exercises-pollinators-datasets-exploration

June 4, 2022

1 Exercises - Pollinators datasets exploration

Exercises with some pollinators datasets.

1.1 Packages import

[1]:

```
import os # operating system functions
import chardet # Universal Character Encoding Detector
import requests # web requests
import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)
import random
import re # regular expression operations
from sklearn.model_selection import StratifiedShuffleSplit # dataset subsetting
from sklearn.preprocessing import StandardScaler
from sklearn.preprocessing import LabelEncoder # mange categorical data
from sklearn import metrics # results evaluation
from sklearn.impute import SimpleImputer # tool for dealing with missing values
import association_metrics as am # implementation of Cramer's V correlation
import matplotlib as plt # data visualization
from mpl_toolkits.mplot3d import Axes3D # visualization 3D
import seaborn as sb # data visualization
import graphviz # grahp visualization
import plotly.express as px # data visualization, also 3D
from matplotlib.animation import FuncAnimation # plot animations
```

We probably will download and save more than 1 datase so let's make a funcition for it

[20]:

```
def DatasetDownload(dataset_url, dataset_directory_path, dataset_file_name):
    print("Download started")
    request_dataset = requests.get(dataset_url, allow_redirects=True)
    print("Download completed")
    if request_dataset.status_code != 200:
        print(f"Request status: {request_dataset.status_code}")
    else:
        print("Writing started")
        os.makedirs(dataset_directory_path, exist_ok=True)
        open( dataset_directory_path + dataset_file_name , 'wb').
↪write(request_dataset.content)
        print("Writing completed")
    print("End")
    return
```

1.2 Insect Pollinator Initiative - Natural History Museum Data Portal

Graham N Stone; Alfried Vogler; Adam Vanbergen; Jacqueline Mackenzie-Dodds (2017). Dataset: Insect Pollinators Archive. Resource: Insect Pollinator Initiative. Natural History Museum Data Portal (data.nhm.ac.uk). https://doi.org/10.5519/0062900

Retrieved: 16:39 19 Mar 2022 (GMT)

1.2.1 IPI-NHMDP - Data download - (One shoot execution)

Let's use the original website.

Next steps are "one shoot execution", you should execute it only the first time, once did it you can go directly to *Starting points* that youll'find along the code.

[4]:
```
# Dataset url
NHMDP_PI_dataset_url = 'https://data.nhm.ac.uk/dataset/
 ↪46e122c6-7acd-44ec-a354-81a412da419a/resource/
 ↪784d74b6-6b0e-4fd4-b0b5-798ac7b1a11b/download/ipifordataportal.xlsx'

# Desired directory
NHMDP_PI_dataset_directory = 'Datasets/Pollinators/NHMDP/PollinatorsInitiative'

# Desired file name
NHMDP_PI_dataset_name = 'PollinatorsInitiative.xlsx'
```

[12]:
```
# Download and Save
DatasetDownload(NHMDP_PI_dataset_url, NHMDP_PI_dataset_directory,␣
 ↪NHMDP_PI_dataset_name)
```

```
Download started
Download completed
Writing started
Writing completed
End
```

1.2.2 IPI-NHMDP - Data import - Starting point

[5]:
```
IPI_NHMDP_dataset = pd.
 ↪read_excel(NHMDP_PI_dataset_directory+NHMDP_PI_dataset_name,␣
 ↪engine='openpyxl')
```

1.2.3 IPI-NHMDP - Exploration

[14]:

```
IPI_NHMDP_dataset.describe()
```

[14]:

```
       Specimen No/Barcode
count         1.185400e+04
mean          1.006605e+07
std           7.403999e+03
min           1.005246e+07
25%           1.005963e+07
50%           1.006886e+07
75%           1.007182e+07
max           1.007598e+07
```

[5]:

```
IPI_NHMDP_dataset.head()
```

[5]:

```
                              Project Name Specimen No Prefix  \
0  Insect Pollinator Initiative - agriland              NHMUK
1  Insect Pollinator Initiative - agriland              NHMUK
2  Insect Pollinator Initiative - agriland              NHMUK
3  Insect Pollinator Initiative - agriland              NHMUK
4  Insect Pollinator Initiative - agriland              NHMUK

   Specimen No/Barcode Specimen Code         Country Province/State/Territory  \
0             10052460   AL_11_01750  United Kingdom                  England
1             10052461   AL_11_01751  United Kingdom                  England
2             10052462   AL_11_01753  United Kingdom                  England
3             10052463   AL_11_01754  United Kingdom                  England
4             10052464   AL_11_01755  United Kingdom                  England

  District/County/Shire Precise Locality  Coll Date    Method     Collector  \
0        West Yorkshire      Harden Moor 2011-06-27  Pan trap  M. McKerchar
1        West Yorkshire      Harden Moor 2011-06-27  Pan trap  M. McKerchar
2        West Yorkshire      Harden Moor 2011-06-27  Pan trap  M. McKerchar
3        West Yorkshire      Harden Moor 2011-06-27  Pan trap  M. McKerchar
4        West Yorkshire      Harden Moor 2011-06-27  Pan trap  M. McKerchar

    Collector 1 Collector 2     Identifier  \
0  M   McKerchar              S P M Roberts
1  M   McKerchar         NaN  S P M Roberts
2  M   McKerchar         NaN  S P M Roberts
3  M   McKerchar         NaN  S P M Roberts
4  M   McKerchar         NaN  S P M Roberts

                                Determination     SEX Stage
0  Lasioglossum cupromicans (Pérez, J., 1903)  Female   NaN
1  Lasioglossum cupromicans (Pérez, J., 1903)  Female   NaN
```

```
2  Lasioglossum cupromicans (Pérez, J., 1903)  Female   NaN
3  Lasioglossum cupromicans (Pérez, J., 1903)  Female   NaN
4        Lasioglossum fratellum (Perez, 1903)  Female   NaN
```

```
[6]: IPI_NHMDP_dataset.columns
```

```
[6]: Index(['Project Name', 'Specimen No Prefix', 'Specimen No/Barcode',
            'Specimen Code', 'Country', 'Province/State/Territory',
            'District/County/Shire', 'Precise Locality', 'Coll Date', 'Method',
            'Collector', 'Collector 1', 'Collector 2', 'Identifier',
            'Determination', 'SEX', 'Stage'],
           dtype='object')
```

Mmm I don't see particularly interesting information.

Let's check how many per state differnt specimes have been collected

```
[14]: IPI_NHMDP_dataset[["Country","Specimen Code"]].groupby("Country").describe()
```

```
[14]:               Specimen Code
                            count unique                 top freq
      Country
      United Kingdom        11852  11807  Wi-01-3.13-P10003    2
```

```
[15]: IPI_NHMDP_dataset[["Province/State/Territory","Specimen Code"]].
       ↪groupby("Province/State/Territory").describe()
```

```
[15]:                          Specimen Code
                                       count unique                 top freq
      Province/State/Territory
      England                          10028   9996  Ca-05-1.12-P30003    2
      Scotland                          1824   1811  Ay-15-3.12-P50013    2
```

```
[16]: IPI_NHMDP_dataset[["Province/State/Territory","District/County/Shire","Specimen␣
       ↪Code"]].groupby("District/County/Shire").describe()
```

```
[16]:                          Province/State/Territory                        \
                                                  count unique       top  freq
      District/County/Shire
      Bedfordshire                                 1053      1   England  1053
      Cambridgeshire                               2356      1   England  2356
      Cumbria                                       113      1   England   113
      Dorset                                        492      1   England   492
      Dumfries and Galloway                         137      1  Scotland   137
      East Ayrshire                                 523      1  Scotland   523
      East Renfrewshire                              29      1  Scotland    29
      East Riding of Yorkshire                     1471      1   England  1471
      Highland                                      651      1  Scotland   651
```

```
Kent                                        173       1    England   173
Lancashire                                  219       1    England   219
North Lanarkshire                           167       1   Scotland   167
North Yorkshire                             254       1    England   254
Renfrewshire                                 14       1   Scotland    14
South Lanarkshire                           303       1   Scotland   303
Staffordshire                              1359       1    England  1359
West Yorkshire                              895       1    England   895
Wiltshire                                  1643       1    England  1643

                         Specimen Code
                                 count unique                top freq
District/County/Shire
Bedfordshire                      1053   1052         AL_11_03988    2
Cambridgeshire                    2356   2340  Ca-01-1.13-P40002    2
Cumbria                            113    113  Yo-08-1.12-P30003    1
Dorset                             492    492         AL_12_07052    1
Dumfries and Galloway              137    137  Ay-08-3.12-P10001    1
East Ayrshire                      523    523  Ay-01-3.12-P20001    1
East Renfrewshire                   29     29  Ay-12-3.12-P10001    1
East Riding of Yorkshire          1471   1467         AL_11_02429    2
Highland                           651    643  In-04-1.12-P50001    2
Kent                               173    173         AL_12_06790    1
Lancashire                         219    219         AL_11_02651    1
North Lanarkshire                  167    162  Ay-15-3.12-P50009    2
North Yorkshire                    254    253         AL_11_06052    2
Renfrewshire                        14     14  Ay-09-3.12-P30001    1
South Lanarkshire                  303    303  Ay-04-3.12-P10009    1
Staffordshire                     1359   1359  St-02-3.12-P10001    1
West Yorkshire                     895    894         AL_11_02507    2
Wiltshire                         1643   1634  Wi-01-3.13-P40001    2
```

Could be nice try to represent these data on a geographical map… but it's a bit out of the exercise scope

1.3 Global pollinator database - Boreux & Klein - Figshare Dataset

Boreux, Virginie; Klein, Alexandra-Maria (2019): Global pollinator database. figshare. Dataset. https://doi.org/10.6084/m9.figshare.9980471.v1

