DENDROECOLOGY PROGRAM LIBRARY - PROGRAM OUTBREAK USERS MANUAL

Detecting Outbreaks of Spruce Budworm and Tussock Moth in Annual Tree-Ring Growth, and Distinguishing Between the Insect Species

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INTRODUCTION

In April 1993 Dr. Thomas W. Swetnam, head of the Fire History group at the Laboratory of Tree-Ring Research at the University of Arizona, requested that a computer program be written to assist in reconstruction and analysis of a multicentury history of outbreaks of western spruce budworm (Choristoneura occidentalis Freeman) and Douglas-fir tussock moth (Orgyia pseudotsugata McDunnough) in Oregon.

Data for this study consisted of sets of annual series of tree-ring width measurements of tree species that serve as hosts to the insects and of control species that do not serve as hosts. From previous work we know that characteristic tree-ring patterns caused by these two insects, known as signatures, may be detected and quantified in tree-ring series. To carry out this task Richard L. Holmes developed Program OUTBREAK, using VAX-VMS Version 6.1 (1993) ANSI Fortran-77 programming language and the University's VAX mainframe computer. Subsequently the program was adapted for Microsoft "PowerStation" (1993) Fortran-77 to run on PC-compatible computers of level 386 or newer.

Features were added to the program as researchers used it to study insect outbreaks. The program may be used for studies similar to this in other locales and with other pests.

PURPOSE OF PROGRAM OUTBREAK

Program OUTBREAK attempts to identify occurrences of spruce budworm and tussock moth outbreaks in indexed series of annual tree-ring width measurements, and to distinguish between outbreaks by the two species. The length and severity of each outbreak is quantified and presented in tables and graphically for each tree and for the mean of all trees. A year-by-year list is printed showing departures and count of trees affected by outbreaks. Histograms show distributions of outbreak length, maximum growth reduction, mean periodic growth reduction and maximum rate of growth reduction. The corrected mean series is listed. A file is produced which may be read directly by spreadsheet and graphics programs.

Upon starting Program OUTBREAK the user gives a run identification of up to five letters and numbers which will identify files created by the program. If no name is given, then "ZZ" is the run identification.

The user provides the names of two (or one) input data files. If two files, the first is a tree-ring control (non-host) index chronology; the second is a set of experimental tree-ring index series, each usually representing individual trees. If only one file, this is a set of experimental tree-ring index series already corrected with a control chronology or not needing correction.

The control chronology, from a species unaffected by these insects, is subtracted from each experimental series to diminish the effects of climatic variation.

A title may be given to describe the run, then a menu of control options which the user may modify.

The following appears on the screen as the program runs. Text typed by the user appears in bold:

*=
==*=*=*

DENDROECOLOGY PROGRAM LIBRARY

P R O G R A M   O U T B R E A K

Finds Outbreaks of BUDWORM and TUSSOCK

Version 1.50P

*=
==*=*=*

Identify job (up to 5 letters) => ABCDE   (In this example, this is the identification for files)

Provide the names of files with
  (1) CONTROL (NON-HOST species) chronology, and
  (2) HOST species experimental tree indices or chronologies

If you respond with <CR> to the CONTROL chronology prompt, the TREE-GROWTH
indices or chronology will be considered to be already corrected.

