

# Moose Trend Analysis

## User's Guide

**Robert A. DeLong and Brian D. Taras**  
**Alaska Department of Fish and Game**  
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A user account is required for access to this website and software. A user account can be obtained by contacting the author at: [rob.delong@alaska.gov](mailto:rob.delong@alaska.gov)

Electronic copies of this publication can be obtained from our website at:  
[http://winfonet.alaska.gov/sandi/trend/pdf/moose\\_trend\\_analysis.pdf](http://winfonet.alaska.gov/sandi/trend/pdf/moose_trend_analysis.pdf)

### *Conventions Used In This Document*

The following typographical conventions are used in this user's guide:

Text format	Description
<i>Italics</i>	Names of menus, pages, or forms
<a href="#">Blue, underlined</a>	Hyperlink
<b>Shaded Boxes</b>	Screen buttons
<b>Arial, bold</b>	Form fields
ARIAL ALL CAP	Section titles on screen
<CTRL>	Keys on the keyboard

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## I. DESCRIPTION

### OBJECTIVE

To provide an analytical tool for estimating trend in moose populations and improving survey estimates of abundance. This analytical tool requires 5 or more survey estimates of abundance for the same survey area (Kellie and DeLong, 2006). The description that follows assumes that the survey estimates of “observable” moose (and their variances) have been inflated by sightability correction factors (SCFs) estimated for each and every survey. If this is not the case, inference will need to be further qualified (see section “Interpretation and Cautions”).

Our experiences indicate that trend analysis often is not as straight forward as one might expect. Although we make an effort to identify and address aspects of this complexity, the manual is by no means comprehensive in this regard. Therefore, we recommend consulting a biometrician to ensure proper analysis and interpretation. In addition, as time series increase in length, trend analysis will become more complex and we anticipate an increased need for biometric assistance.

### MIXED EFFECTS MODEL:

The series of R functions implementing this model were authored and provided by JM Ver Hoef. Trend and abundance are combined in this mixed effects model (Zhang et al. 1998, McCulloch and Searle, 2001) as

$$y_i = \lambda_0 + \lambda_1 t_i + \lambda_2 t_i^2 + \gamma_i + \varepsilon_i, \quad \text{Model Equation}$$

where:

$y_i$  is the survey estimate of true abundance at the  $i^{\text{th}}$  time;

$\varepsilon_i$  is the sampling error associated with  $y_i$ ;

$\gamma_i$  is the random effect associated with the  $i^{\text{th}}$  time; and,

$\mu_i \equiv \lambda_0 + \lambda_1 t_i + \lambda_2 t_i^2$ , is trend, a fixed effect that is a function of only time,  $t_i$ .

In this model, estimates of abundance are “improved” over survey estimates by “borrowing” strength from the complete data set. The improved estimates lie closer to the trend line and have tighter confidence intervals. We will refer to these improved estimates as “smoothed” estimates. Trend may be modeled as a first order polynomial (linear) or a 2<sup>nd</sup> order polynomial (quadratic). Autocorrelation in abundance is not modeled nor are covariate effects explicitly incorporated.

## II. USING THE TOOL

The trend analysis software is hosted on the Alaska Department of Fish and Game (ADF&G) Intranet at <http://winfonet.alaska.gov> (Winfonet). A user account is required for access to this website. A user account and the appropriate permissions to access the trend analysis tool can be obtained by contacting Rob DeLong by email at [rob.delong@alaska.gov](mailto:rob.delong@alaska.gov).

From the Winfonet main menu, navigate to the trend analysis software by clicking the [Survey and Inventory Tools](#) link in the gold sidebar and then clicking the [Trend Analysis](#) link which appears in the gold sidebar below the [Survey and Inventory Tools](#) link.

This will bring you to the *Trend Analysis Main Menu* (Fig 1.)



