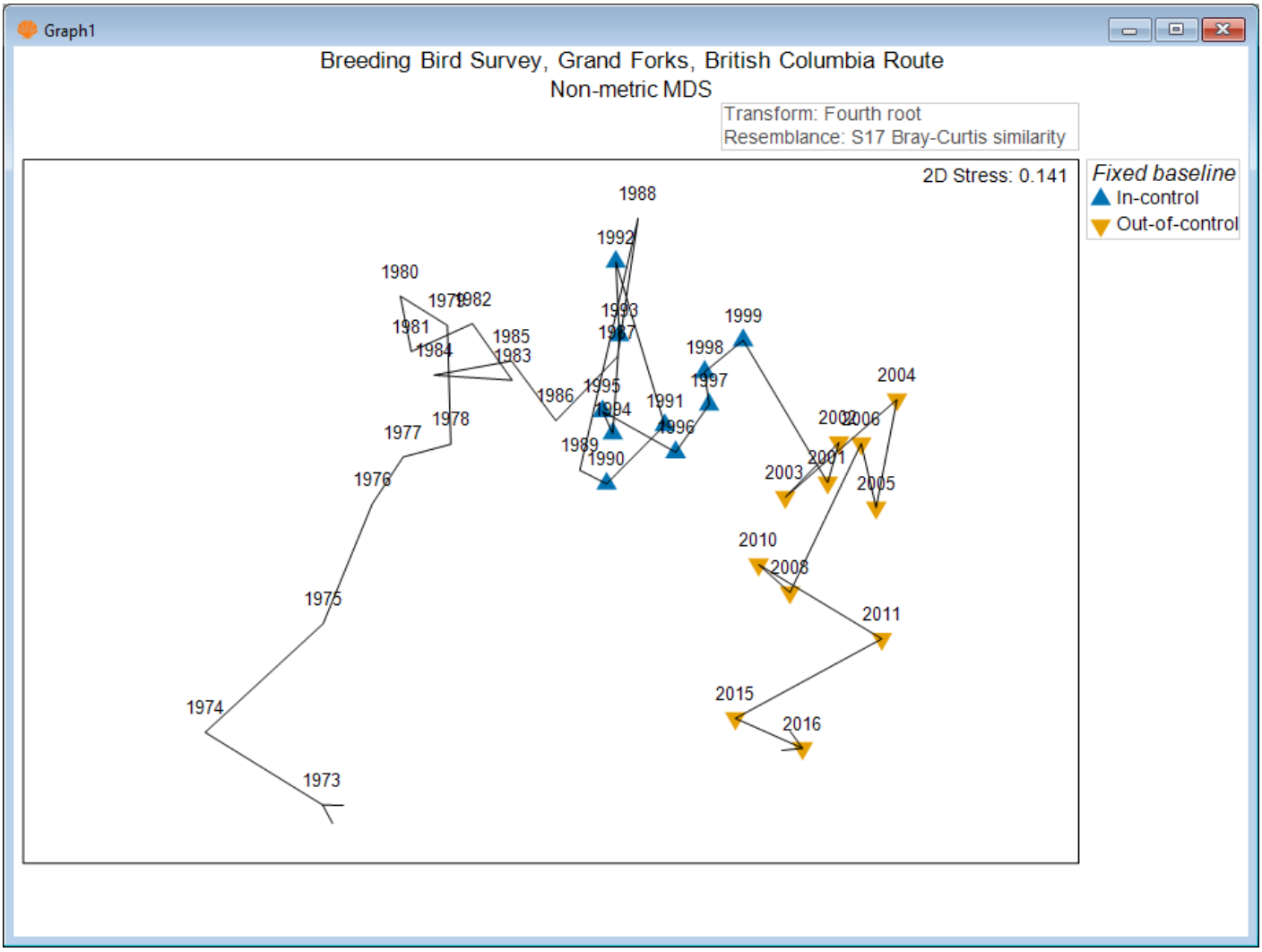
Samples

	Sample index	Number control samples	Observed T-squared	Upper control limit (0.95)	Matrix correlation	Ordination dimension	Year
1990	18	17	1.2511	2.5925	0.99218	6	1990
1991	19	17	1.5747	2.5162	0.99167	6	1991
1992	20	17	2.1653	2.6081	0.9924	6	1992
1993	21	17	0.88117	2.5231	0.9925	6	1993
1994	22	17	0.99319	2.4129	0.99326	7	1994
1995	23	17	1.1313	2.5465	0.99147	6	1995
1996	24	17	1.5127	2.5096	0.99086	6	1996
1997	25	17	1.6038	2.5771	0.9923	6	1997
1998	26	17	1.6208	2.5921	0.99107	6	1998
1999	27	17	2.0879	2.6215	0.99067	6	1999
2001	28	17	3.1855	2.5951	0.99233	6	2001
2002	29	17	2.8895	2.6023	0.99282	6	2002
2003	30	17	2.6421	2.617	0.99235	6	2003
2004	31	17	3.7894	2.6372	0.99206	6	2004
2005	32	17	3.7842	2.5841	0.99124	6	2005
2006	33	17	3.0975	2.6962	0.99222	6	2006
2008	34	17	3.5948	2.617	0.9917	6	2008
2010	35	17	2.9087	2.6111	0.99126	6	2010
2011	36	17	5.3483	2.6399	0.99341	6	2011
2015	37	17	4.0666	2.6421	0.99219	6	2015
2016	38	17	5.5121	2.6524	0.99336	6	2016

