Example of an Ecological Data Set
Oak Woodlands in the Willamette Valley, Oregon, USA

In 1961 and 1962 John F. Thilenius sampled vascular plants in oak forests in the Willamette Valley for his Ph.D. at Oregon State University (Thilenius 1963, 1968). The data came from a fairly narrow range of habitats – all of the stands were closed forests dominated by *Quercus garryana*. This resulted in a data set with fairly low beta diversity. The environmental differences among the sites are rather modest. Much of the variation in species composition presumably is derived from the particular histories of each stand, such as episodes of grazing, logging, and fire. Of course we have limited information on those histories, so you will see that much of the variation in the plant communities is not readily explained by the measured environmental and historical variables. Nevertheless a definite environmental gradient emerges from the analysis.

The abstract from Thilenius (1968) is reproduced below:

> "*Quercus garryana* forests, prominent at low elevations throughout the Willamette Valley, Oregon, have developed from oak savanna subsequent to settlement of the valley in the mid-nineteenth century. Interruption of the ground fires that were common in the pre-settlement environment probably caused the change. The understory of the oak forest is dominated by shrubs, and well-defined strata are present. Four plant communities occur: (1) *Quercus garryana/Corylus cornuta* var. *californica/Polystichum munitum* (most mesic); (2) *Quercus garryana/Prunus avium/Symphoricarpos albus*; (3) *Quercus garryana/Amelanchier alnifolia*; (4) *Quercus garryana/Rhus diversiloba* (most xeric). All are in seral condition because of their relatively recent development and because they have been disturbed throughout their existence by man's activities. The soils supporting the oak forest are generally deep and well drained and have developed profiles with illuvial horizons and acidic reaction. They are derived from sedimentary and basic igneous rocks and old valley-filling alluvium. Seven established soil series are present: Steiwer, Carlton, Peavine, Nekia, Dixonville, Olympic, and Amity. The Steiwer series and its catenary associate, Carlton, are the most common soils."

Thilenius' goals were to describe "the floristic composition, stand structure, physical environment, and successional status of plant communities where *Quercus garryana* is the major component of the overstory." Although quantitative data were carefully recorded, Thilenius had few possibilities for multivariate analysis. His primary analyses were first arranging his data "according to similarities in species composition, importance ranks, and environmental attributes." He then tabulated averages for species and environmental variables within the four groups.

Here is an interesting challenge for modern community analysts: what can you add to his account (Thilenius 1968) based on a more sophisticated quantitative analysis of the data? I mentioned above that a single strong environmental gradient emerges from the analysis, but this is only hinted in Thilenius' abstract. What is that gradient?

After a listing of the files and variables contained in the files, three example procedures are given. The first demonstrates modification of the raw data into a form suitable for analysis. The second is an ordination with nonmetric multidimensional scaling. The third compares groups of sample units, as defined by landform.

Files Provided

OakWoods.doc – Microsoft Word file containing this document.

OakWood1.wk1 – Main matrix containing species abundances in a matrix of 47 stands x 103 species. Abundances were derived from basal areas for trees and canopy cover for other species. Some species are listed more than once because abundance was evaluated separately for different height classes, as indicated by the suffixes: t = tree, s = shrub. Species with fewer than three occurrences were deleted, then the matrix was relativized by species maximum (i.e. each element in the matrix is expressed as a proportion of the maximum value in each column). Relativization by columns is necessary for some analyses because different columns were measured in different units. See OakRaw.wk1 for the raw data.

OakWood2.wk1 – Second matrix of 47 stands x 27 attributes. The attributes are described in detail below. They include environmental variables, indicators of stand history. I have also added some community summary variables, including species richness, groups derived from cluster analysis, and community types as originally designated by Thilenius.

OakRaw.wk1 – The raw data matrix containing 47 stands x 189 species, before any modifications. The values are basal areas (ft^2/acre) for trees and percentage cover for lower strata, based on 60, 0.2 m^2 quadrats/stand. "Trace" was converted to 0.5%. A check on the field data sheet was converted to 0.2%. Be careful! Any use of these raw data must recognize that the columns representing the tree stratum differ in units from the lower strata; hence, use of a relativized matrix in OakWood1.wk1.