1.3.1 GPD-F - Data download - (One shoot execution)

[3]:

```
# Dataset url
GPD_F_dataset_url = 'https://figshare.com/ndownloader/files/18003863'

# Desired directory
GPD_F_dataset_directory = 'Datasets/Pollinators/Figshare/
 ↪GlobalPollinatorDatabase'
```

```
# Desired file name
GPD_F_dataset_name = 'GlobalPollinatorDatabase.csv'


# Description dataset url
GPD_F_description_dataset_url = 'https://figshare.com/ndownloader/files/
 ↪18003860'

# Desired file name
GPD_F_description_dataset_name = 'GlobalPollinatorDatabaseDescription.csv'
```

[21]:
```
# Download and Save
DatasetDownload(GPD_F_dataset_url, GPD_F_dataset_directory, GPD_F_dataset_name)
```

```
Download started
Download completed
Writing started
Writing completed
End
```

[22]:
```
# Download and Save description
DatasetDownload(GPD_F_description_dataset_url, GPD_F_dataset_directory,␣
 ↪GPD_F_description_dataset_name)
```

```
Download started
Download completed
Writing started
Writing completed
End
```

1.3.2 GPD - Data import - Starting point

[7]:
```
GPD_dataset = pd.read_csv(GPD_F_dataset_directory+GPD_F_dataset_name)
```

read_csv on dtaset description rise an error of text decoding: *UnicodeDecodeError: 'utf-8' codec can't decode byte 0x96 in position 292: invalid start byte*

Let's check the encoding

[27]:
```
with open(GPD_F_dataset_directory+GPD_F_description_dataset_name, 'rb') as file:
    print(chardet.detect(file.read()))
```

```
{'encoding': 'Windows-1252', 'confidence': 0.73, 'language': ''}
```

[28]:
```
with open(GPD_F_dataset_directory+GPD_F_dataset_name, 'rb') as file:
    print(chardet.detect(file.read()))
```

```
{'encoding': 'ascii', 'confidence': 1.0, 'language': ''}
```

[29]:

```
GPD_dataset_description = pd.
 ↪read_csv(GPD_F_dataset_directory+GPD_F_description_dataset_name,␣
 ↪encoding='Windows-1252')
```

1.3.3 GPD-F - Exploration

[31]:

```
GPD_dataset.describe()
```

[31]:

```
       Unnamed: 0    diameter      tongue        body
count  796.000000  474.000000  293.000000  633.000000
mean   398.500000   27.781814    7.291297   11.592891
std    229.929699   31.164702    4.009739    3.862993
min      1.000000    2.000000    2.000000    2.000000
25%    199.750000   12.200000    5.000000    9.000000
50%    398.500000   25.000000    5.500000   11.500000
75%    597.250000   25.000000    9.000000   13.500000
max    796.000000  150.000000   26.400000   25.000000
```

So… seems we have to deal with a lot of missing values… yeah! XD

[33]:

```
GPD_dataset.columns
```

[33]:

```
Index(['Unnamed: 0', 'crop', 'type', 'season', 'diameter', 'corolla', 'colour',
       'nectar', 'b.system', 's.pollination', 'inflorescence', 'composite',
       'visitor', 'guild', 'tongue', 'body', 'sociality', 'feeding'],
      dtype='object')
```

[34]:

```
GPD_dataset_description.describe()
```

[34]:

```
       Unnamed: 0
count   15.000000
mean     8.000000
std      4.472136
min      1.000000
25%      4.500000
50%      8.000000
75%     11.500000
max     15.000000
```

[36]:

```
GPD_dataset_description
```

[36]:

```
   Unnamed: 0          Name      Group        Type    Unit  \
0           1          type      Plant    discrete  levels
1           2        season      Plant    discrete  levels
2           3      diameter      Plant  continuous      mm
3           4       corolla      Plant    discrete  levels
4           5        colour      Plant    discrete  levels
```

```
5            6         nectar       Plant    discrete  levels
6            7       b.system       Plant    discrete  levels
7            8  s.pollination       Plant    discrete  levels
8            9  inflorescence       Plant    discrete  levels
9           10      composite       Plant    discrete  levels
10          11          guild  Pollinator    discrete  levels
11          12         tongue  Pollinator  continuous      mm
12          13           body  Pollinator  continuous      mm
13          14      sociality  Pollinator    discrete  levels
14          15        feeding  Pollinator    discrete  levels

                                          Description  \
0                       arboreous or herbaceous plant
1   Flower season: Describes the seasonal range. F…
2                                     Flower diameter
3                                 Flower corolla type
4                                       Flower colour
5                      Whether flower contains nectar
6                                Type of bloom system
7                                    Self pollination
8                               Type of inflorescence
9                  Whether flower is composite or not
10                                   Pollinator guild
11                           Pollinator tongue length
12                             Pollinator body length
13             Whether pollinator is sociality or not
14                                  Feeding behaviour

                                               Levels
0                               arboreous, herbaceous
1   sprisum, summer, spriaut, spring, autspri, sum…
2                                                 NaN
3                           campanulate open, tubular
4       white, yellow, purple, pink, green, blue, red
5                                             yes, no
6   insects, insects/bats, insects/bats, insects/b…
7                                             yes, no
8    solitary, solitary/clusters, solitary/pairs, yes
9                                             yes, no
10  andrenidae, bumblebees, butterflies, coleopter…
11                                                NaN
12                                                NaN
13                                            yes, no
14                 oligolectic, parasitic, polylectic
```

[37]:

```
GPD_dataset.head()
```

[37]:

```
   Unnamed: 0                  crop        type   season  diameter   \
0           1  Vaccinium_corymbosum   arboreous  sprisum       NaN
1           2  Vaccinium_corymbosum   arboreous  sprisum       NaN
2           3        Brassica_napus  herbaceous   summer      12.5
3           4        Brassica_napus  herbaceous   summer      12.5
4           5        Brassica_napus  herbaceous   summer      12.5

       corolla  colour nectar      b.system s.pollination inflorescence   \
0  CAMPANULATE   white    yes       insects            no           yes
1  CAMPANULATE   white    yes       insects            no           yes
2         OPEN  yellow    yes  wind/insects            no           yes
3         OPEN  yellow    yes  wind/insects            no           yes
4         OPEN  yellow    yes  wind/insects            no           yes

  composite               visitor       guild  tongue  body sociality   \
0        no     Andrena_wilkella  ANDRENIDAE     NaN  10.5        no
1        no  Andrena_barbilabris  ANDRENIDAE     NaN  10.5        no
2        no    Andrena_cineraria  ANDRENIDAE     NaN  12.0        no
3        no     Andrena_flavipes  ANDRENIDAE     NaN  11.0        no
4        no      Andrena_gravida  ANDRENIDAE     NaN  13.0        no

       feeding
0  oligolectic
1   polylectic
2   polylectic
3   polylectic
4   polylectic
```

Maybe we can try some clusterng tecnique on this dataset to find out some interesting relationship

Missing values Let's check how many missing values we have and somehow how are distributed

[38]:

```python
# Number of missing values per column
GPD_dataset.isnull().sum()
```

[38]:

```
Unnamed: 0          0
crop                0
type                0
season             30
diameter          322
corolla             3
colour              5
nectar             29
b.system            0
s.pollination       0
inflorescence       0
composite           0
```

```
visitor              0
guild                0
tongue             503
body               163
sociality           32
feeding             51
dtype: int64
```

[39]:
```
# Percentage of missing values per column
GPD_dataset.isnull().sum()/len(GPD_dataset)*100
```

[39]:
```
Unnamed: 0          0.000000
crop                0.000000
type                0.000000
season              3.768844
diameter           40.452261
corolla             0.376884
colour              0.628141
nectar              3.643216
b.system            0.000000
s.pollination       0.000000
inflorescence       0.000000
composite           0.000000
visitor             0.000000
guild               0.000000
tongue             63.190955
body               20.477387
sociality           4.020101
feeding             6.407035
dtype: float64
```

[64]:
```
# Let's check rows
# Let's try to select only rows with some missing values
# Note that GPD_dataset.isnull().sum() is a pandas Series
len(GPD_dataset.isnull().sum(axis=1)[~GPD_dataset.isnull().sum(axis=1).
  ↪isin([0])])
```

[64]:
```
662
```

[9]:
```
# Clearly a lot of rows since only for toungue column we have 60% of missing.
# Lets' check rows excluding the columns with a consistent number of missing␣
  ↪(toungue, diametere, body)
# To make the code more readable let's make two steps
GPD_dataset_subset = GPD_dataset.loc[:, ~GPD_dataset.columns.
  ↪isin(["tongue","diameter","body"])]
```

```
len(GPD_dataset_subset.isnull().sum(axis=1)[~GPD_dataset_subset.isnull().
 ↪sum(axis=1).isin([0])])
```

```
[9]: 132
```

```
[61]: # Let's chek how many have more than 1 missing
len(GPD_dataset_subset.isnull().sum(axis=1)[~GPD_dataset_subset.isnull().
 ↪sum(axis=1).isin([0,1])])
```

```
[61]: 17
```