**Figure 1** *Trend Analysis Main Menu*

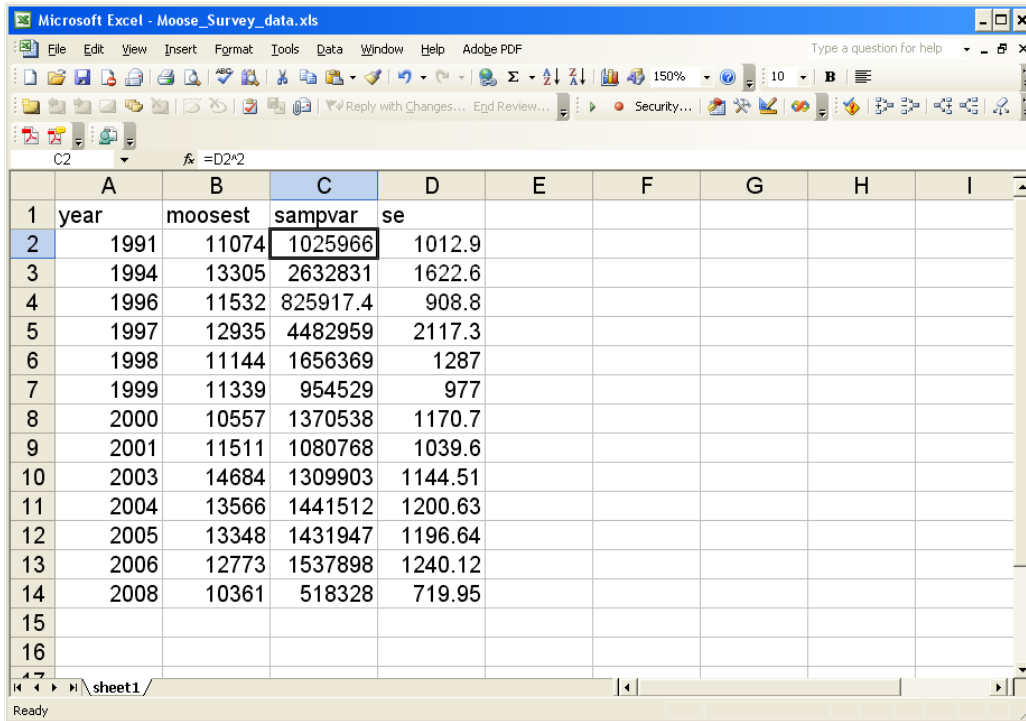
The software provides two options for entering a series of abundance estimates for analysis. You can upload a series of estimates from an Excel file, or you can manually enter a series of estimates for analysis. The software does not apply the SCF to estimates of “observable moose” and its variance; therefore, these calculations must be performed beforehand and uploaded as SCF corrected estimates of abundance.

### **ANALYZING FROM EXCEL**

To upload a series of abundance estimates contained in an Excel file, you must provide a spreadsheet with named columns containing the year of each estimate, your estimate values, and the variance for each estimate. The name of each column should be placed in the first row of the spreadsheet and the relevant values in each column in subsequent rows. As noted above, you will need to provide at least 5 estimates of abundance to run this analysis.

Your spreadsheet may also contain any number of additional columns. During the analysis you specify which columns in the spreadsheet are to be considered for that particular run. Other columns are ignored for that analysis. Values in the columns may be either numeric values or the result of Excel formulas within the spreadsheet. For example, if you have been provided with a standard error for an estimate, you may utilize an Excel formula to produce a column containing the square of that value for use as the variance term in the trend analysis. An example of a correctly formatted Excel spreadsheet can be seen in figure 2. Note that the ‘sampvar’ column in this example contains an Excel formula that provides the square of the ‘se’ column

value.

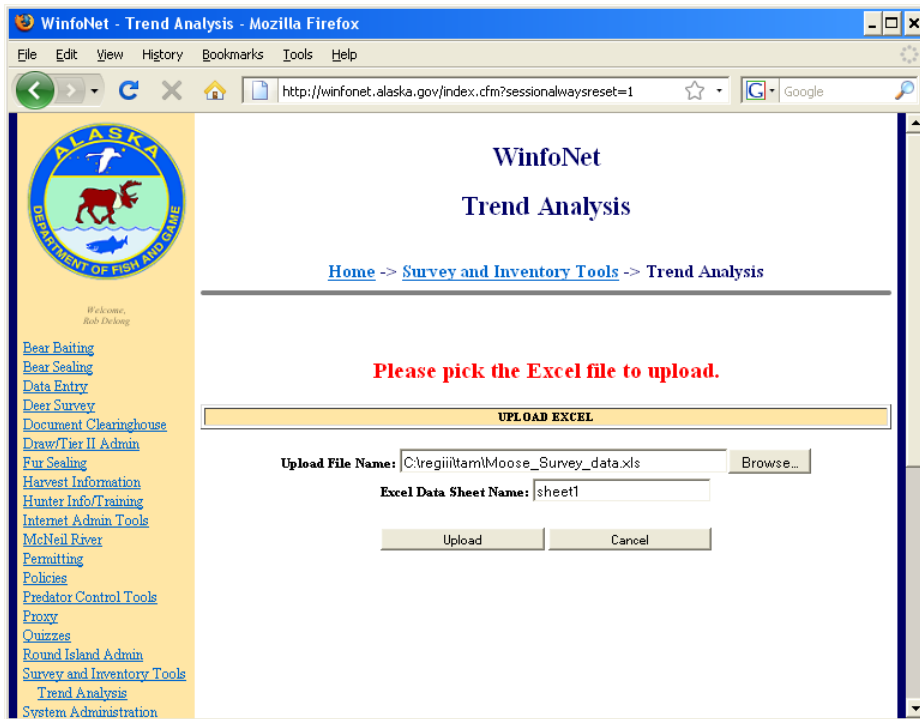


The screenshot shows a Microsoft Excel spreadsheet titled "Moose\_Survey\_data.xls". The spreadsheet has four columns: "year", "moosest", "sampvar", and "se". The data is as follows:

	A	B	C	D	E	F	G	H	I
1	year	moosest	sampvar	se					
2	1991	11074	1025966	1012.9					
3	1994	13305	2632831	1622.6					
4	1996	11532	825917.4	908.8					
5	1997	12935	4482959	2117.3					
6	1998	11144	1656369	1287					
7	1999	11339	954529	977					
8	2000	10557	1370538	1170.7					
9	2001	11511	1080768	1039.6					
10	2003	14684	1309903	1144.51					
11	2004	13566	1441512	1200.63					
12	2005	13348	1431947	1196.64					
13	2006	12773	1537898	1240.12					
14	2008	10361	518328	719.95					
15									
16									

**Figure 2** Sample Excel Spreadsheet

To upload your spreadsheet for analysis, select [Analyze Trend from Excel](#) from the *Trend Analysis Main Menu* (fig 1). This will take you to the *Upload Spreadsheet* page (fig 3).



**Figure 3** Upload Spreadsheet Page

To select the file you wish to upload, click the **Browse** button, then navigate to the Excel file on your hard drive. You can also specify the name of the worksheet in the Excel file that contains your data. If you do not specify a worksheet name, the system will attempt to read data from a worksheet named Sheet1 in your uploaded Excel file.

Once you successfully upload the Excel file, you will be asked to specify which columns to use in the trend analysis (fig 4).