More on the methods from Thilenius (1968):

> "Investigations were confined to closed-canopy stands 4 ha or more in area where *Quercus garryana* was the major component of the overstory. Basal area, frequency, and density of overstory trees were determined on twenty 0.004-ha circular plots spaced at 9-m intervals in four rows parallel to the slope contour. Density was recorded in four classes: saplings (< 10 cm dbh); poles (11-40 cm dbh); mature (41-100 cm dbh) and relict (> 100 cm dbh). The maximum height of trees on each plot was measured with an optical rangefinder."
>
> "Frequency and percentage crown coverage of shrub and herbaceous species were recorded on sixty 0.2 m^2 quadrats spaced at 3-m intervals in four rows coincident with the rows of 0.004-ha plots. Very low crown coverage was recorded as trace and arbitrarily assigned a value of 0.5% for calculation purposes. Above trace, the intervals were 1% and 5%. Coverage greater than 5% was estimated to the nearest 10%."

Coding for Variables in the Second Matrix

Topographic and geographic variables

Elev,m = elevation above sea level in meters.

LatAppx = approximate latitude, decimal degrees, based on automated conversion of Township/Range/Section, using the program TRS2LL.exe.

LongAppx = approximate longitude, decimal degrees, based on automated conversion of Township/Range/Section, using the program TRS2LL.exe.

SlopeDeg = slope in degrees (originally recorded in percentages)

AspClass = aspect class, 1=SW, 2=S or W, 3=SE or NW, 4=N or E, 5=NE.

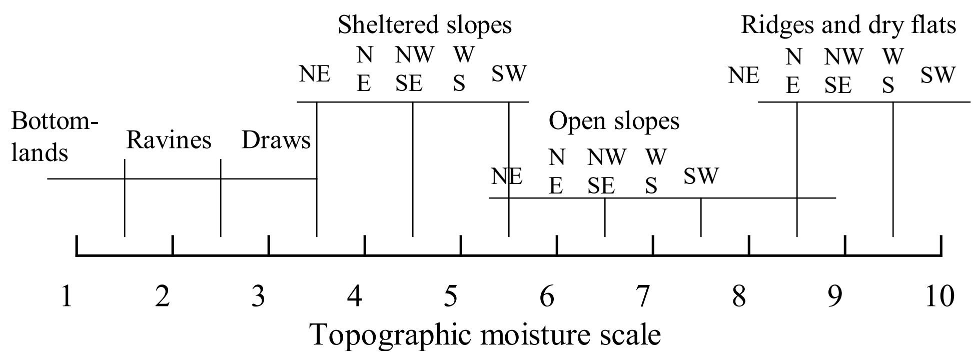
AspDeg = aspect in degrees E of N

PDIR = Potential annual direct incident radiation, MJ/cm^2/yr, calculated according to McCune and Keon (2002) Eq. 3.

HeatLoad = Heat load index, calculated according to McCune and Keon (2002).

Landform: 1=valley bottom, 2=draw or slope of draw, 3=slope, 4=ridge

TopoClas = Topographic position class: adapted from scales used by Whittaker & Kessell (Kessell 1979):



Soil variables

Drainage: 1=poor, 2=moderate, 3=good, 4=well.

Soil series: 1=Steiwer, 2=Peavine, 3=Dixonville, 4=Nekia, 5=Carlton, 6=Olympia, 7=Amity

SoilGrp: 1=sedimentary, 2=basic igneous, 3=alluvial

A-horiz = thickness of A horizon, cm

B1-horiz = thickness of B1 horizon, cm

B2-horiz = thickness of B2 horizon, cm

B3-horiz = thickness of B3 horizon, cm (if profile truncated, e.g. “44+ inches”, add 20 inches)

B-horiz = sum of B1+B2+B3, cm

Indicators of stand history

GrazCurr = signs of current grazing recorded on field data sheet (0=no, 1=yes)

GrazPast = signs of past grazing recorded on field data sheet (0=no, 1=yes, must be 1 if GrazCurr=1)

NotLogged = NPL recorded under “Influences” on data sheet. I guessed this means “no past logging", i.e. no signs of past logging.

Que>60cm = number of *Quercus garryana* recorded in the 60 cm (24 inch) size class and larger. (No stands had large *Pseudotsuga*; one stand (Stand05) had a large *Acer macrophyllum* and one stand (Stand07) had two large *Arbutus menziesii*)

LogQ>60 = log of (x+1) where x is the number of *Quercus garryana* recorded in the 60 cm (24 inch) size class and larger (i.e. x = "LogQ>60").