Show control-chart results on the original ordination

Note that the in-control/out-of-control factor (which we called 'Fixed baseline' for this example) can be accessed now in association with the original resemblance matrix ('Resem1') by clicking **Edit** > **Factors**. Thus, in addition to the control chart itself, we can also show the control-chart results on the original nMDS plot by choosing symbols according to the control-chart factor we just created.

8. From the 2D nMDS plot ('Graph1'), click **Graph** > **Sample Labels & Symbols...**, and in the resulting dialog, choose (Symbols > $\checkmark$Plot > ($\checkmark$By factor: Fixed baseline). The nMDS plot now looks like this:



This provides a nice perspective on the analysis. We can see the baseline set of points (no symbols, but the trajectory is there), then the symbols corresponding to the 'in control' samples (through the 90's), followed by the suite of 'out of control' samples from 2001 onwards.

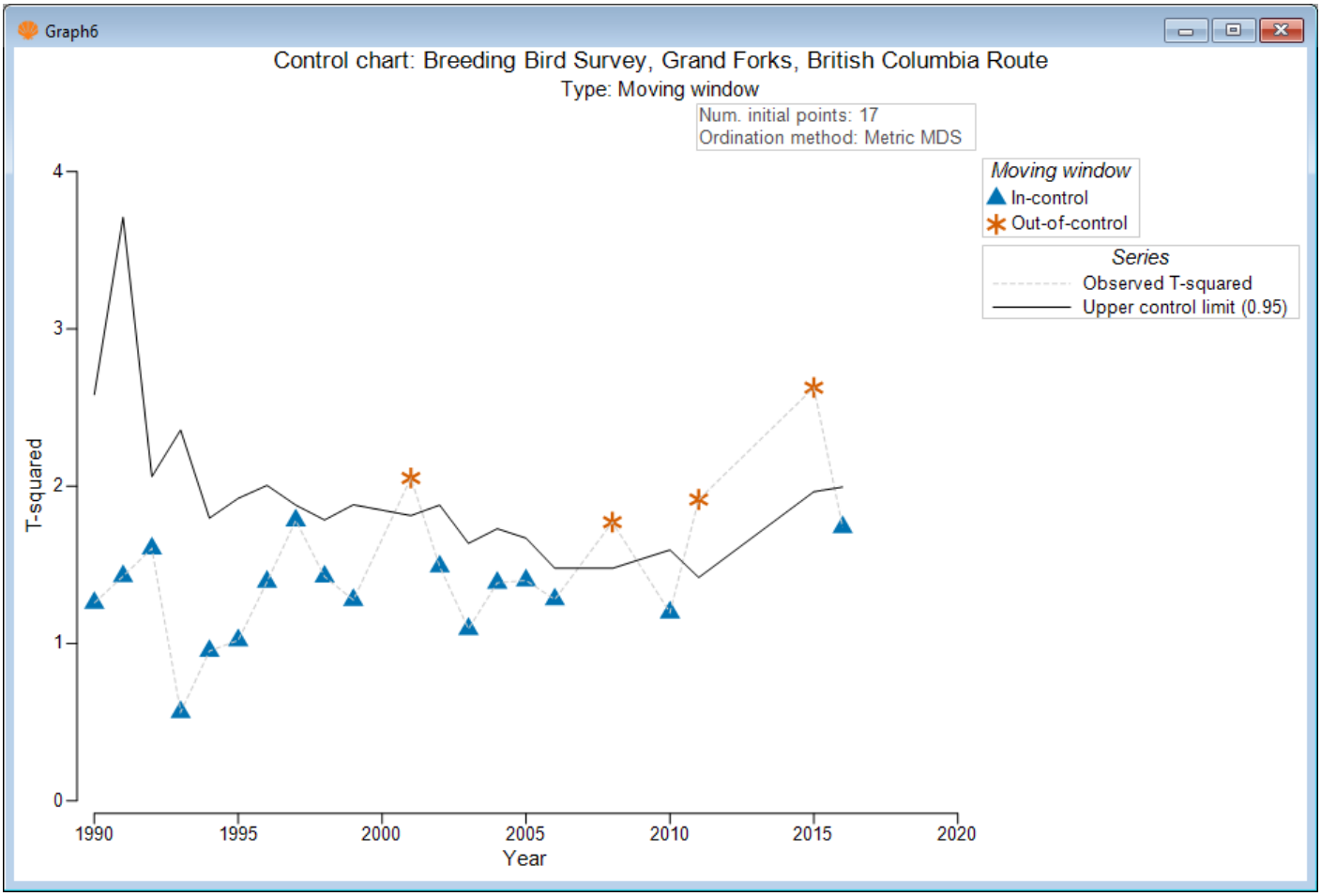
Create a 'moving window' control chart

Now let's run the control chart routine on these data again, but now we will choose to implement a 'moving window' type of control chart. In this type of chart, we compare each time point t with a set 'window' frame containing the n_c points that occur immediately prior to time t. So, for example, if the window size is chosen to be n_c = 17, then point number 25 will be compared with the 17 points from 8 through 24. The purpose of the moving window option is to permit a certain amount of natural drift over time, but places a stronger focus on the detection of big significant 'jumps' in the time series.