So maybe we can try to make a first clusterization excluding this 17 rows and the 3 problematic columns.

```
[10]: GPD_dataset_subset = GPD_dataset_subset.drop(GPD_dataset_subset.isnull().
 ↪sum(axis=1)[~GPD_dataset_subset.isnull().sum(axis=1).isin([0,1])].index)
```

```
[70]: GPD_dataset_subset.describe()
```

```
[70]:        Unnamed: 0
count  779.000000
mean   395.503209
std    230.662477
min      1.000000
25%    195.500000
50%    392.000000
75%    594.500000
max    796.000000
```

```
[71]: GPD_dataset_subset.describe
```

```
[71]: <bound method NDFrame.describe of      Unnamed: 0                 crop
type   season      corolla  \
0             1  Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE
1             2  Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE
2             3         Brassica_napus  herbaceous   summer         OPEN
3             4         Brassica_napus  herbaceous   summer         OPEN
4             5         Brassica_napus  herbaceous   summer         OPEN
..          …                     …         …      …          …
791         792       Allium_oleraceum  herbaceous   summer  CAMPANULATE
792         793        Jatropha_curcas   arboreous  spriaut         OPEN
793         794        Malus_domestica   arboreous   spring         OPEN
794         795    Phaseolus_coccineus  herbaceous   summer         OPEN
795         796       Capparis_spinosa   arboreous   summer         OPEN

     colour nectar      b.system s.pollination inflorescence composite  \
0     white    yes       insects            no           yes        no
```

```
1     white    yes      insects            no           yes         no
2    yellow    yes  wind/insects            no           yes         no
3    yellow    yes  wind/insects            no           yes         no
4    yellow    yes  wind/insects            no           yes         no
..      …    …           …           …           …       …
791  purple    yes      insects            no           yes         no
792   green    yes      insects            no           yes         no
793   white    yes      insects            no           yes         no
794   white    yes      insects            no           yes         no
795   white    yes      insects            no      solitary         no

                     visitor       guild sociality      feeding
0           Andrena_wilkella  ANDRENIDAE        no  oligolectic
1        Andrena_barbilabris  ANDRENIDAE        no   polylectic
2          Andrena_cineraria  ANDRENIDAE        no   polylectic
3           Andrena_flavipes  ANDRENIDAE        no   polylectic
4            Andrena_gravida  ANDRENIDAE        no   polylectic
..                       …         …       …          …
791  Dolichovespula_saxonica       WASPS       yes   polylectic
792       Bembecinus_tridens       WASPS        no          NaN
793         Vespula_vulgaris       WASPS       yes   polylectic
794    Philanthus_triangulum       WASPS        no   polylectic
795       Bembecinus_tridens       WASPS        no          NaN

[779 rows x 15 columns]>
```

[72]:

```
# Percentage of missing values per column
GPD_dataset_subset.isnull().sum()/len(GPD_dataset_subset)*100
```

[72]:

```
Unnamed: 0       0.000000
crop             0.000000
type             0.000000
season           2.952503
corolla          0.000000
colour           0.641849
nectar           2.824134
b.system         0.000000
s.pollination    0.000000
inflorescence    0.000000
composite        0.000000
visitor          0.000000
guild            0.000000
sociality        3.209243
feeding          5.134788
dtype: float64
```

We have no way to infer the values of blooming season, flowers colour, nectar presence, sociality or feeding (I mean no way before the analysis of the dataset and the application of ML algorithms). So for the moment let's add a fixed value "undefined" for the missing.

[11]:
```
impute_undefinded = SimpleImputer(strategy = 'constant', fill_value =␣
 ↪'undefined')
GPD_dataset_subset_0missing_array = imput_undefinded.
 ↪fit_transform(GPD_dataset_subset)
# Note that SimpleImputer returns a numpy array
```

[12]:
```
GPD_dataset_subset_0NaN = pd.DataFrame(GPD_dataset_subset_0missing_array,␣
 ↪columns = GPD_dataset_subset.columns)
```

[13]:
```
GPD_dataset_subset_0NaN.isnull().sum()
```

[13]:
```
Unnamed: 0       0
crop             0
type             0
season           0
corolla          0
colour           0
nectar           0
b.system         0
s.pollination    0
inflorescence    0
composite        0
visitor          0
guild            0
sociality        0
feeding          0
dtype: int64
```

Let's save the new dataset

[14]:
```
GPD_dataset_subset_0NaN.to_pickle(GPD_F_dataset_directory+"GPD_F_subset_0NaN.
 ↪pkl")
```

1.4 GPD-F - Post missing cleaning - Starting point

[6]:
```
GPD_dataset_subset_0NaN = pd.
 ↪read_pickle(GPD_F_dataset_directory+"GPD_F_subset_0NaN.pkl")
```

[16]:
```
GPD_dataset_subset_0NaN.describe
```

[16]:
```
<bound method NDFrame.describe of     Unnamed: 0                 crop
type   season      corolla  \
0            1  Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE
1            2  Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE
```

```
2            3        Brassica_napus  herbaceous   summer         OPEN
3            4        Brassica_napus  herbaceous   summer         OPEN
4            5        Brassica_napus  herbaceous   summer         OPEN
..         …                   …         …      …          …
774        792      Allium_oleraceum  herbaceous   summer  CAMPANULATE
775        793       Jatropha_curcas   arboreous  spriaut         OPEN
776        794       Malus_domestica   arboreous   spring         OPEN
777        795   Phaseolus_coccineus  herbaceous   summer         OPEN
778        796      Capparis_spinosa   arboreous   summer         OPEN

     colour nectar      b.system s.pollination inflorescence composite  \
0     white    yes       insects            no           yes        no
1     white    yes       insects            no           yes        no
2    yellow    yes  wind/insects            no           yes        no
3    yellow    yes  wind/insects            no           yes        no
4    yellow    yes  wind/insects            no           yes        no
..      …    …           …           …            …      …
774  purple    yes       insects            no           yes        no
775   green    yes       insects            no           yes        no
776   white    yes       insects            no           yes        no
777   white    yes       insects            no           yes        no
778   white    yes       insects            no      solitary        no

                     visitor       guild sociality      feeding
0           Andrena_wilkella  ANDRENIDAE        no  oligolectic
1        Andrena_barbilabris  ANDRENIDAE        no   polylectic
2          Andrena_cineraria  ANDRENIDAE        no   polylectic
3           Andrena_flavipes  ANDRENIDAE        no   polylectic
4            Andrena_gravida  ANDRENIDAE        no   polylectic
..                       …          …       …          …
774  Dolichovespula_saxonica       WASPS       yes   polylectic
775       Bembecinus_tridens       WASPS        no    undefined
776         Vespula_vulgaris       WASPS       yes   polylectic
777    Philanthus_triangulum       WASPS        no   polylectic
778       Bembecinus_tridens       WASPS        no    undefined

[779 rows x 15 columns]>
```

[17]:
```
GPD_dataset_subset_0NaN.isnull().sum()
```

[17]:
```
Unnamed: 0       0
crop             0
type             0
season           0
corolla          0
colour           0
nectar           0
```

```
b.system          0
s.pollination     0
inflorescence     0
composite         0
visitor           0
guild             0
sociality         0
feeding           0
dtype: int64
```

Most of the columns are categorical, let's check if we have also some numerical data

```
[44]: for index, column in enumerate(GPD_dataset_subset_0NaN.columns.tolist()[1:]):
          if str(GPD_dataset_subset_0NaN.iloc[1,index+1]).isnumeric():
              print(column)
```

So we have only categorical data.

```
[61]: GPD_dataset_subset_0NaN.dtypes
```

```
[61]: Unnamed: 0        object
      crop              object
      type              object
      season            object
      corolla           object
      colour            object
      nectar            object
      b.system          object
      s.pollination     object
      inflorescence     object
      composite         object
      visitor           object
      guild             object
      sociality         object
      feeding           object
      dtype: object
```

But actually are stored as mixed columns values, so let's remove first column wich we are not interested in and convert all the others column in categorical pandas's data type

```
[7]: GPD_dataset_subset2_0NaN = GPD_dataset_subset_0NaN.iloc[:,1:]
```

```
[65]: for column in GPD_dataset_subset2_0NaN.columns.tolist():
          GPD_dataset_subset2_0NaN[column] = GPD_dataset_subset2_0NaN.loc[column].
       ↪astype('category')
```

```
  Input In [65]
```

```
    GPD_dataset_subset2_0NaN.loc[,column] = GPD_dataset_subset2_0NaN.
 ↪loc[,column].astype('category')
                                ^

SyntaxError: invalid syntax
```

[67]:
```
GPD_dataset_subset2_0NaN.dtypes
```

[67]:
```
crop             category
type             category
season           category
corolla          category
colour           category
nectar           category
b.system         category
s.pollination    category
inflorescence    category
composite        category
visitor          category
guild            category
sociality        category
feeding          category
dtype: object
```