TreeHtM = maximum height of *Quercus garryana* in meters.

Community summary variables derived from the species matrix

SppRich = species richness, calculated from OakRaw.wk1, counting each species x layer combination as a separate species.

ThilType = vegetation types from Thilenius (1968)

1 = *Quercus/Corylus/Polystichum*

2 = *Quercus/Prunus/Symphoricarpos*

3 = *Quercus/Amelanchier/Symphoricarpos*

4 = *Quercus/Rhus*

FlxB-.25 = community types defined at the 4-group level from hierarchical cluster analysis, Flexible beta method, Sørensen distance, beta= -0.25.

List of Species Codes

Note: because woody species may occur in more than one stratum, a suffix (-s, -t) is used to indicate a given species in the shrub or tree stratum.

```
Abgr-s Abies grandis SHRUB
Abgr-t Abies grandis
Acar   Actea arguta
Acgld  Acer glabrum var. douglasii
Acma-s Acer macrophyllum shrub
Acma-t Acer macrophyllum
Acmi   Achillea millefolium
Adbi   Adenocaulon bicolor
Agha   Agrostis hallii
Agre   Agropyron repens
AGRO   Agrostis sp?
Agse   Agrostis semiverticullata
              (subsecundum)
Agte   Agrostis tenuis
Aica   Aira caryophyllea
ALL    Allium sp.
Alpr   Alopecurus pratensis
Amal-s Amelanchier alnifolia shrub
Amal-t Amelanchier alnifolia
Apan   Apocynum androsaemifolium
Aqfo   Aquilegia formosa
Arel   Arrhenatherum elatius
Arme-s Arbutus menziesii SHRUB
Arme-t Arbutus menziesii
Avfa   Avena fatua
Beaq   Berberis aquifolium
Brpu   Brodiaea pulchella
Brco   Bromus commutatus
Brla   Bromus laevipes
Brri   Bromus rigidus
Brse   Bromus secalinus
Brst   Bromus sterilis
Brvu   Bromus vulgeris
Caqu   Camassia quamash
CAR    Carex sp.
Cato   Calochortus tolmiei
Cear   Cerastium arenses
Ceum   Centaurium umbellatum
Ceve   Ceanothus velutinus
Cipa   Circaea pacifica
Civu   Cirsium vulgare
Coco-s Corylus cornuta shrub
Coco-t Corylus cornuta
Cogr   Collomia grandiflora
Conu-S Cornus nuttallii SHRUB
Conu-t Cornus nuttallii
CORY   Corylus sp.
Cost   Corallorhiza striata
Crca   Crepis capillaris
Crdo-t Crataegus douglasii
Crdo-s Crataegus douglasii
Crox   Crataegus oxyacantha
Cyec   Cynosurus echinatus
Cyfo   Cystopteris fragilis
Cygr   Cynoglossum grande
Daca   Danthonia californica
Dacar  Daucus carota
Dagl   Dactylus glomerata
Deel   Deschampsia elongata
Diar   Dianthus armeria
Doel   Downingia elegans
Drar   Drysopterus arguta
Drar   Dryopteris arguta
Elgl   Elymus glaucus
Erla   Eriophyllum lanatum
Erog   Erythronium oregonum
Eucr   Euphorbia crenulata
Feca   Festuca californica
Fede   Festuca dertonenses
Feel   Festuca elatior var. arendmaceae
Feme   Festuca megalura
Feoc   Festuca occidentalis
Feru   Festuca rubra
Frbr   Fragaria bracteata (vesca)
Frcu   Fragaria cuneifolia
Frla-s Fraxinus latifolia shrub
Frla-t Fraxinus latifolia
Frvi   Fragaria virginiana
GAL    Galium sp.
Gema   Geum macrophyllum
Geog   Geranium oreganum (incisum)
Gepu   Geranium pusillum
Haob   Habenaria orbiculata
Haun   Habenaria unalacensis
Hehe   Hedera helix
Hemi   Heuchera micrantha
Hodi   Holodiscus discolor
Hola   Holcus lanatus