9. From the 'Resem1' matrix, click **PERMANOVA+** > **Control Chart...** and keep all of the same choices you had before (at step 7 above), except for the following:

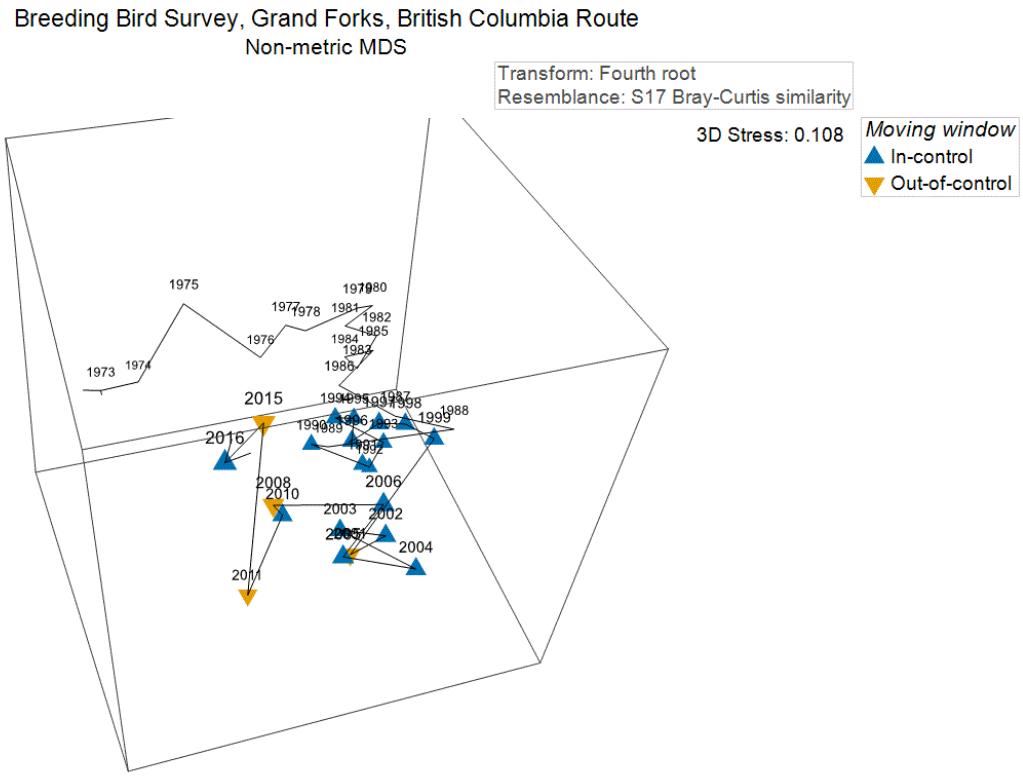
- Type: ($\bullet$ Moving window) & (Num. initial control samples: 17).
- Output: ($\checkmark$Plot control chart) & ($\checkmark$Results to worksheet) & ($\checkmark$Add factor to original data: Moving window).

The resulting control chart looks like this:



This shows that there have been significant 'jumps' of change in the bird assemblages over time, and that those shifts have occured more often in more recent years. Specifically, we have identified (based on the 17-year moving window) that a significant shift occured in 2001, 2008, 2011 and again in 2015.

Super-imposed on the original nMDS ordination, we can see these significant shifts as well. It is perhaps easiest to see them, however, in a 3D plot, and drawn without the initial 17 time-points, thus:



The above results may well change if we alter our choice of window size. Note also that another tool we might consider using here is the SIMPROF tool in a CLUSTER analysis, which can also be used to find significant 'breaks' in a time-series of samples.

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