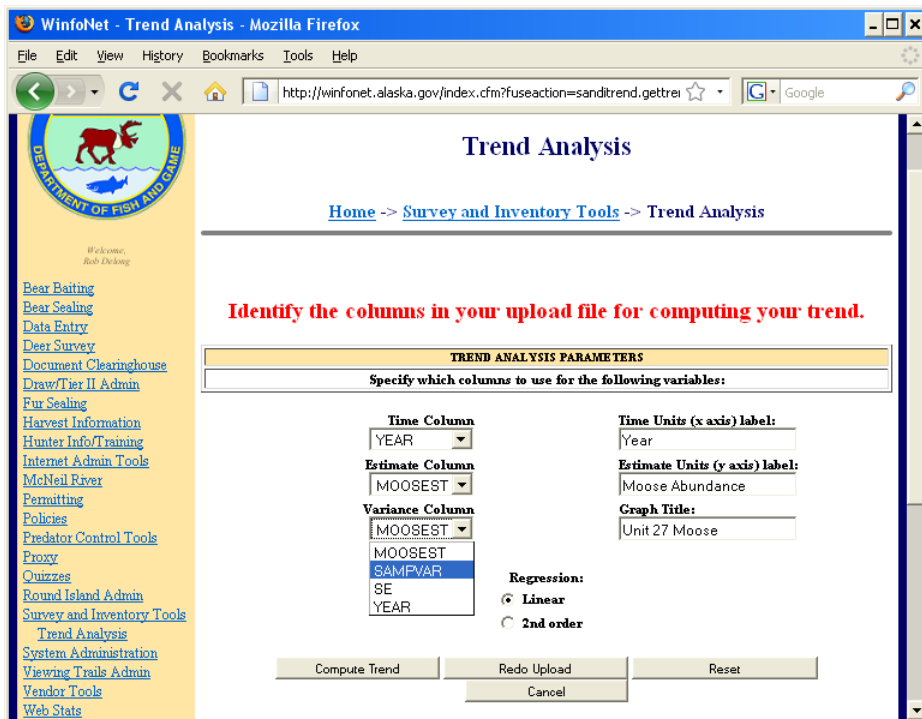


Figure 4 Trend Analysis Parameters Page

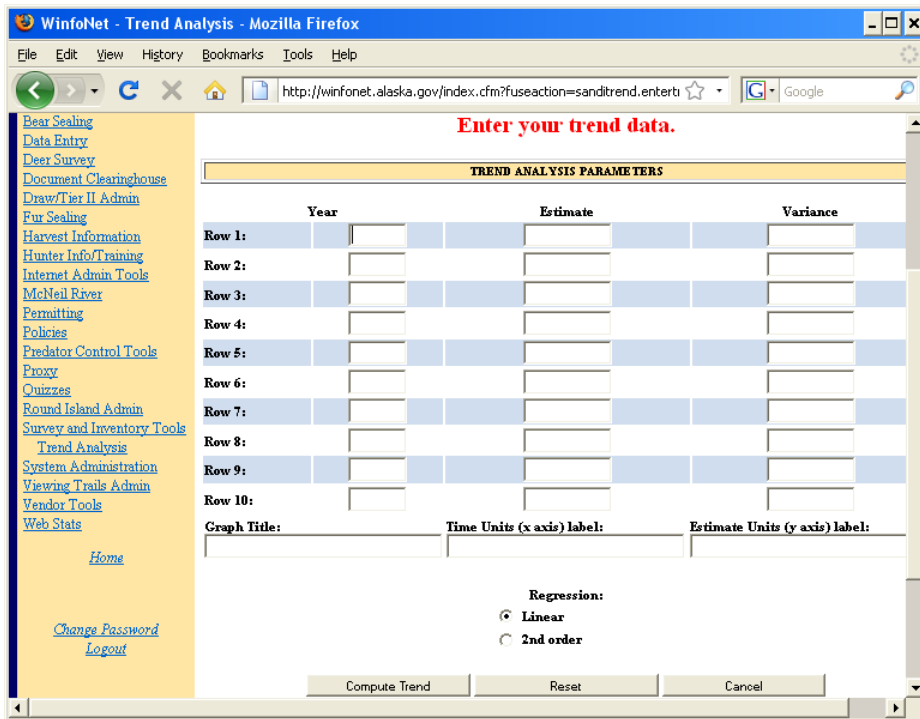
You will need to specify the columns containing your time, estimate, and variance variables.

This screen also provides you with the option of specifying a title and axis labels for the graph produced during the analysis.

You are also asked to select between a linear or 2<sup>nd</sup> order (quadratic) trend for modeling the data. The linear model is used by default.

## MANUAL ENTRY OF ESTIMATES

If you have a small number of estimate values to analyze, you may wish to enter the values directly into the system. To do this, select [Analyze Trend Manually](#) from the *Trend Analysis Main Menu* (fig 1). This will take you to the *Trend Data Entry* page (fig 5). Direct entry of a series of abundance estimates is limited to a maximum of 10 records. If you need to analyze a longer series, you must utilize the Excel upload feature of the tool.



**Figure 5** Trend Data Entry Page

Enter the year, estimate, and associated variance values for each abundance estimate. You will need to enter a minimum of 5 estimates to proceed with the analysis.

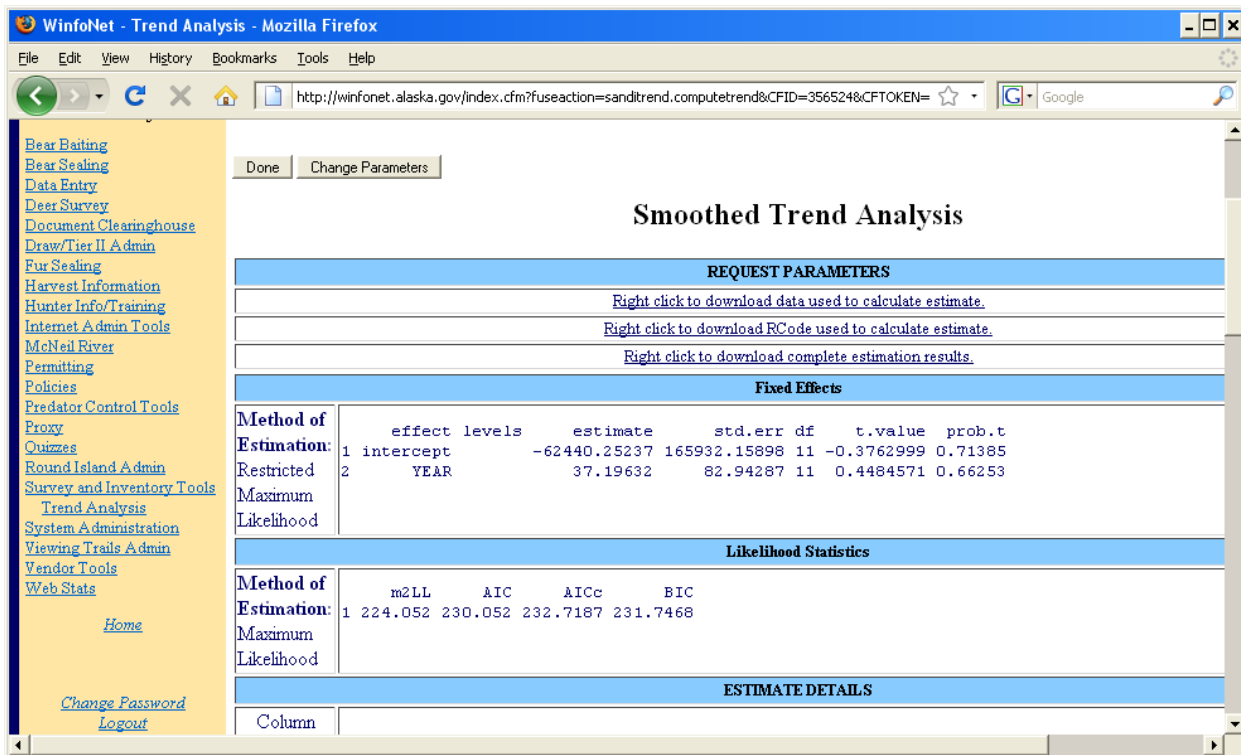
Similar to the Excel upload process, this screen provides the option of specifying a title and axis labels for the graph produced during the analysis.