Hyoc   Hydrophyllum occidentale
Hype   Hypericum perforatum
Hyra   Hypochaeris radicata
Irte   Iris tenax
JUNC   Juncus sp.
Kocr   Koeleria cristata
Laco   Lapsana comunis
Lapo   Lathyrus polyphyllus
Lasa   Lathyrus sativus (Pisum sativum)
Liap   Ligusticum apiifolium
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Libu	Lithophragma bulbifera
Lico	Lilium columbianum
Lide-t	Libocedrus deccurens
Lide-s	Libocedrus deccurens
LILI	Lilium sp.
Loci	Lonicera ciliosa
Lope	Lolium perenne
LOT	Lotus sp.
Lotr	Lomatium triternatum
Lumu	Luzula multiflora
Maex	Madia exigua
MAL	Malvaceae sp.
Maor	Marah oreganus
Mebu	Melica bulbosa
Mila	Microseris laciniata
Mope	Montia perfoliata
Mosi	Montia sibirica
Nepa	Nemophylla parviflora
ONGR	Onagraceae sp.
Osce-t	Osmaronia cerasiformis tree
Osce-s	Osmaronia cerasiformis
Osch	Osmorhiza chilensis
Osnu	Osmorhiza nuda (chilensis)
Phca	Physocarpus capitatus
Phle	Philadelphus lewisii
Phpr	Phleum pratense
Phvi	Phoradendron villosum
Pipo-s	Pinus ponderosa
Pipo	Pinus ponderosa
Plla	Plantago lanceolata
Poco	Poa compressa
Pogl	Potentilla glandulosa
Pogr	Potentilla gracilus
Pogr	Potentilla gracilis
Pomu	Polystichum munitum
Popr	Poa pratensis
Povu	Polypodium vulgare
Prav-s	Prunus avium shrub
Prav-t	Prunus avium
Prde-t	Prunus virginiana var. demissa
Prde-s	Prunus virginiana var. demissa shrub
Prvu	Prunella vulgeris
Psme-s	Pseudotsuga menziesii shrub
Psme-t	Pseudotsuga menziesii
Ptan	Pterospora andromedia
Ptaq	Pteridium aquilinum var. lanuginosum
Pyco-s	Pyrus communis shrub
Pyco	Pyrus communis
Pyfu-s	Pyrus fusca SHRUB
Pyfu-t	Pyrus fusca
Quga-s	Quercus garryana shrub
Quga	Quercus garryana
Raoc	Ranunculus occidentalis
Rhdi	Rhus diversiloba
Rhpu-s	Rhamnus purshiana shrub
Rhpu	Rhamnus purshiana
Risa	Ribes sanguinius
Rodu	Rosa???
Roeg	Rosa eglanteria
Rogy	Rosa gymnocarpa
Ronu	Rosa nutkana
Ropi	Rosa pisocarpa
Ropi	Rosa pisocarpa
Ruac	Rumex acetosella
Rula	Rubus laciniatus
Rule	Rubus leucodermus
Rupa	Rubus parvifloris
Rupr	Rubus procerus
Ruur	Rubus ursinus
S-2	Carex sp2.
S-1	Carex sp1.
Sacr	Sanicula crassicaulis
Sado	Satureja douglasii
Sagr	Sanicula graveolens
Seja	Senecio jacobaea
Siho	Silene hookeri
Smra	Smilacina racemosa
Smse	Smilacina sessilifolia
Syal	Symphoricarpus albus
Taas	Taeniatherum asperum
Taof	Taraxacum officinale
Tegr	Tellima grandiflora
Thoc	Thalictrum occidentale
Toar	Torilis arvensis
Trca	Trisetum canescens
TRIF	Trifolium sp
Trla	Trientalis latifolia
Trov	Trillium ovatum
Trpr	Trifolium procumbens
V#1	Vicia sp.
Valo	Valerianella locusta
Viam	Vicia americana
Viel	Viburnum ellipticum
Vinu	Viola nuttallii
VIOL	Viola sp
Zice	Zygadenus venosus

EXAMPLE ANALYSES

Derivation of an adjusted data matrix (OakWood1.wk1) from the raw data matrix (OakRaw.wk1).

(Note: for more on the rationale behind these steps, see McCune & Grace (2002), "Analysis of Ecological Communities."

1. Open the file OakRaw.wk1 as the main matrix (*File* | *Open* | *Main matrix*).
2. Delete species with fewer than three occurrences (*Modify Data* | *Delete Columns* | *Fewer than N Non-zero Values* | select *N=3* (The rationale for this is explained by McCune & Grace 2002, pp. 75-76)