CONTROL CHRONOLOGY (Non-host)
  ... Name of EXISTING INPUT file => CONTROL.DAT

```
First 5 lines of file CONTROL.DAT
524=N    1469=I Ctrl_A
-5(13F6.0)
183503149290130316 98827 98021 57144
93379115283144453182103160605135777108928
 80869 56846 81879 30804 76632 85818 76330 34742 54224 58162 46654
41305 18794
 17683 36561 39287   522135697 87039 75733 54927 97020
88493134429138973124737
13523712751112504113862111398910505516537515951710389212004310060 9
80616 71540
....:....
1....:....2....:....3....:....4....:....5....:....6....:....7....:....
8
Format is Compact, correct?  <Yes>/No => <CR>

HOST TREE INDICES or CHRONOLOGIES
  ... Name of EXISTING INPUT file => SPRUCE.DAT

First 5 lines of file SPRUCE.DAT
107=N    1885=I Spruce
-5(13F6.0)
151504 91983 98648105514 98116 95978110323 97063129198112198129061
89229128924
14385811949415189814187 9 92890 73192 71768 52886 63070 77692 78993
69399 69894
 60102 77940 907341153161473511248 58 95520 86843 84010 87020 75125
57293 80944
101889118553 98546116311108059 937861105401223701241611390961303 48
87388 72027
....:....
1....:....2....:....3....:....4....:....5....:....6....:....7....:....
8
Format is Compact, correct?  <Yes>/No => <CR>

TITLE FOR THIS RUN => Spruce tree summaries and Control chronology A

A menu then appears on the screen, listing the options and current
selected values:

Options:                                              Current values

       P  Names of pests                              BUDWORM TUSSOCK

Maximum growth reduction threshold in STD DEV
       1  BUDWORM                                        -1.28
       2  TUSSOCK                                        -1.28

Minimum number of years for outbreak
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```
       3  BUDWORM                                                 8
       4  TUSSOCK                                                 3

Maximum years to count in outbreak
       5  TUSSOCK                                                 4
       6  Rate of increase in growth reduction to
            identify TUSSOCK outbreaks                      1.000

       7  File for plotting with PAGEPLOT                         N
       8  File of negative corrected indices                      N
       9  Fractional power for control indices > 1           1.0000

Number of option to modify or <CR> to proceed => 9            (In this
example, you select item 9)

Fractional power to raise Control chronology indices greater than 1.0
to avoid false corrections

Power to raise indices > 1.0  (0. to 1.) => .3

The menu reappears on the screen, listing current selected values.
The one that was changed was:

9  Fractional power for control indices > 1.0     .3000

Finally, touching Enter (<CR>) in response to the prompt starts
execution of the program:

Number of option to modify or <CR> to proceed => <CR>

Files created by the program are:

      ABCDEOBR.OUT   output for printing
      ABCDEOBR.COR   tree indices corrected, Measurement format
      ABCDEOBR.MNC   mean of corrected tree indices, Measurement
format
      ABCDEOBR.NOR   tree indices corrected, normalized, Compact
format
      ABCDEOBR.DIF   differences, uncorrected minus corrected, Compact
format
      ABCDEOBR.COL   data in tab-delimited columns for spreadsheet
           OBR.CRN   mean chronology in publication format, appended

And if you choose menu item 7, "File for plotting with PAGEPLOT":
      ABCDEOBR.PLU         Uncorrected experimental indices & control
to plot overlaid

OPERATION OF PROGRAM OUTBREAK

Correcting by means of the control chronology
```

The control chronology is read, then one by one the experimental tree-ring index series are read. For each series descriptive statistics for the common time span of the control chronology and experimental series are printed. If requested, these series and their differences are saved on disk file for plotting.

Each yearly index value in the experimental series is corrected by subtracting from it the corresponding control chronology index, adjusting for differences in the means and standard deviations of both series by the equation:

$$Hc(i) = Hi(i) - (Ci(i) - Cmn)\ Hsd / Csd$$

where Hc(i) is the host chronology corrected index for year (i)
Hi(i) is the host tree-growth index for year (i)
Ci(i) is the control chronology index for year (i)
Cmn is the control chronology mean in the common time span
Hsd is the host series standard deviation in the common time span
Csd is the control chronology standard deviation in the common time span

If negative values occur in the corrected experimental series, they are set to zero.

If menu item 9 was set to a value less than 1.0, each index in the control chronology exceeding 1.0 is raised to the specified fractional power before subtracting it from the experimental series, but the original mean and standard deviation are used in the equation. The purpose of this adjustment is to suppress the effect of large positive excursions in the control chronology which, when subtracted from the experimental series, will introduce apparent growth depressions that may be erroneously diagnosed as insect outbreaks.

If the user has not provided the name of a control chronology file, the experimental series are considered to be already corrected or to need no correction, and the process just described is not done.

After reading all tree-ring index series, mean series and descriptive statistics are computed for:

(1) Mean of corrected tree-ring indices
(2) Mean of normalized corrected tree-ring indices
(3) Differences, uncorrected minus corrected series

Processing the corrected series

Each corrected experimental series is scanned as described below for evidence of insect outbreaks over its entire time span, or over time spans specified by the user.

Spruce budworm outbreaks

To locate spruce budworm outbreaks, a preliminary scan flags with "b" all years in the normalized series that are negative, that is, where experimental tree growth is less than growth in the control chronology.

Since during a budworm outbreak there may occasionally be a single year where growth is normal or above (meaning growth increase rather than reduction), the outbreak is allowed to have up to one positive value between negative values within the outbreak period before the year of maximum growth reduction, and one such value after that year. If more than one is found the potential outbreak span is shortened accordingly and the new outbreak span is checked again.