You are also asked to select between a linear or 2<sup>nd</sup> order (quadratic) trend for modeling the data. The default is use a linear model.

### III. INTERPRETING THE RESULTS

#### OUTPUT:

The output of the trend analysis tool is formatted into several sections. The first section provides links that allow you to access and download the data set used in the analysis, the R code that was executed for the analysis, and the tables generated by the analysis. These links are provided under the section labeled REQUEST PARAMETERS (fig 6).



**Figure 6** Trend Analysis Output (linear model)

You may directly view the contents of these links by clicking on them with your left mouse button. If you would like to save the files to your hard drive, then right click on the appropriate link and choose “Save Link As” (Firefox) or “Save Target As” (Internet Explorer).

The fixed effects estimates and tests of significance are provided in The **FIXED EFFECTS** section of the output (fig 6). These parameters are estimated using the method of restricted maximum likelihood (REML). For a linear trend model the slope and its standard error are provided in the row “YEAR”. Assuming negligible autocorrelation, the significance of the slope can be determined using the p-value listed in the second row (in the final column, which is labeled “prob.t”).

For the 2<sup>nd</sup> order (quadratic) trend model the coefficient values and their standard errors are listed in the rows “YEAR” and “YEAR2” (fig 7). The associated significance test results for this model cannot be used to evaluate the importance of these polynomial coefficients. Instead, likelihood statistics that are estimated using the method of maximum likelihood (ML) are provided for this purpose (see section “Interpretation and Cautions”) in the **LIKELIHOOD STATISTICS** (figs 6 and 7) section of the output.