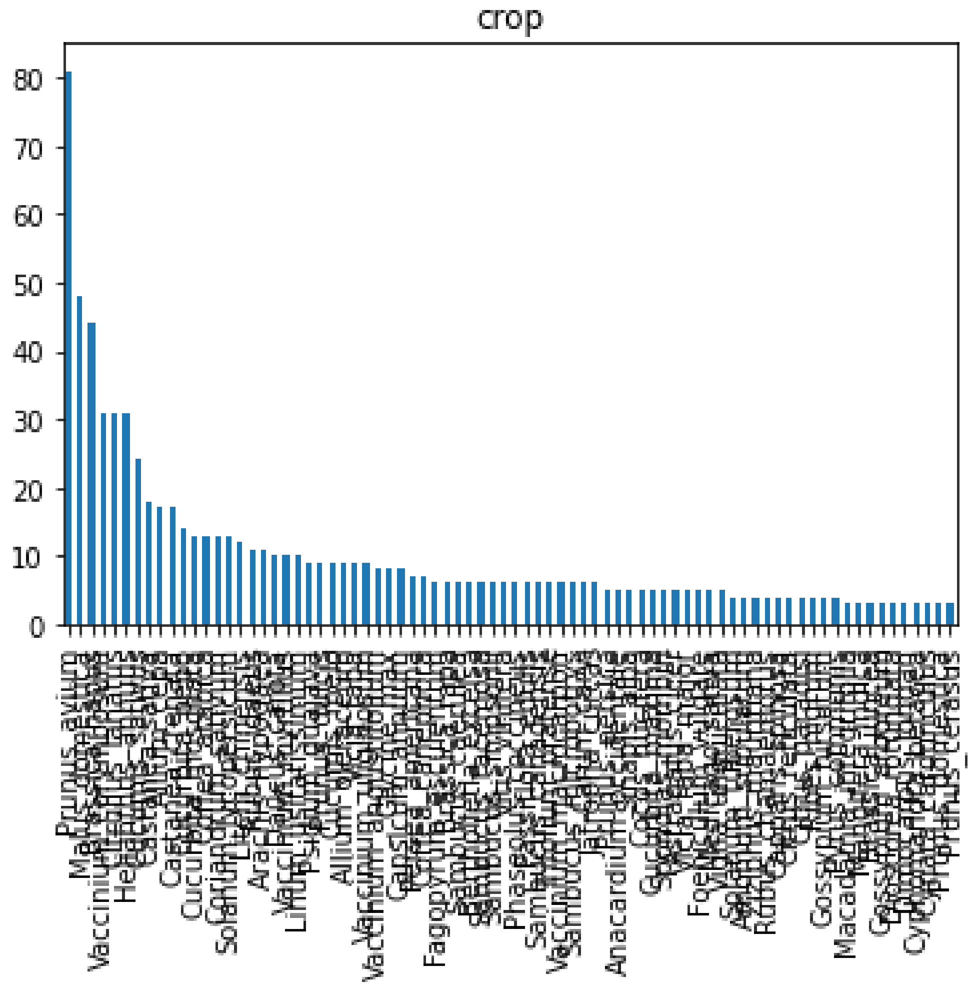
[66]:
```
GPD_dataset_subset2_0NaN.describe
```

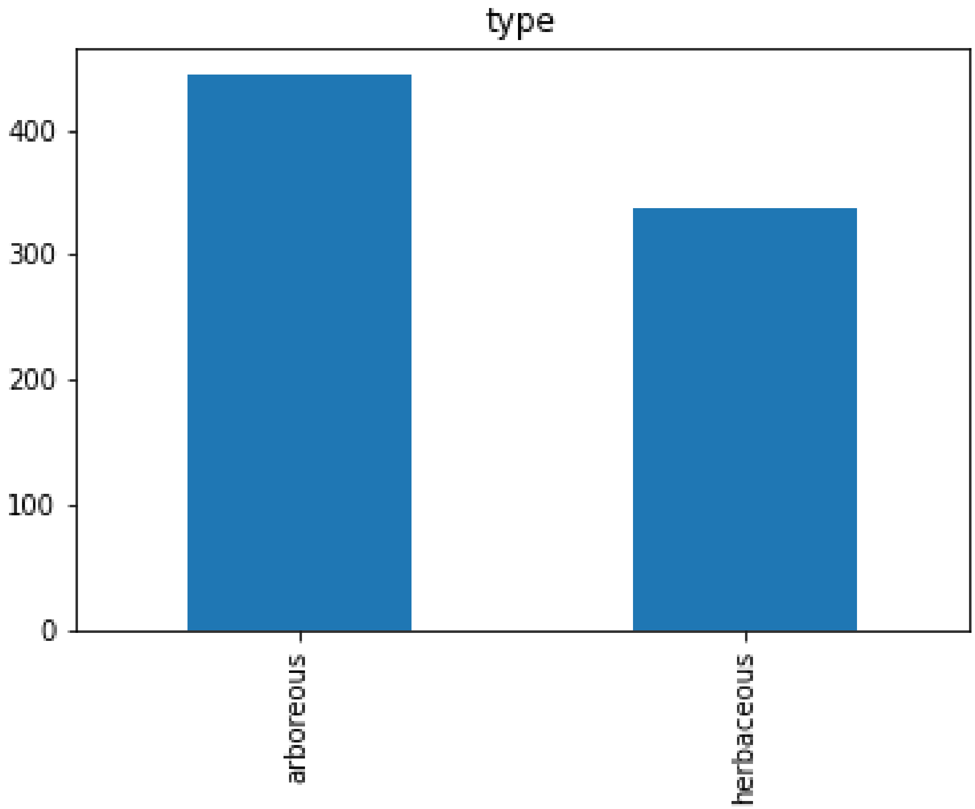
[66]:
```
<bound method NDFrame.describe of                      crop        type   season
corolla  colour nectar  \
0    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
1    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
2          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
3          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
4          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
..                    …         …      …          …     …    …
774      Allium_oleraceum  herbaceous   summer  CAMPANULATE  purple    yes
775       Jatropha_curcas   arboreous  spriaut         OPEN   green    yes
776       Malus_domestica   arboreous   spring         OPEN   white    yes
777   Phaseolus_coccineus  herbaceous   summer         OPEN   white    yes
778      Capparis_spinosa   arboreous   summer         OPEN   white    yes

         b.system s.pollination inflorescence composite  \
0         insects            no           yes        no
1         insects            no           yes        no
2    wind/insects            no           yes        no
3    wind/insects            no           yes        no
4    wind/insects            no           yes        no
..            …           …           …       …
```

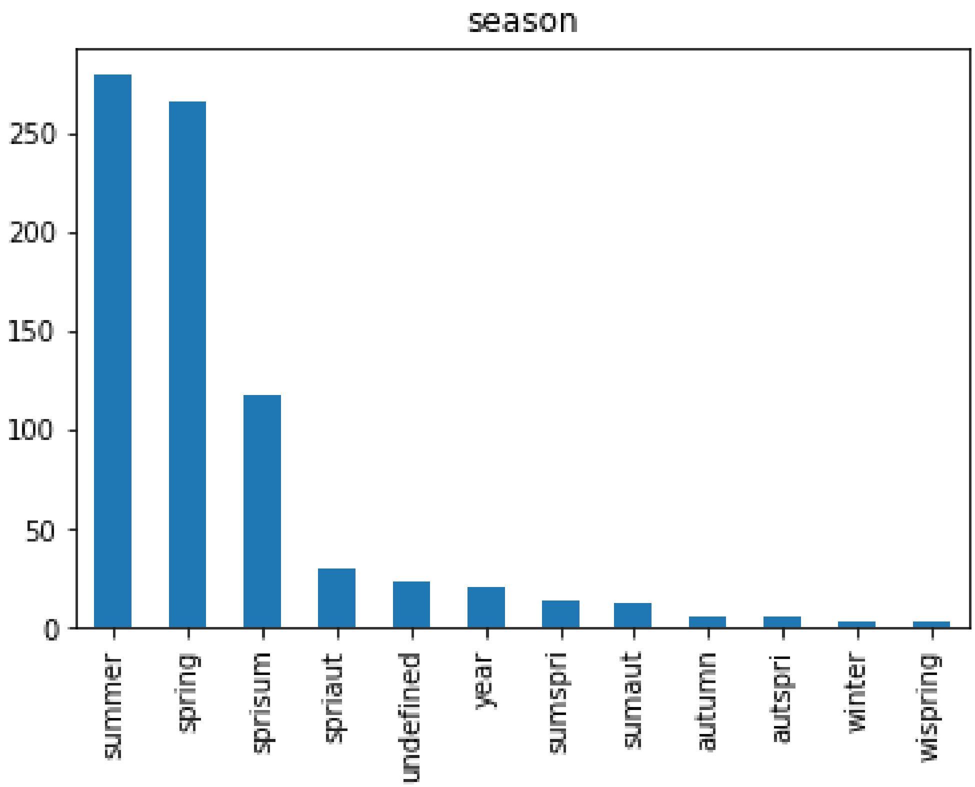
```
774       insects            no          yes        no
775       insects            no          yes        no
776       insects            no          yes        no
777       insects            no          yes        no
778       insects            no     solitary        no

                     visitor       guild sociality      feeding
0           Andrena_wilkella  ANDRENIDAE        no  oligolectic
1        Andrena_barbilabris  ANDRENIDAE        no   polylectic
2          Andrena_cineraria  ANDRENIDAE        no   polylectic
3           Andrena_flavipes  ANDRENIDAE        no   polylectic
4            Andrena_gravida  ANDRENIDAE        no   polylectic
..                       …         …       …          …
774  Dolichovespula_saxonica       WASPS       yes   polylectic
775       Bembecinus_tridens       WASPS        no    undefined
776         Vespula_vulgaris       WASPS       yes   polylectic
777    Philanthus_triangulum       WASPS        no   polylectic
778       Bembecinus_tridens       WASPS        no    undefined

[779 rows x 14 columns]>
```

