PHENOLOGICAL PREDICTABILITY INDEX IN BRAHMS

A TOOL FOR HERBARIUM-BASED PHENOLOGICAL STUDIES

BRAHMS documentation

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Introduction

This document explains how to use the Phenological Predictability Index (PPI) module in BRAHMS. The module calculates a range of results concerning the phenology of the selected taxa. Standard phenological events are buds, flowers, fruit, mature fruit, leaf fall, vegetative as well as extra user-selected periodical events.

PPI results allows you to analyse and estimate phenophases for the selected taxa based on a minimum set of phenology data recorded by month. PPI produces three taxon-specific results:

- Maximum probability period (currently month) for the phenophase;
- A predictability index, varying between ~0 (= 0.02) and 1;
- Chart of the predictability indexes for the periods (currently 12 months of the year).

Some potential applications:

1. Phenology using herbarium material: bud-break, flowering, fruiting, fruit maturation, leaf fall, new leaves;
2. Periodic phenomena such as fungal infections, galling, insect attack, etc.;
3. Testing synchrony of mimetic seasonal phenomena;
4. Seasonal changes in short life cycle invertebrates.

For those new to BRAHMS, introductory training materials are available to:
http://dps.plants.ox.ac.uk/bol/content/documentation/BRAHMStraining2010.pdf

PPI score and chart examples

The following provide some PPI results for species with different flowering strategies. The following results and charts are generated by the BRAHMS PPI function (procedure explained below).
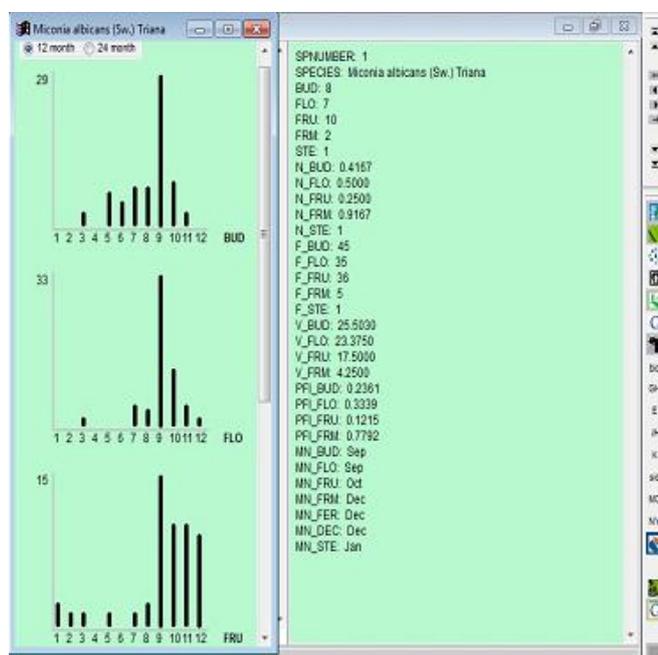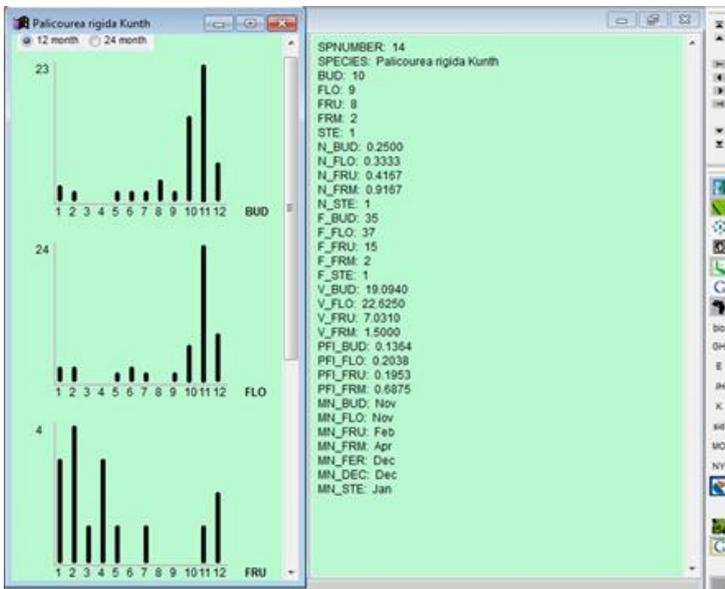