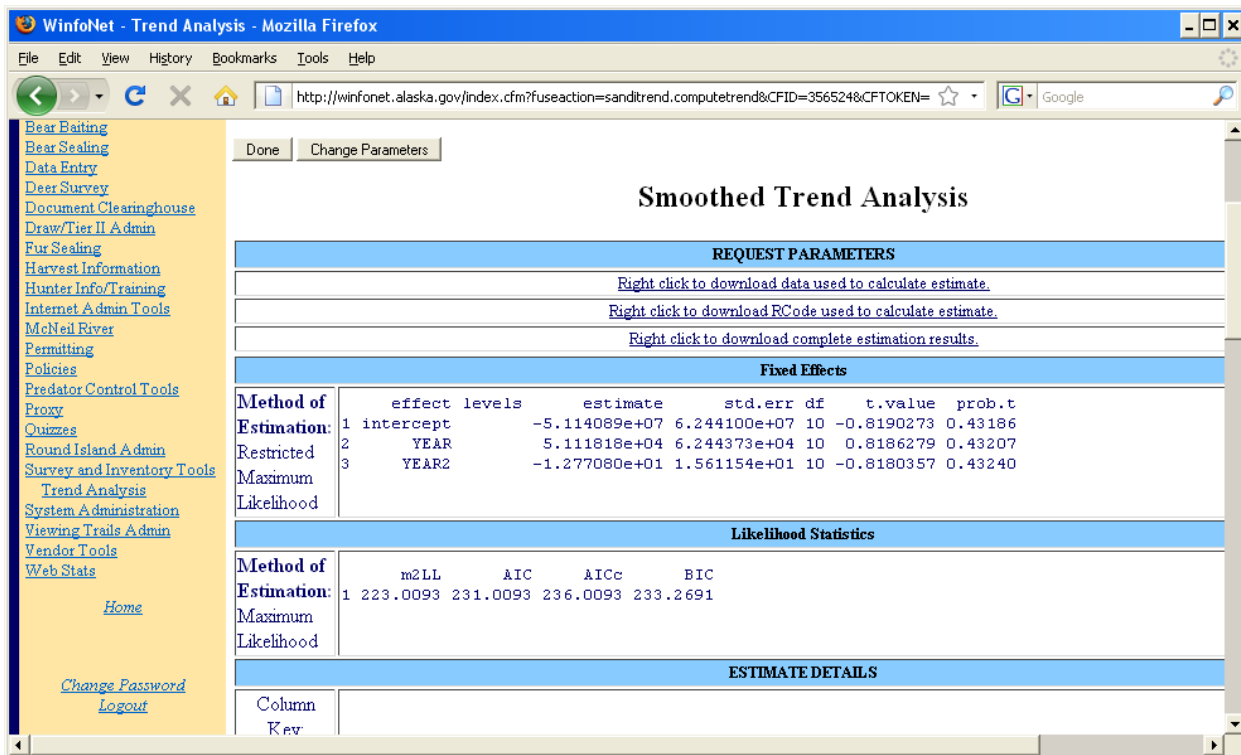


Figure 7 Trend Analysis Output (quadratic model)

As stated above, the mixed effects model provides trend line estimates and smoothed estimates of abundance using your survey estimates. The smoothed estimates of abundance are linear combinations of the trend estimates and the random effects. Parameter estimates and test of significance for the random effects along with covariance parameter estimates are provided, but not displayed. You can view these statistics in the file accessed through the link titled [Right click to download complete estimation results](#) located in the REQUEST PARAMETERS section of the output. These parameters are estimated using REML. The random effects are included in the model regardless of their significance. If all the random effects are highly insignificant, the model effectively reduces to a weighted regression with weights equal to the inverse of the variance associated with the survey estimates of true abundance ( $y_i$ 's). This will be the case when the smoothed estimates end up lying on the trend line.

The ESTIMATE DETAILS section (fig 8) displays the trend and smoothed abundance estimates provided by the model. These parameters are estimated using REML.

The table contains the contents of your original data set in the time, Y, and Yse columns, where time=year of the estimate, Y=your original estimate and Yse=the standard error associated with your original estimate. The mu.\* columns (in terms of the model formula,  $\mu_i$ 's) provide the estimated trend values and 95% confidence intervals for each time value, where mu contains the trend value and mu.se contains the standard error of that estimate. Mu.uci and mu.lci respectively contain the 95% upper and lower confidence limits for each time value.

Similarly, the theta.\* columns provide the smoothed estimates of true abundance (in terms of the

model formula,  $\theta = \mu_i + \gamma_i$ ) and their 95% confidence intervals for each time value, where  $\theta$  contains the smoothed estimate and  $\theta.se$  contains the standard error of that estimate.  $\theta.uci$  and  $\theta.lci$  respectively contain the 95% upper and lower confidence limits for each time value.