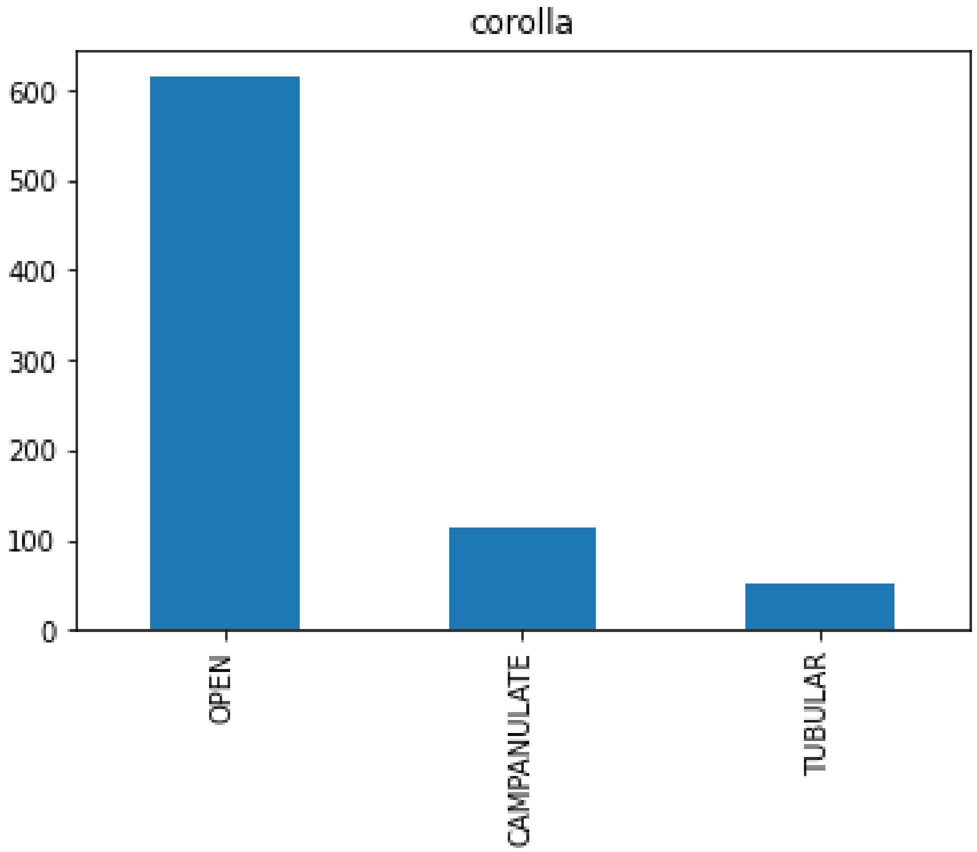
[68]:

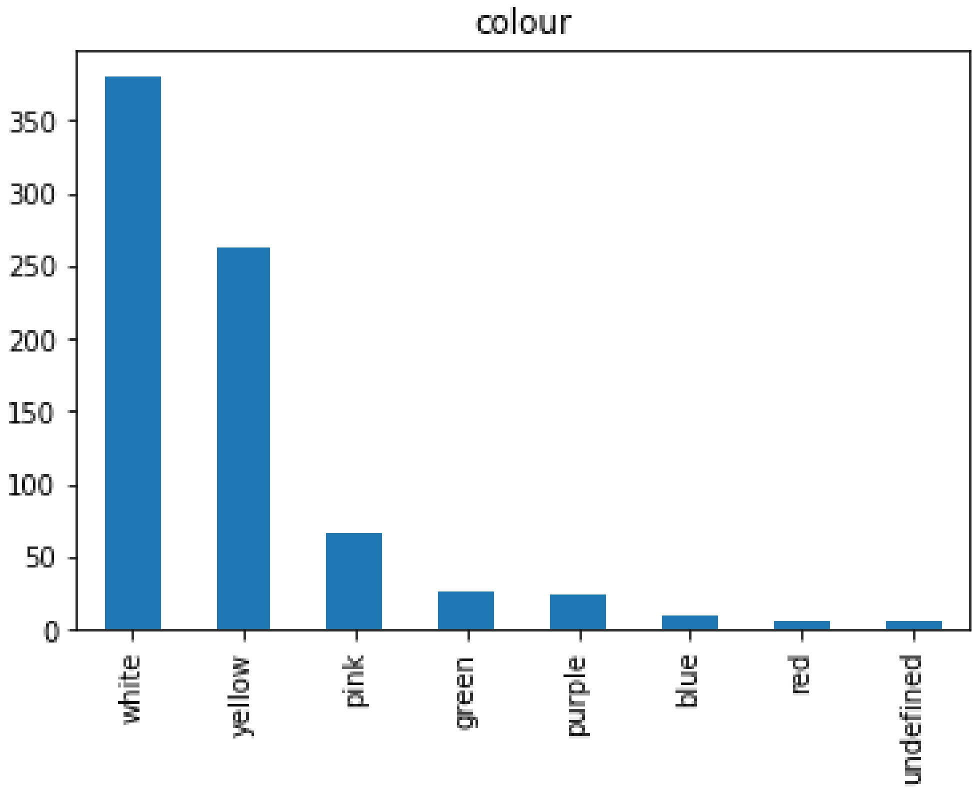
```python
for column in GPD_dataset_subset2_0NaN.columns.tolist():
    plt.pyplot.figure()
    plt.pyplot.title(column)
    GPD_dataset_subset2_0NaN[column].value_counts().plot(kind = 'bar')
```