Annual flowering species

Miconia albicans (Sw.) Triana (Melastomataceae) is a widespread species that showed a relatively short annual flowering event from 2000 to 2003 (Lenza & Klink, 2006). The PPI score graph shows an approximately normal distribution. Unique records (35) are from approximately 1o. Lat. x 1o. Long. in the same area where the field study was done.
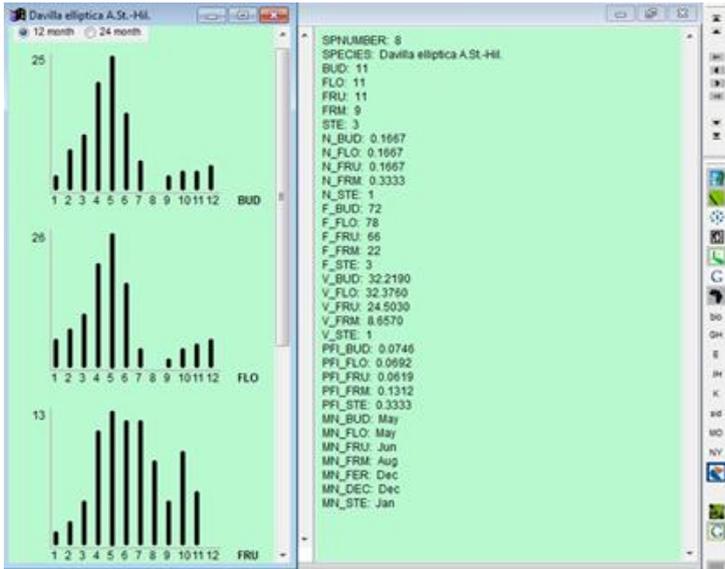
Annual uni-modal prolonged flowering species.

Davilla elliptica A. St.-Hil. (Dilleniaceae) showed a prolonged annual flowering pattern from 2000 to 2003 in Central Brazil (Lenza & Klink, 2006). Unique records (72) are from approximately 1o. Lat. x 1o. Long. in the same area where the field study was done. The PPI score graph shows a negative-skewed distribution with a peak in May.

Annual bi-modal flowering species.

Palicourea rigida Kunth (Rubiaceae) has two flowering episodes a year, a more intense one during the rainy season and a weaker one during the dry season; observations were from August 1993 to April 1995 (Silva, 1995 – unpubl. M. Sc. Thesis). PPI score and field data are shown below. Unique records (37) are from approximately 1o. Lat. x 1o. Long. in the same area where the field study was done.
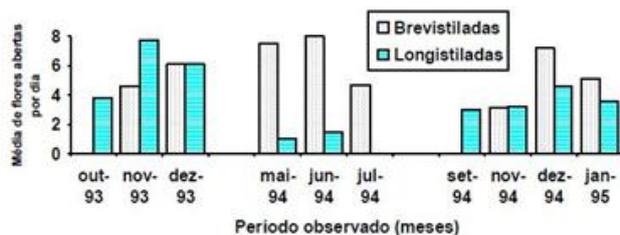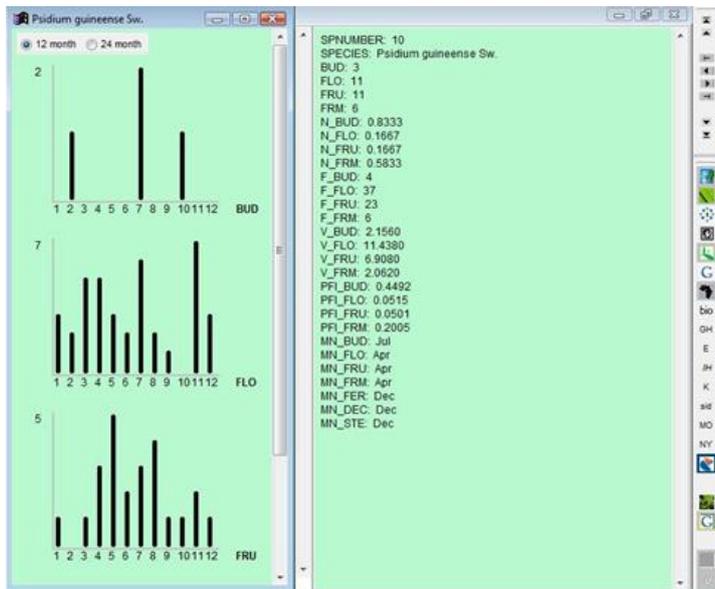