3. Click *OK* in answer to *Do you wish to use Temp.wk1 as the new Main Matrix?*
4. Note that the result file now shows a list of the 86 columns (species) that were deleted.
5. *Modify Data* | *Relativizations* | *Relativization by Maximum* | select *Columns: Species* | *OK.* (It is essential to relativize by columns (species) in this case, because some species have abundances as basal areas and some as percent cover; see p. 73 in McCune & Grace 2002).
6. You will be asked, *Current temporary RESULT.TXT file will be lost. Save file now?* Click on *Discard* (you do not normally need to save this, as it just has the list of the species that were deleted.)
7. Click *OK* in answer to *Do you wish to use Temp.wk1 as the new Main Matrix?*
8. You will be asked, *Current temporary work file WORK.WK1 will be lost. Save file now?* Click on *Discard* – no need to save this file. It contains the matrix after the infrequent species were deleted but before the relativization.
9. The main matrix should now be relativized by species maximum and contain 47 rows and 103 columns. The contents should be identical to OakWood1.wk1.

Nonmetric multidimensional scaling of the community data, with overlays from the second matrix.

1. Open the file OakWood1.wk1 as the main matrix (*File* | *Open* | *Main matrix*).
2. Select *Ordination* | *NMS.*
3. Select the Autopilot tab, check Autopilot mode, and select *Medium.* (If you have a fast computer you might wish to select *Slow and Thorough.*
4. On the Distance Measure tab, select *Sørensen*. (The selections on the other tabs cannot be set because you have turned on autopilot. Any options previously selected on those tabs will be ignored.)
5. Click *OK.*
6. Enter a descriptive title for the results, for example, "Thilenius data, NMS medium thoroughness," then click *OK.*
7. If unsaved results from a previous action are showing in the result window, you will be asked, *Current temporary RESULT.TXT file will be lost. Save file now?* Click on *Discard* or one of the other options, depending on what you want.
8. NMS will run, using 40 random starts with the real data set and 50 random starts using different randomizations of the data (shuffling within columns). For each starting configuration NMS will seek a stable 6-, 5-, 4-, 3-, 2-, and 1-dimensional solution.

9. When the run is complete, a new result file will appear, along with windows containing coordinates for the stands (GRAPHROW.GPH) and the species (GRAPHCOL.GPH). Save each of these under a new name. For example, select *File | Save as | Result.txt,* then enter a new name, for example NMSThil.txt. Use a similar procedure to save the row and column coordinates, for example as NMSThil.gph and NMSThilSpp.gph.
10. Inspect the result file. See the chapter in McCune & Grace (2002) on NMS. Because random starts are used, your results will differ somewhat from those given here. A key portion of the results file is the following table.