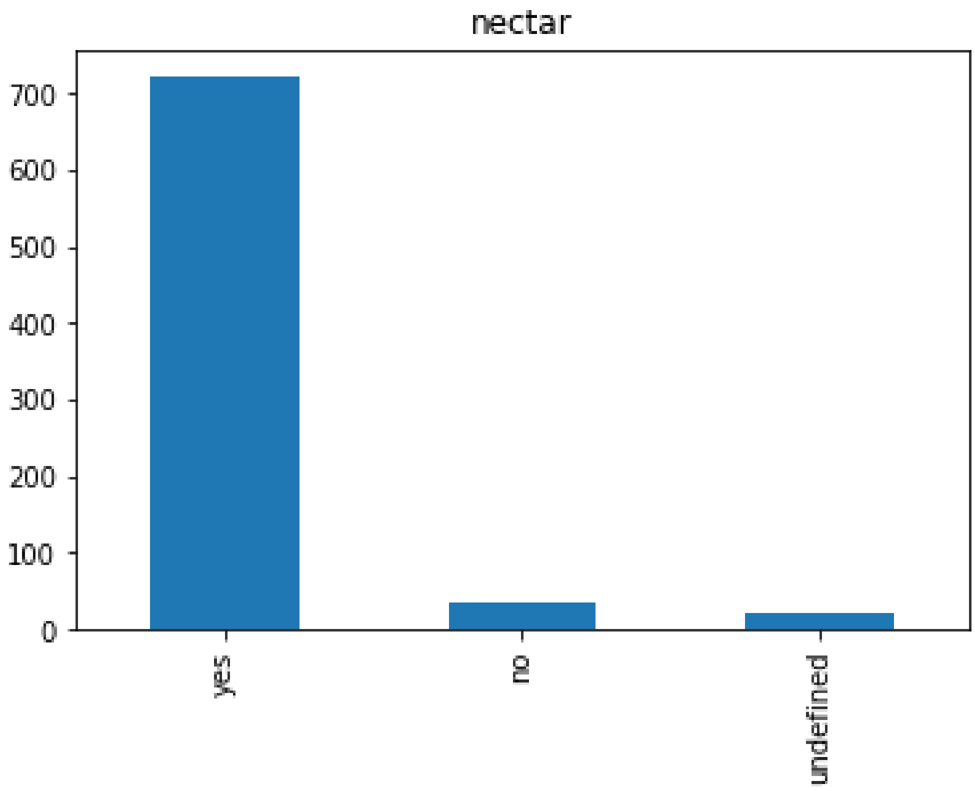

crop
0
10
20
30
40
50
60
70
80
Prunus_avium

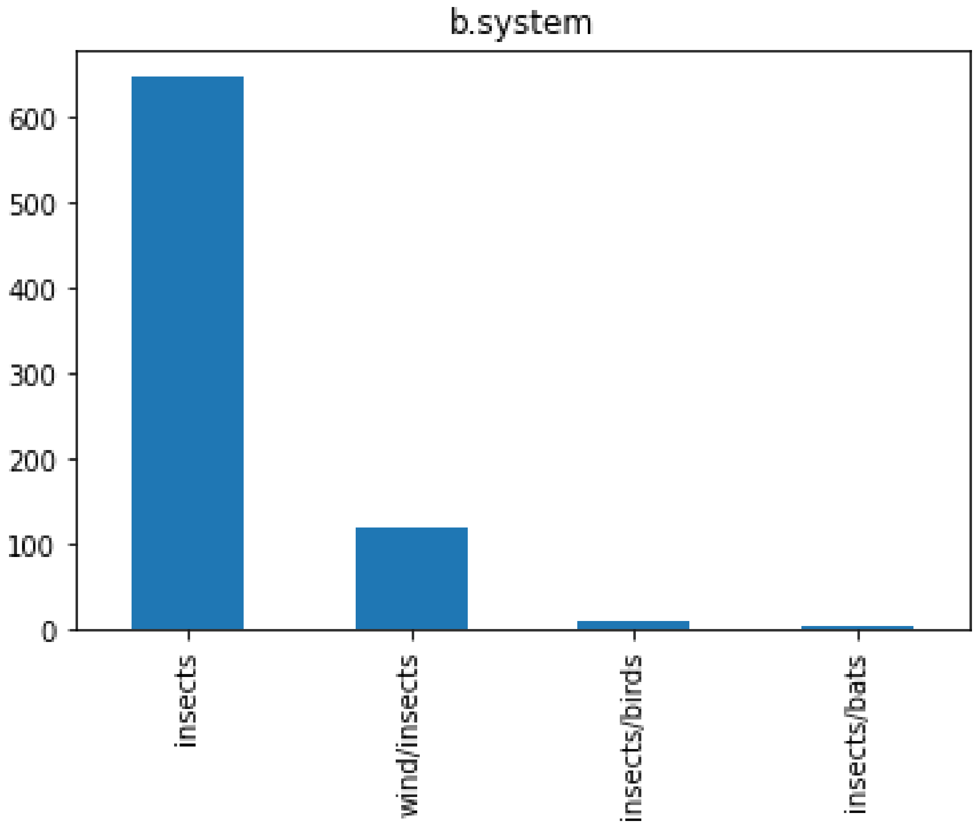

type
400
300
200
100
0
arboreous
herbaceous

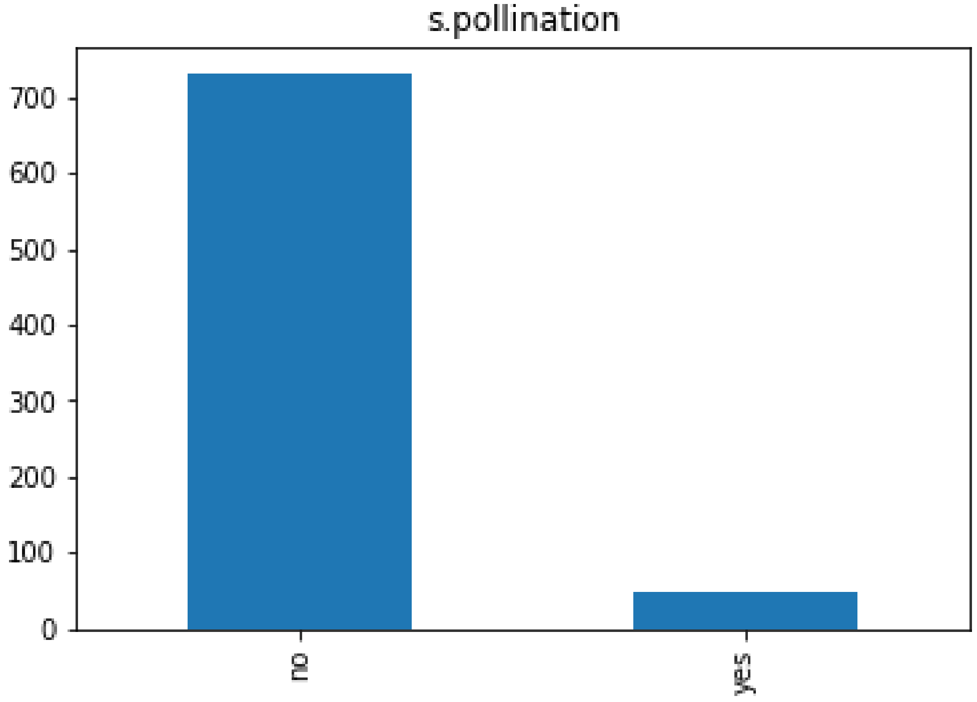

season
0
50
100
150
200
250
summer
spring
sprisum
spriaut
undefined
year
sumspri
sumaut
autumn
autspri
winter
wispring

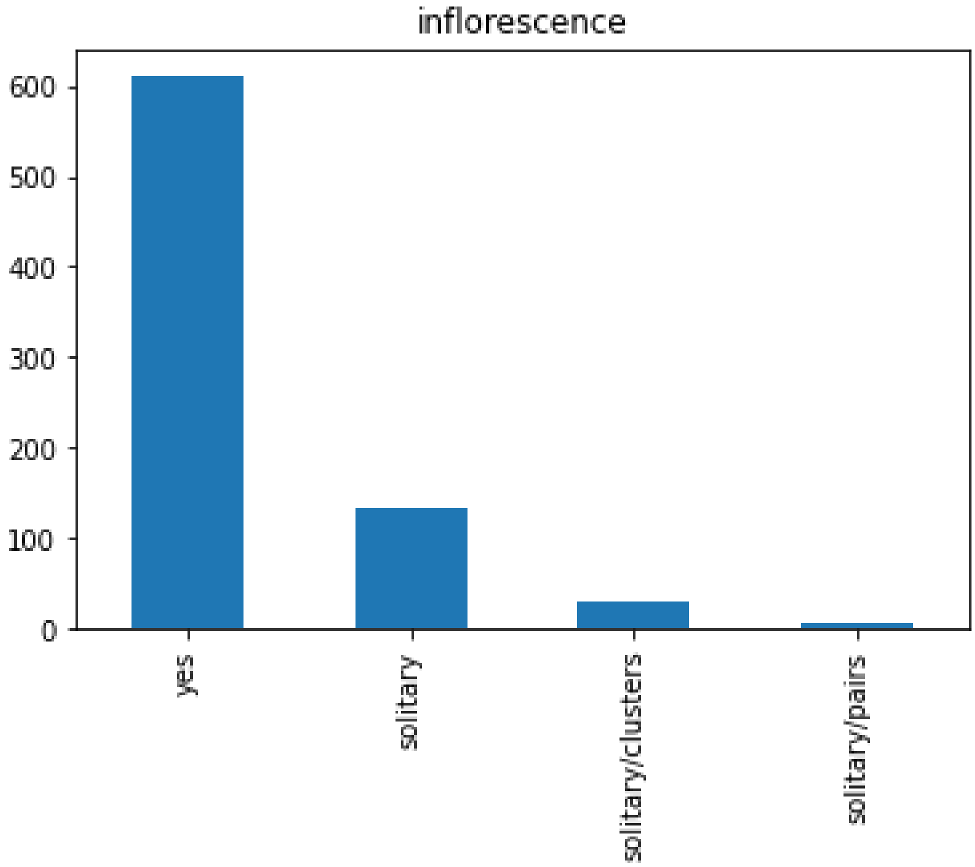

corolla
600
500
400
300
200
100
0
OPEN
CAMPANULATE
TUBULAR

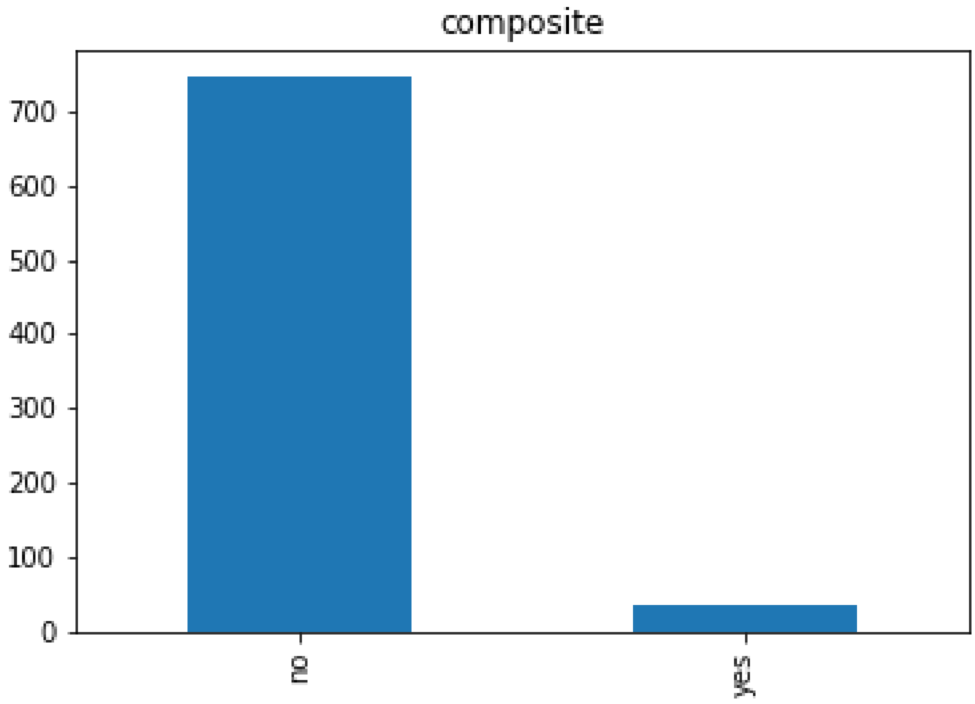

colour
0
50
100
150
200
250
300
350
white
yellow
pink
green
purple
blue
red
undefined