Figura 9- Valores médios de flores abertas por dia, por inflorescência de plantas longistiladas e brevistiladas durante os três períodos de floração observados.

Translation: Figure 9 - Mean values of open flowers per day per inflorescence of pin and thrum plants during the three flowering periods observed. X axis: Mean number of flowers per day. Y axis: Period observed (months). Grey bars: Pin plants. Turquoise bars: Thrum plants.

Silva, A.P. 1995. Biologia reprodutiva e polinizacao de *Palicourea rigida* H.B.K. (Rubiaceae). Unpublished M. Sc. thesis. Pós-Graduação em Botânica, Universidade de Brasilia.

Sub-annual multi-modal continuous-flowering species

Psidium guineense Sw. (Myrtaceae) showed continuous-flowering with five peaks of varying intensity over a 14 month period in Costa Rica (Suarez & Esquivel, 1987) at c. 1200 m. Unique records (37) are from Mesoamerica over a large altitudinal gradient of 0-2000 m above sea-level.

Storing phenology data in BRAHMS

To calculate the PPI in BRAHMS, you must have phenology data for individual botanical records. Botanical records are typically vouchered collections (specimens) and/or field observations but may also include data from the literature.

Phenology data can be added directly to BRAHMS or via Rapid Data Entry RDE files and subsequently transferred into BRAHMS.

You can calculate PPI with a very small number of data fields. For each botanical record, the minimum requirements are the species name, the collection (or observation) month and year, and the phenological state of each record. Other typical botanical record fields such as collector name, number and collection location, while desirable for refining selections, are not obligatory.

Phenophases are recorded by adding '*' to one or more of the following *single character fields* in the botanical record link file. Permitted link file fields are:

bud (floral buds present on specimen)
flo (specimen has open flowers)
fru (specimen has fruits at any stage of development)
frm (specimens has mature fruits)
fer (specimen is fertile)
dec (specimen is leafless due to deciduous behaviour)
ste (specimen is sterile).
phe1, phe2, … (user defined fields such as male flowers, rust attack, young leaves present)

These are optional BRAHMS fields and thus are not stored in the main botanical record file. They are added to the botanical record link file (appendix to main file). To add these fields and/or check all

have been added, select: **BotanicalRecords > View/edit botanical records in database** followed by **Tools > Add standard PPI phenology fields to link file**. A similar tool is available in RDE.

*A view of the botanical records link file showing the single character PPI fields. An * is added to indicate presence of the phenology state.*

Additional fields phe1, phe2, … can be manually added to the link file by opening the link file and using the standard **File > Modify file structure** option

Existing BRAHMS users can rename relevant link file fields as appropriate, for example FLCODE to FLO, and ensure values are marked with an * to indicate a positive event. Not all fields are required.

More than one option may be marked. Whenever **frm** is marked, then **fru** should also be marked as obviously, any specimen with mature fruit also qualifies as having fruits of any stage. **Fer** may be used for taxa in which buds, flowers and fruits are hard to tell apart, but users should not mix **fer** with a **bud**, **flo**, or **fru** code for the same taxon since the program does not automatically expand the **fer** code to encompass specimens marked with any of these codes.