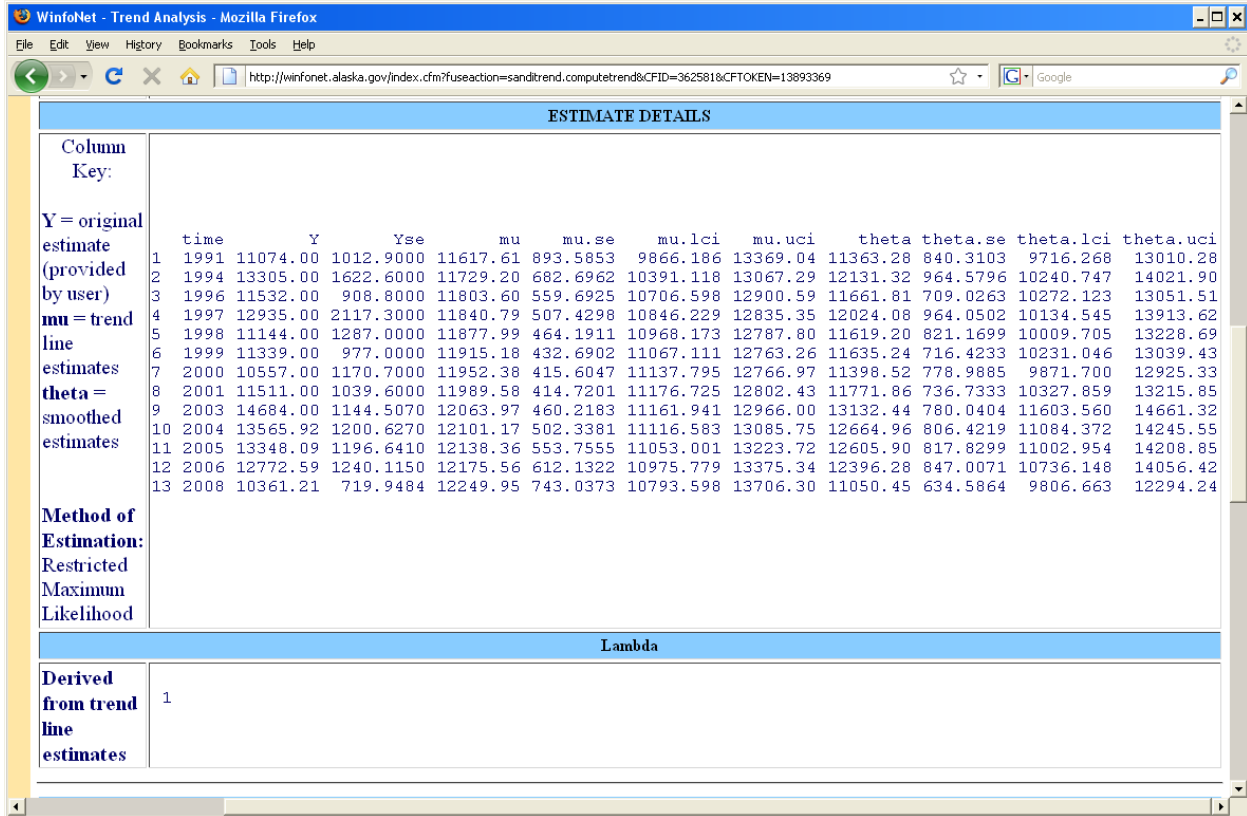


Figure 8 Trend Analysis Output (details of the estimate)

The first and last trend line estimates,  $\mu_i$  and  $\mu_f$ , are used to calculate the finite rate of population growth ( $\lambda$ ) as follows:

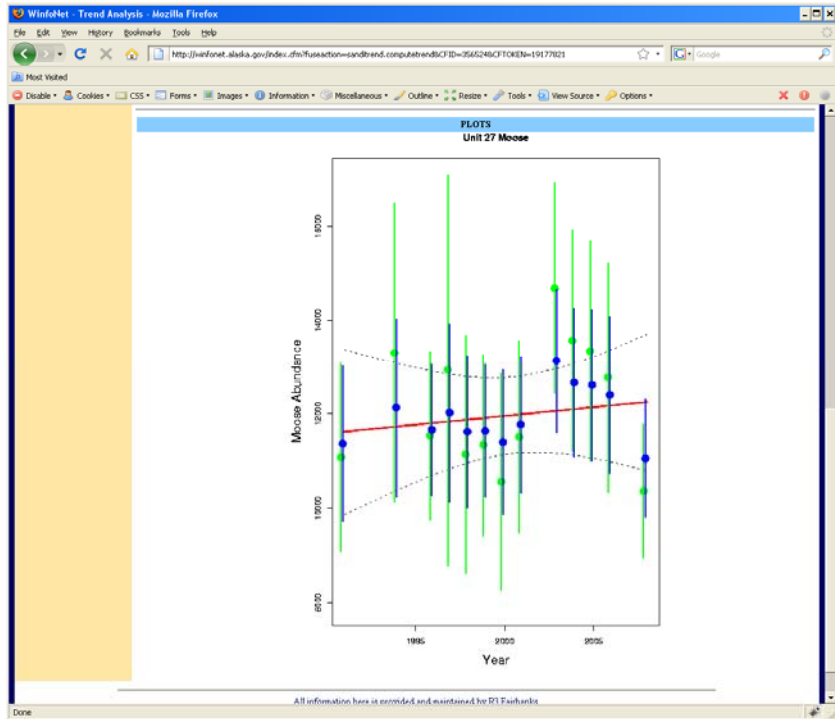
$$\lambda = \left( \frac{\mu_f}{\mu_i} \right)^{\frac{1}{(t_f - t_i)}}$$

where  $t_i$  and  $t_f$  are the initial and final years of the time series.

This calculation assumes that  $\lambda$  is constant between  $t_i$  and  $t_f$ , which may not be the case (for example, a quadratic fit may indicate an increasing then decreasing trend). The standard error for  $\lambda$  is not provided. The significance of your trend should be determined as described above.  $\lambda$ , rounded to 2 digits, is displayed below the ESTIMATE DETAILS in the output (fig 8).

The final section of the output, labeled PLOTS (fig 9), contains a graph of the original sampling and smoothed estimates together with their 95% confidence intervals. Additionally, the

estimated trend and its associated 95% point-wise confidence interval are plotted. To improve the readability of the graph, survey estimates and “smoothed” estimates for the same time are “jittered” or displaced by a small amount of time.