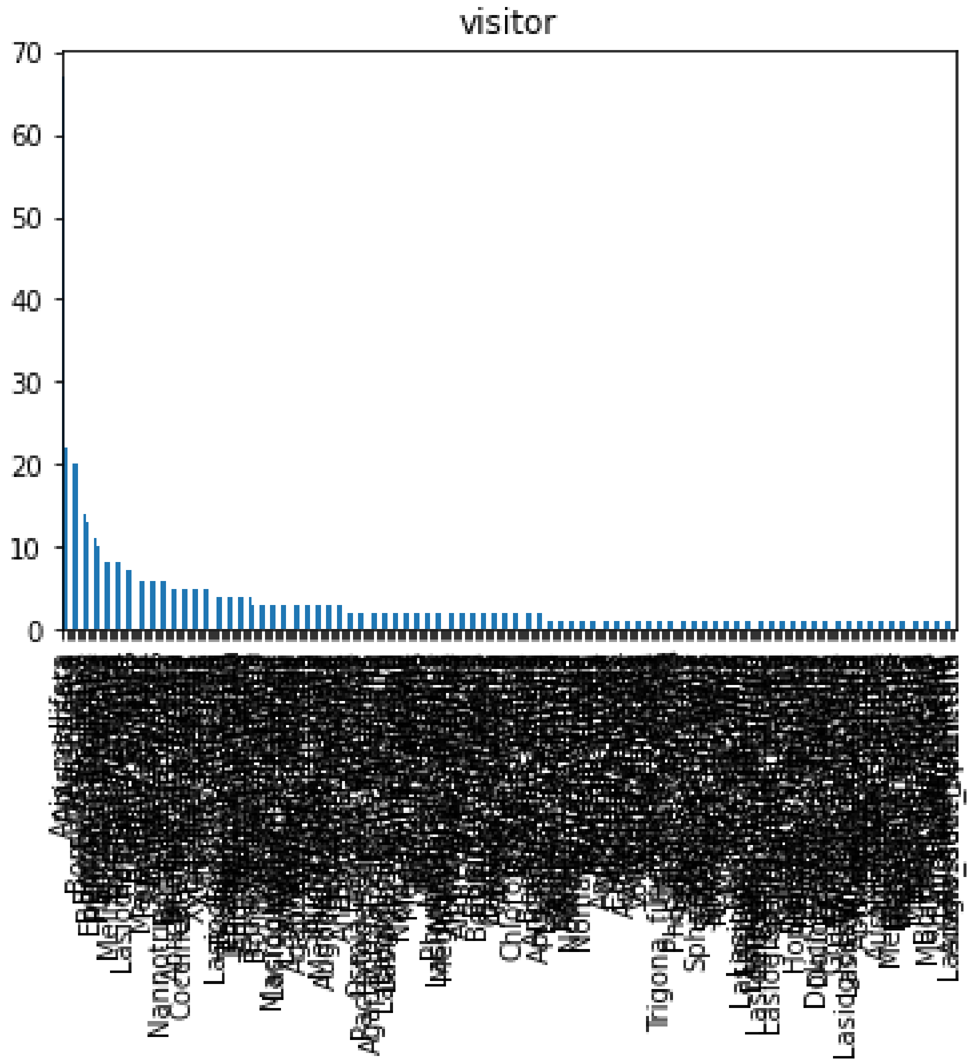

nectar
700
600
500
400
300
200
100
0
yes
no
undefined

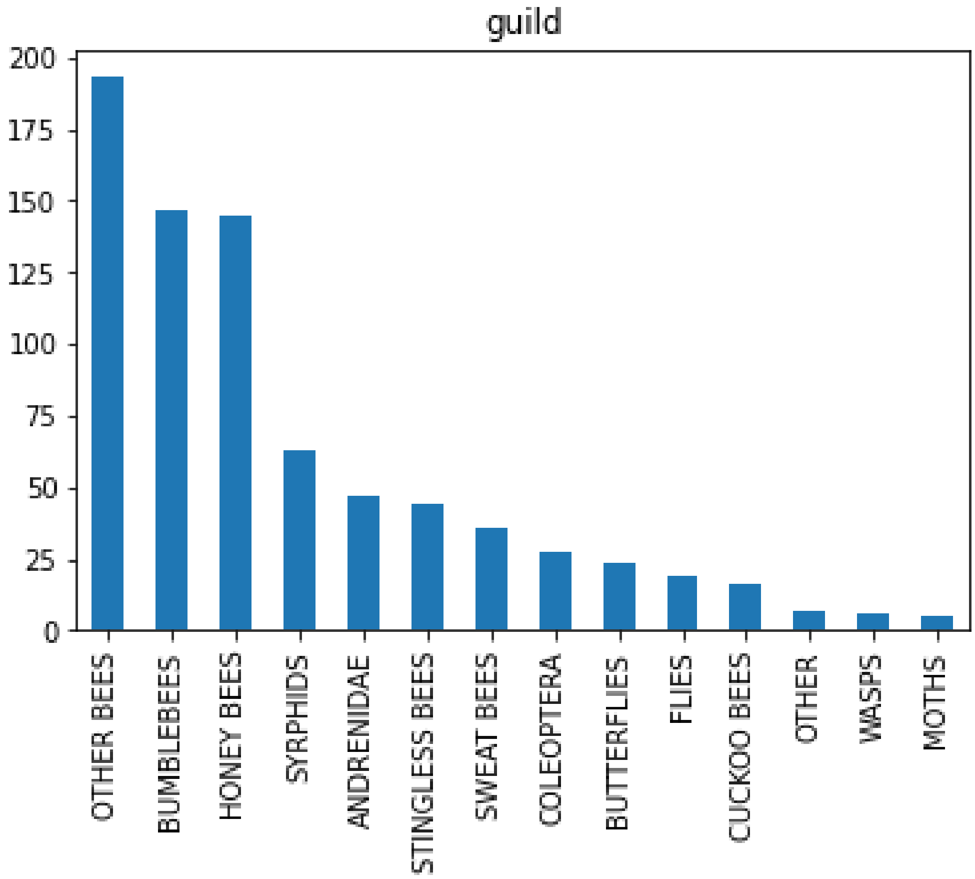

b.system
0
100
200
300
400
500
600
insects
wind/insects
insects/birds
insects/bats

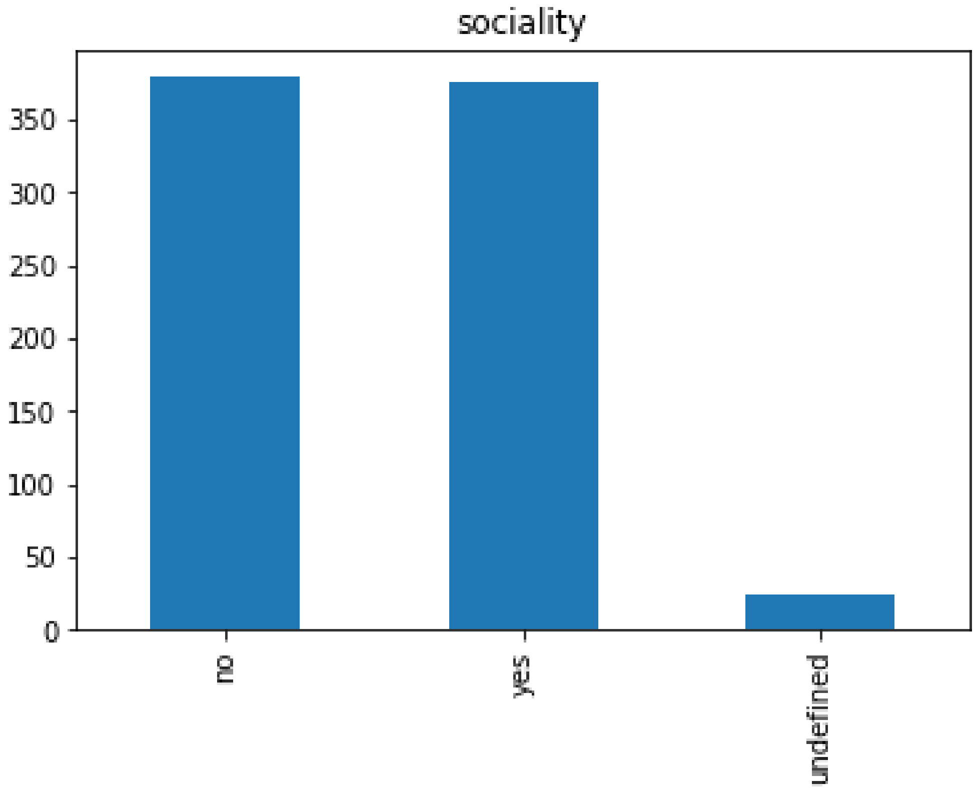

s.pollination
0
100
200
300
400
500
600
700
no
yes

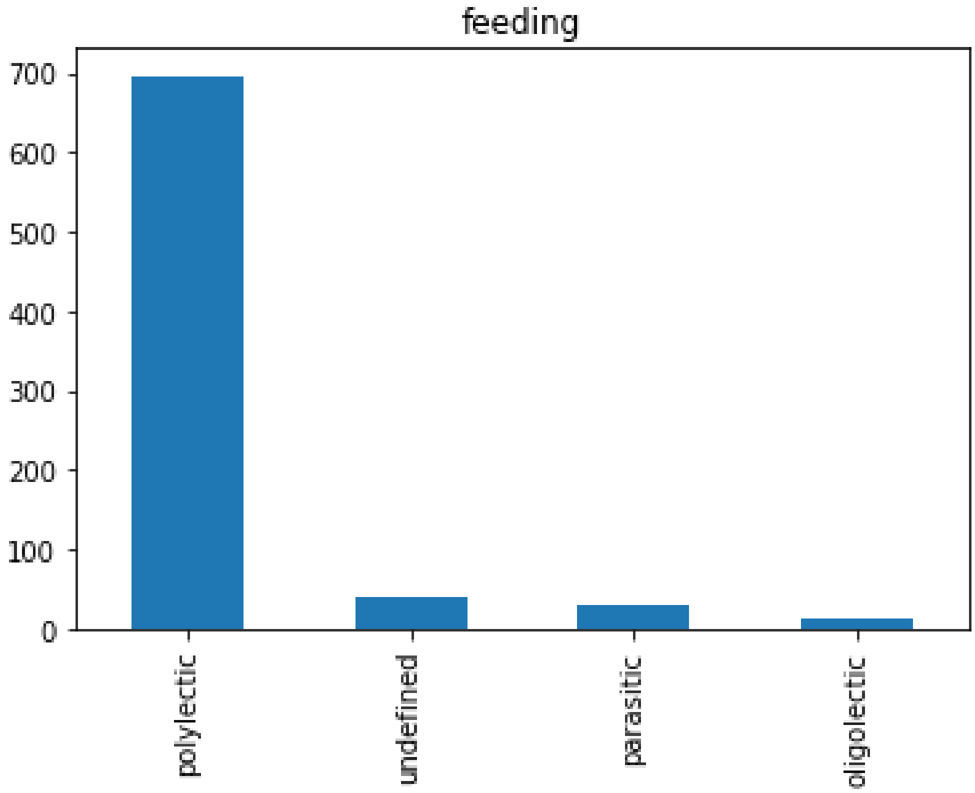

inflorescence
600
500
400
300
200
100
0
yes
solitary
solitary/clusters
solitary/pairs


composite
700
600
500
400
300
200
100
0
no
yes


visitor
70
60
50
40
30
20
10
0
Trigona_fu


guild
200
175
150
125
100
75
50
25
0
OTHER BEES
BUMBLEBEES
HONEY BEES
SYRPHIDS
ANDRENIDAE
STINGLESS BEES
SWEAT BEES
COLEOPTERA
BUTTERFLIES
FLIES
CUCKOO BEES
OTHER
WASPS
MOTHS


sociality
0
50
100
150
200
250
300
350
no
yes
undefined



We can use Cramer's V correlation value to present a heatmap of correlation between these categorical variables.

Unfortunately this metric seems a bit biased for "large" number of variables (Bergsma, Wicher. (2013). A bias-correction for Cramér's V and Tschuprow's T. Journal of the Korean Statistical Society. 42. 10.1016/j.jkss.2012.10.002.').