Ideally, images or the specimens themselves should be consulted to ensure best possible scoring.

Transfers from Excel and other formats

If you have relevant botanical record data in another format such as an Excel spread sheet, for example, a list of phenology coded specimens, these data can be transferred into BRAHMS for PPI analysis. In summary:

- Ensure that your data include the minimum required fields (see above).

- Ensure that the fields are correctly named in the external file.
- Use the BRAHMS data import feature provided to transfer your data from the excel file to RDE format.
- Transfer the RDE file into BRAHMS.

Further details on each of these steps are available in the BRAHMS training guide and manual.
http://dps.plants.ox.ac.uk/bol/content/documentation/BRAHMStraining2010.pdf

Assembling the taxa to analyse

The PPI module works on the taxa you assemble into the BRAHMS taxon query (extract) file. You can analyse as many taxa as you wish at the same time. Results are always presented separately for each entry in your query file.

If your species list includes accepted names and synonyms, you may want to restrict the query to accepted names. Thus:

Select **Taxa > Extract/Query data** and choose a suitable extract option.
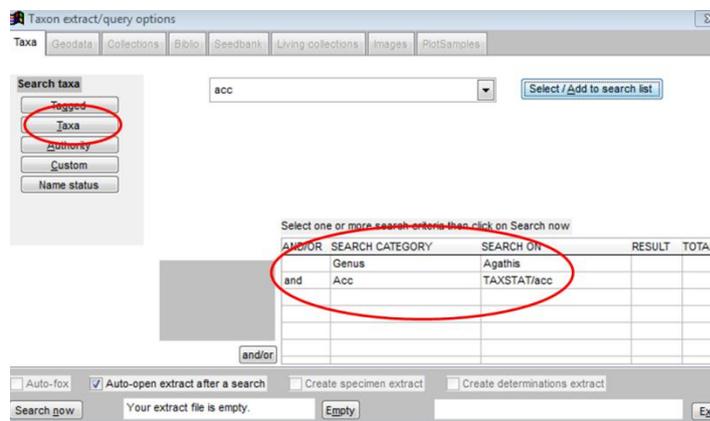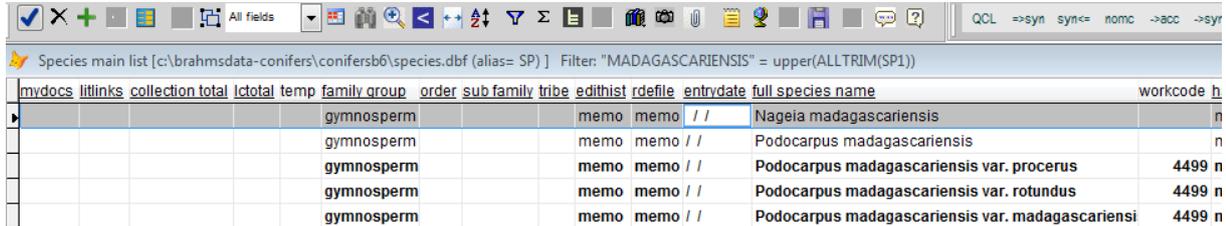