**Figure 9** Trend Analysis Output (graph)

**INTERPRETATION AND CAUTIONS:**

If estimates of “observable moose” are used in the analysis instead of estimates of abundance (i.e., estimates of “observable” moose adjusted by survey specific SCFs), then two additional considerations are necessary. First, using “observable” moose as an index for the population assumes that the true SCF was the same for each survey or that it varied randomly about a fixed mean. If this is not the case, estimates of trend will be biased, as will be the “smoothed” estimates of abundances. Even if the true SCF is constant though time, trend estimates from the analysis of “observable” moose will differ from those obtained using estimates of “observable” moose adjusted by a constant SCF. For example, an SCF = 1.2 applied to an increase in “observable” moose from 5,000 to 6,500 over 5 years (a slope of 300 moose/year) would result in an increase in estimated moose abundance from 6,000 to 7,800 (a slope of 360 moose/year). Note that the slope obtained using the SCF corrected survey estimates is equal to the SCF times the slope obtained from the analysis of observable moose. In both of these cases, the annual population growth rate is 6%; however, the example indicates that trends in terms of number of moose per year will be underestimated if not corrected for sightability.

Second, because the SCFs are estimated (e.g., by using radiocollared moose) there is uncertainty associated with these values that needs to be taken into account. As a result, applying SCFs not only results in adjusted point estimates but also increases the variance associated with estimates of total abundance. Because the analyses of observable moose fails to account for the sample

variance associated with SCFs, the resulting smoothed estimates will be biased in that they will lie further from the trend line and have smaller variances (and CIs) than appropriate. Trend line results (i.e., fixed effects) obtained using this mixed effects model are fairly robust to this variance effect. However, care must still be taken not to compare smoothed estimates obtained through the analysis of estimates observable moose in a separate analysis (e.g., a t-test to assess the significance of a difference between the first and last year's smoothed abundance estimates will produce biased results). Applying even a constant SCF (and its variance) to the estimates of "observable moose" helps mitigate the magnitude of these potential biases.

If there is a statistically significant linear trend, then a model selection approach may be used to determine if a model with 2<sup>nd</sup> order (quadratic) trend is more appropriate. The model selection criterion AICc (Not AIC nor BIC) can be used to compare these models following methods described in Burnham and Anderson 1998. AICc, which is provided in the output, accounts for small sample sizes, which will be the case for nearly all moose trend analyses for the near term. This approach requires at least 6 survey estimates; otherwise, the AICc value will equal infinity (reported as "Inf") and the comparison is not possible. Testing the significance of the quadratic model by comparing it to a statistically significant linear trend guards against inadvertently identifying a quadratic model as a statistically significant fit when it is not; however, this approach is not without the potential for misinterpretation. For example, a population may increase for a number of years then decrease for a number of years resulting in little net gain or loss over the entire time period and an insignificant linear trend, but a quadratic model may provide an acceptable fit. In its current form, this software does not allow for an independent assessment of the quadratic model.

Relatively short time series will likely be fit best by 1<sup>st</sup> order (linear) trend models and a quadratic model may be better suited for longer time series (e.g., 10-20 years); particularly if smoothed estimates are desired. In fact, fitting a linear trend to data for which a quadratic (or a higher order polynomial) model is a better fit will result in biased smoothed estimates. In some situations it may be appropriate to break long time series into shorter segments to evaluate trend. An additional word of caution is in order relative to the possible effects of autocorrelation. Autocorrelation, if significant, will bias the selection towards the 2<sup>nd</sup> order (more complex) model.

As the time series lengthens, a long steady increasing or decreasing trend has the potential for "masking" or delaying the recognition of a change in trend. One clue that this may be happening will be that the most recent survey estimates of true abundance ( $y_i$ 's) fall above or below the trend for a number of consecutive years. In addition, biological parameters other than abundance (e.g., twinning rates) may provide evidence for a change in trend. If such evidence supports a change in trend that is not identified during your trend analysis, we recommend you contact your biometrician.

The paragraphs in this section are intended to serve as an admonition: performing trend analysis and interpreting the results may not be straight forward. As a result we strongly advise the user to consult a biometrician.

#### **IV. ACKNOWLEDGEMENTS**

Special thanks to JM Ver Hoef for authoring the statistical software implementing the mixed model and for consenting to allow its use by the Alaska Department of Fish and Game on Winfonet.

#### **V. LITERATURE CITED:**

- Kellie KA and RA DeLong. 2006. Geospatial survey operations manual. Alaska Department of Fish and Game. Fairbanks, Alaska, USA.
- McCulloch, CE and SR Searle. 2001. Generalized, Linear, and Mixed Models. Wiley Series in Probability and Statistics. John Wiley & Sons, Inc. New York, USA.
- Burnham KP and DR Anderson. 1998. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2<sup>nd</sup> Edition. Springer-Verlag. New York, USA.
- Zhang, Daowen, Xihong Lin, Jonathan Raz, and MaryFran Sowers. 1998. Semiparametric Stochastic Mixed Models for Longitudinal Data. Journal of the American Statistical Association. Vol. 93, No. 442, pp. 710-719.