The first and last years of potential budworm outbreaks are determined by locating the ends of consecutive strings of flagged years.

Each potential budworm outbreak is checked for compliance with the selected values in the menu. If it does not attain the threshold in standard deviations for maximum growth reduction or the minimum length for budworm outbreaks it is eliminated as a possible outbreak. Maximum growth reduction and percentage of growth reduction is calculated, and the maximum year-to-year increase in growth reduction is found. The year of maximum growth reduction is flagged with a capital "B".

Mean periodic growth reduction is summed over the span of each outbreak. Information on spruce budworm outbreaks for the experimental tree-ring series is recorded.

Tussock moth outbreaks

A procedure similar to that for spruce budworm is followed for tussock moth. To locate tussock moth outbreaks, a preliminary scan flags with "t" all values in the normalized series that are negative. The first and last years of potential tussock outbreaks are determined by locating the ends of consecutive strings of flagged years.

Each potential tussock moth outbreak is checked for compliance with the selected values in the menu. If it does not attain the threshold in standard deviations for maximum growth reduction or the minimum length for tussock outbreaks, or if the rate of increase in growth reduction fails to meet the threshold, it is eliminated as a possible outbreak. Only the first four years (by default) are

considered to be part of the tussock outbreak, and the outbreak is eliminated if it does not have four years by the end of the series. Maximum growth reduction and the percentage of growth reduction is calculated, and the maximum year-to-year increase in growth reduction is found. The year of maximum growth reduction is flagged with a capital "T".

Mean periodic growth reduction is summed over the span of each outbreak. Information on tussock moth outbreaks for the experimental tree-ring series is recorded.

Tabulation of outbreaks by series

A listing of outbreaks is printed for each tree, indicating which insect was determined to be responsible, the time span of the outbreak, year and amount of maximum growth reduction, the mean periodic growth reduction, and the year and amount of maximum year-to-year increase in growth reduction. If an outbreak fits the criteria established for both insects, it may be attributed to both; the time span and other characteristics may however be different.

Following the listing a two-line time plot is printed, one line for budworm, one for tussock, covering one century across the page. For each year is indicated whether there was determined to be no outbreak ("."), a budworm ("b") or tussock ("t") outbreak, or a maximum growth reduction year for a budworm ("B") or tussock ("T") outbreak.

Yearly list of departures and counts

A yearly list of departures is printed for each tree, one column per year, a decade per section. Each departure value is flagged as above if it is in a budworm ("b") or tussock ("t") outbreak, or if it is a maximum growth reduction year for a budworm ("B") or tussock ("T") outbreak. At the foot of the column for each year are counts of the number of trees, the count of infested trees ("ct") and the count of trees in maximum growth reduction ("mx") in the outbreak, for budworm and tussock.

Plot of outbreaks by series and year

The next section of printed output is a condensed version of the two-line time plot described above in the section on tabulation of outbreaks by series, allowing an overview of outbreak intervals. The corrected mean series is also included in this plot with the same analysis as is done for individual trees.

Histograms

A set of histograms presents the distribution of counts of

outbreaks for spruce budworm ("[" toward the left) and tussock moth ("]" toward the right) for:

(1) Length of outbreak in years
(2) Maximum growth reduction as departure in standard deviations
(3) Maximum growth reduction as corrected index
(4) Maximum growth reduction as percent
(5) Mean periodic growth reduction
(6) Maximum rate of increase of growth reduction

Corrected mean series

Finally the corrected mean series is listed, showing annual indices and number of trees.

Data file in tab-delimited columns for spreadsheet

A disk file is produced which may be read directly by spreadsheet and graphics programs. The file name is ABCDEOBR.COL. The ten tab-delimited columns in this file contain:

(1) Year
(2) Number of trees in the analysis
(3) Count of trees in a BUDWORM outbreak event
(4) Percent of trees in a BUDWORM outbreak event
(5) Count of trees in a BUDWORM year of maximum growth reduction
(6) Count of trees in a TUSSOCK outbreak event
(7) Percent of trees in a TUSSOCK outbreak event
(8) Count of trees in a TUSSOCK year of maximum growth reduction
(9) Mean corrected tree index
(10) Normalized corrected mean index

Program capacity

Maximum length of tree-ring series	4096 years
Maximum time span of tree-ring series	2076 BC to AD 2020
Maximum number of trees	2560
Maximum number of outbreaks per series	128