In the above example, taxa are being queried by accepted names in the genus Agathis. The accepted names in the genus will be assembled to the taxa query file.
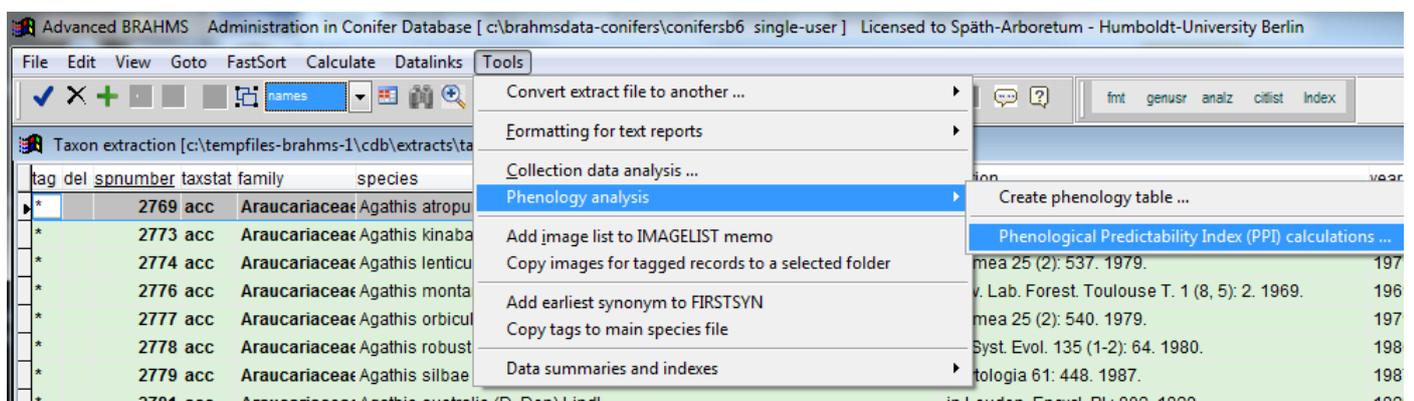
The resulting taxa query file showing the Tools menu options

Combining taxa for analysis

In some cases, you may want to group several taxa together for a combined analysis. This could be infraspecific taxa for a species or even all taxa in a genus. To do this, you must make use of the WORKCODE fields in the main species file.
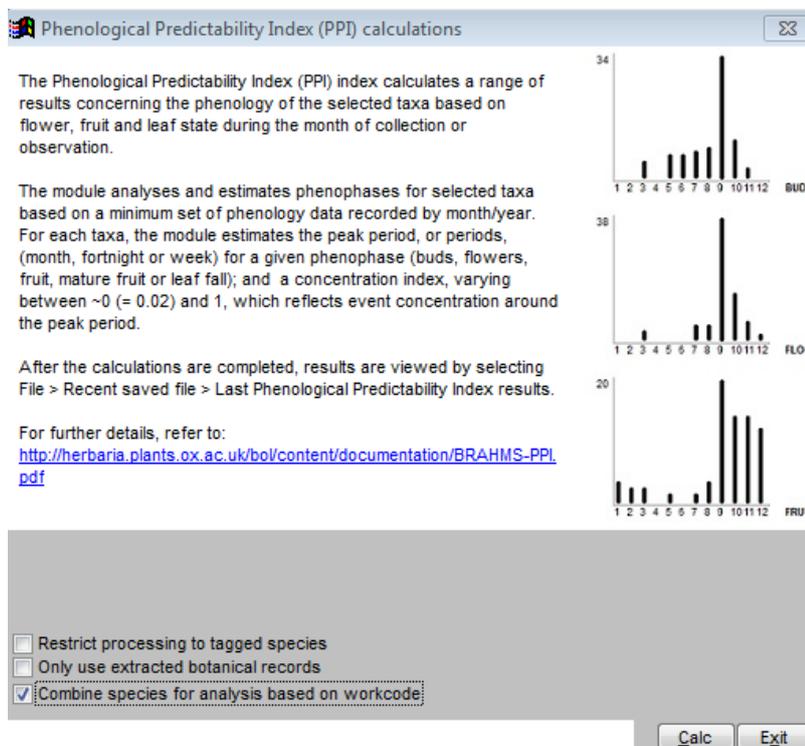

In the above example, three varieties of Podocarpus madagascariensis has been given the same workcode in the main species file. 4499 is the SPNUMBER value of one of the varieties.

Running the PPI analysis

In the taxon extract file, select **Tools > Phenology analysis > Phenological Predictability Index (PPI) calculations** (see above screen).