```
STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)
--------------------------------------------------------------------
          Stress in real data          Stress in randomized data
               50 run(s)               Monte Carlo test,   50 runs
      -------------------------  -----------------------------------
Axes  Minimum      Mean  Maximum  Minimum      Mean  Maximum      p
--------------------------------------------------------------------
   1   34.486   49.777   56.481   47.752   54.478   56.485    0.0196
   2   22.609   23.664   25.109   29.697   31.914   34.104    0.0196
   3   16.419   16.771   17.741   21.380   22.776   24.139    0.0196
   4   12.320   12.396   12.918   16.923   17.810   19.277    0.0196
--------------------------------------------------------------------
p = proportion of randomized runs with stress < or = observed stress
i.e., p  = (1 + no. permutations <= observed)/(1 + no. permutations)


Conclusion:  a 3-dimensional solution is recommended.
Now rerunning the best ordination with that dimensionality.
```

11. Note that the *p*-values indicate that solutions of any dimensionality from 1 through 6 are stronger than expected by chance. Autopilot chose a 3-D solution because it reduces the stress by over 5 units, versus a 2-D solution, while the giving a small *p*-value. The final stress for the best 3-D solution was 16.4.
12. Open the second matrix so you can study the relationship between those variables and the community structure: *File | Open | Second Matrix | OakWood2.wk1*.
13. View the ordination graph. Select *Graph | Graph Ordination* See Chapters 13 and 16 in McCune & Grace (2002) for suggestions on how to interpret the results. For example you might wish to:
    a. display a joint plot (*Graph | Joint Plot*), and examine each pair of axes,
    b. see how much of the variation in the distance matrix is represented in the ordination diagram (*Statistics | Percent of Variance in Distance Matrix*),
    c. graphically examine the relationships between the ordination and individual variables in the second matrix (*Graph | Overlay From Second Matrix*),
    d. calculate linear and rank correlation coefficients between axis scores and variables in the second matrix (*Statistics | Correlations With Second Matrix*),
    e. rotate the diagram so that major vectors in the joint plot are aligned with the axes (select *Graph | Joint* plot, then *Rotate | By Angle Continuous*. Select 5 degrees for the increment and click *Next* repeatedly to gradually rotate the ordination. See Chapter 15 in McCune and Grace (2002). If you wish to save your rotation, select *File | Save Scores As | Rows*: *Stands | Text File*, then choose a filename, such as NMSThilRot.gph.
    f. explore the options – there is a lot here. Take the time to familiarize yourself with the various menu items and options.

Comparison of communities among groups of stands as defined by categorical variables.

1. Open the file OakWood1.wk1 as the main matrix (*File* | *Open* | *Main matrix*).
2. Open the second matrix because it contains the grouping variables: *File* | *Open* | *Second Matrix* | *OakWood2.wk1*.
3. Select *Groups* | *MRPP* | *Define Classes From Secondary Matrix*.
4. Select one of the categorical variables, for example "Landform" as the grouping variable.
5. In the MRPP Setup dialog, select the *Sørensen* distance measure, n/sum(n) as the weighting method, and check the box, *Rank transform distance matrix*.
6. Click *OK*.
7. Enter a descriptive title for the results, for example, "Thilenius data, rank-transformed MRPP, Sorensen distance", then click *OK*.
8. If unsaved results from a previous action are showing in the results window, you will be asked, *Current temporary RESULT.TXT file will be lost. Save file now?* Click on *Discard* or one of the other options, depending on what you want.
9. MRPP then runs, writing the results into RESULT.TXT.
10. Inspecting the results window, you should see the following.

```
Chance-corrected within-group agreement, A =    0.07630772
Probability of a smaller or equal delta, p =    0.00772772
```

This *A* value tells us that species composition differs only modestly among landforms, while the *p*-value tells us that it is fairly unlikely for us to obtain this result just by chance. For more help interpreting the results from MRPP, see Chapter 24 in McCune and Grace (2002).

11. If you wish to see which species underlie the differences among landforms, try Indicator Species Analysis. From the main menu, select *Groups* | *Indicator Species Analysis* | *Define Classes From Secondary Matrix*.
12. Again, select Landform as the grouping variable.
13. In the Setup dialog, uncheck *Exclude one or more groups* and check *Monte Carlo test*.
14. For the random numbers, select *Use time of day*. Click *OK*.
15. Select *Number of runs = 1000*, then *OK*.
16. Enter a descriptive title for your results, to be used as a header in the results file, then click *OK*.
17. If unsaved results from a previous action are showing in the results window, you will be asked, *Current temporary RESULT.TXT file will be lost. Save file now?* Click on *Discard.*
18. The results from ISA will appear in the results window. See Chapter 25 in McCune & Grace (2002) for help in interpreting the results.
19. One particularly good indicator of landform is "Arel" (*Arrhenatherum elatius*), which has the following result in the final table:

Column	Maxgrp	Observed Indicator Value (IV)	IV from randomized groups Mean	S.Dev	p *
15 Arel	1	86.5	16.6	11.47	0.0050

The Maxgrp=1 tells us that it is particularly consistent in Landform 1 (valley bottom). Looking back at the preceding tables, we see that it has a high concentration of abundance in group 1 (86% in the Relative Abundance table) and it was always present in that group (100% in the Relative Frequency table). You p-value may not be exactly the same as this, because you probably had a different sequence of random numbers for the monte carlo test.

Acknowledgments

The original raw data cards from Thilenius' study in 1963 (data collected in 1961 and 1962) were obtained from John Thilenius via Bob Frenkel. Thanks to John Thilenius for granting permission to distribute his data. Bill Daly did the initial data entry. Bibit Traut added more variables and resolved numerous nomenclatural questions regarding the species codes used by Thilenius.

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