You can restrict processing to tagged taxa records in your extract file. You can also restrict the analysis to a subset of your botanical records, for example records from a selected continent, country, latitudinal band or any other relevant restriction. Do this by first querying the required botanical records to your botanical record extract file and then selecting the option **Extracted botanical records** on the form. In this example, any species records with the same workcode entry will be combined for the analysis.

Viewing and interpreting results

PPI results are calculated to a separate analysis file which is opened using **Extracts > Recent saved files > Last PPI (Phenological Predictability Index) analysis**.

Charts are opened using the **Tools** menu option provided or the quick link **Chart** toolbar. The results file includes one record per species included in the analysis.
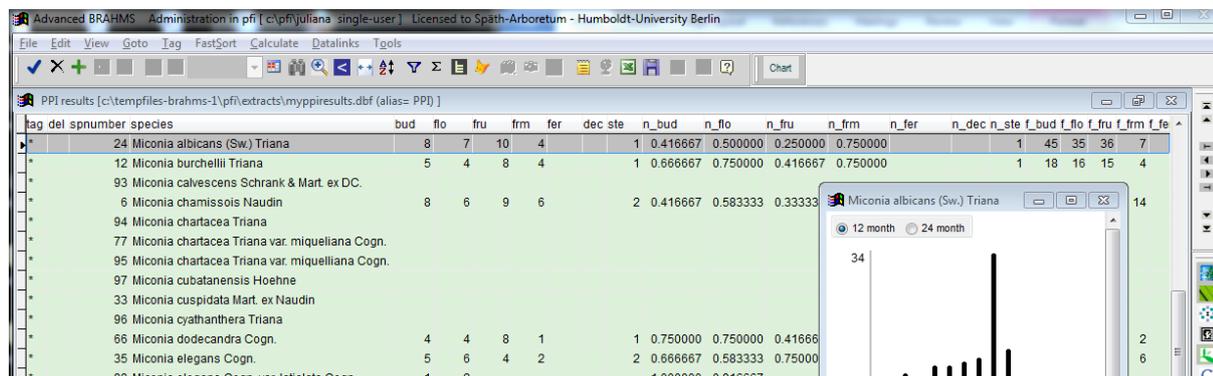
Partial view of the analysis file with the Chart option opened

The PPI module analyses phenology and produces a peak and a predictability index for a given phenophase between near 0 and 1. Records that lack either year & month or month are excluded.

A PPI analysis will include:

- **m_phe**: number of months in which the phenophase was found in the database – varies from 1-12.

- **f_phe**: number of unique records (unique phenophase/month/year combinations) in the database – will always be equal to or below the number of actual specimens of the taxon; below if there is more than one specimen collected in the same phenophase in the same month and same year. This value is the statistical "n" value for the index and should ideally be >50 (see Proença et al., 2011 for additional information on the index)
- **pkm_phe**: maximum-activity month for phenophase
- **ppi_phe**: Phenological Predictability Index (a complex value, combining event duration, concentration, synchrony, and periodic environmental fluctuation – see Proença et al., 2011). The index varies from near 0 (0.02) to 1. An index of 1 indicates that the phenophase is restricted to the maximum-activity month, i.e., the data predicts the phenophase occurs exclusively in that month. The lower the index, the more likely the phenophase is to also occur in other months. The PPI monthy score graph allows visual inspection of the probability per month.

References

Lenza, E. and Klink, C. A. 2006. Comportamento fenológico de espécies lenhosas em um cerrado sentido restrito de Brasília, DF. – Rev. Bras. Bot. 29: 627–638.

Silva, A.P. 1995. Biologia Reprodutiva e Polinização de *Palicourea rigida* H.B.K. (Rubiaceae). Unpublished M. Sc. Thesis, Universidade de Brasília. Available at: <http://bdtd.bce.unb.br/tedesimplificado/tde_busca/arquivo.php?codArquivo=3476>

Suarez, E. and Esquivel, C. 1987. Fenologia del guisaro (*Psidium guineense* Swartz) en Barva de Heredia, Costa Rica. – Brenesia 28: 97–105.