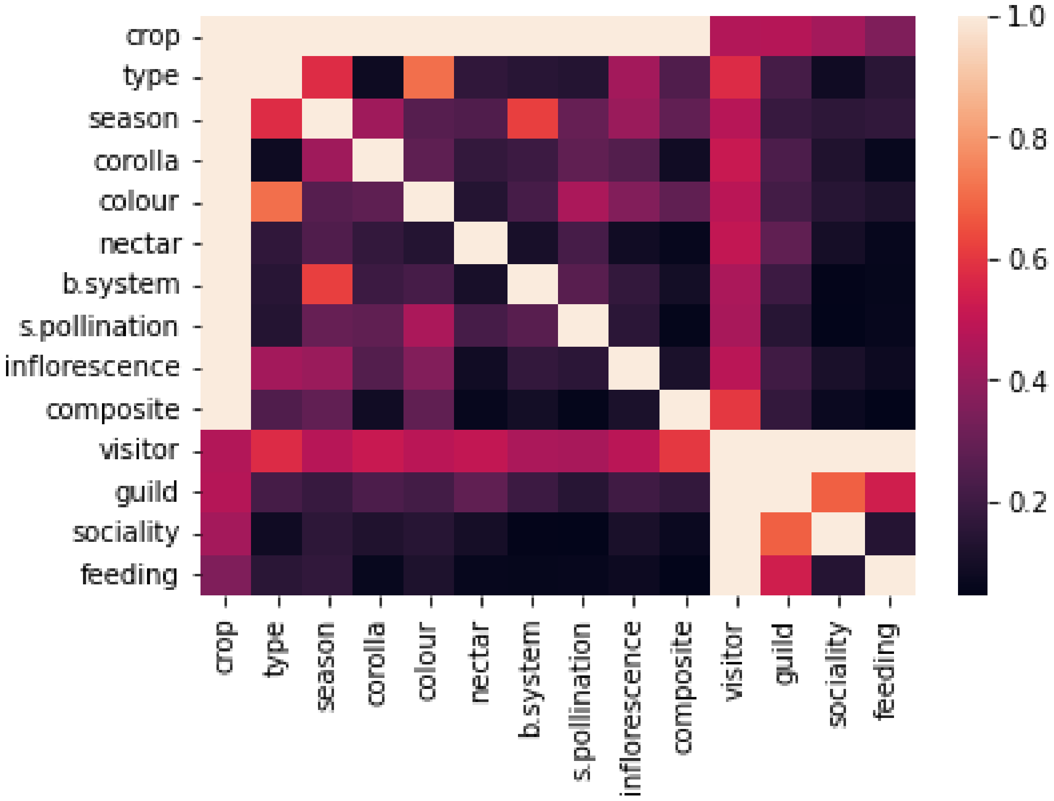
For the moment let's apply Cramer's V in a future we will improve the implementation with the bias correction.

[69]:
```
CramersV_GPD_subset_object = am.CramersV(GPD_dataset_subset2_0NaN)
```

[70]:
```
CramersV_GPD_subset_matrix = CramersV_GPD_subset_object.fit()
```

[71]:
```
sb.heatmap(CramersV_GPD_subset_matrix)
```

[71]:
```
<AxesSubplot:>
```

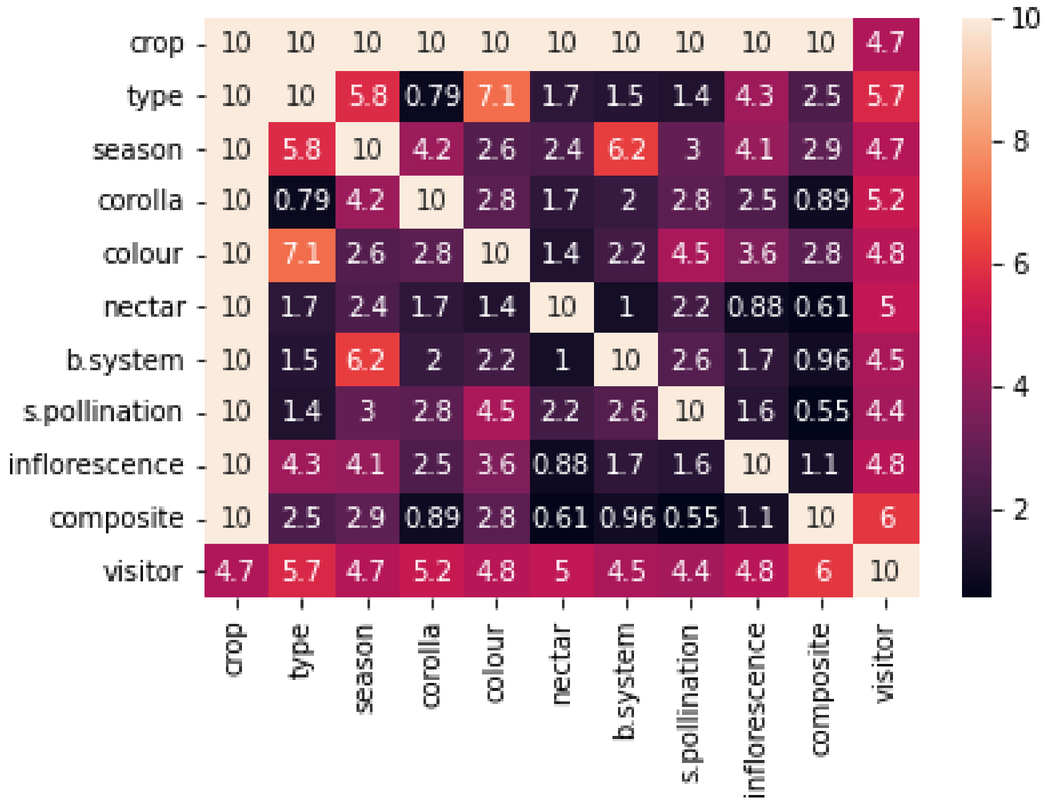


As we could expect whe have an evident separation of correlation between plants and bees where the crop is higly coreelated with the information about the plants charateristics; the guild is higly related with the pollintators charateristics and the "visitor" variable is the link between the two groups.

Let's focus on the two groups

```
[89]: sb.heatmap(CramersV_GPD_subset_matrix.iloc[:11,:11]*10, annot=True)
      # since we know that values are betwee 0 and 1 we multply for 10 to avoid most␣
       ↪of unusefull "0."
```

```
[89]: <AxesSubplot:>
```

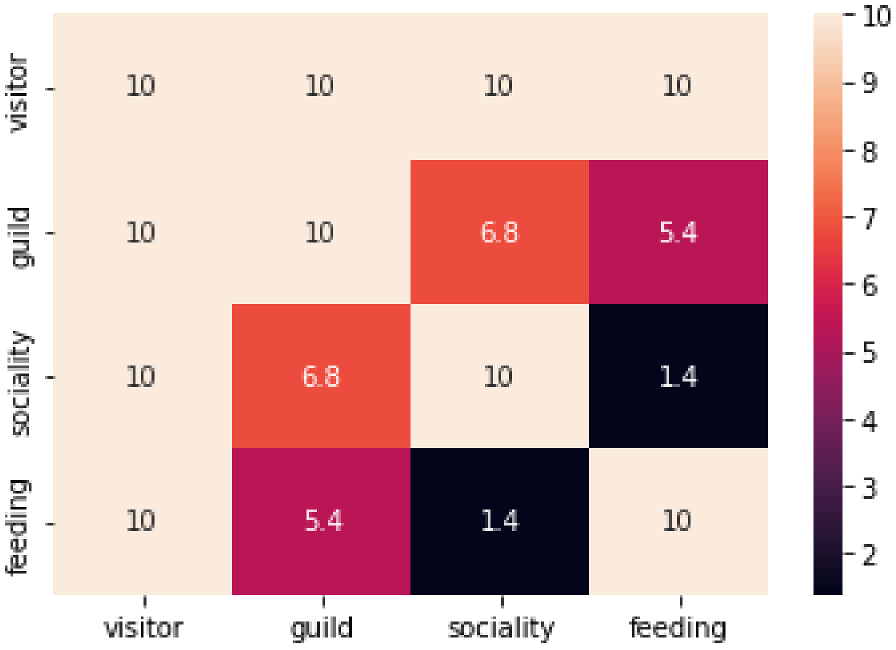


We can see that type (arboreous or heraceous) seems higly related to the flower colour and also quite related with the season.

The bloom system (bytheway from the values seems more a "pollination type") seems higly related with the flower season. Despite that, the bloom system seems not related with the flower colour and the plant type.

[92]:
```
sb.heatmap(CramersV_GPD_subset_matrix.iloc[10:,10:]*10, annot=True)
```

[92]:
```
<AxesSubplot:>
```



Quite self-explanatory

Let's have a closer look at the cited plants variables

Multi-categorical plot First of all let's encode the desired variable with numeric values.

For the visualization we can have an advantage encoding with an order even if the variables that we are considering don't have a natural order.

```
[93]: GPD_dataset_subset2_0NaN.columns
```

```
[93]: Index(['crop', 'type', 'season', 'corolla', 'colour', 'nectar', 'b.system',
             's.pollination', 'inflorescence', 'composite', 'visitor', 'guild',
             'sociality', 'feeding'],
            dtype='object')
```

```
[99]: type_encoder = LabelEncoder()
      type_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'type'])
      type_encoder.classes_
```

```
[99]: array(['arboreous', 'herbaceous'], dtype=object)
```

```
[100]: colour_encoder = LabelEncoder()
       colour_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'colour'])
       colour_encoder.classes_
```

[100]:
```
array(['blue', 'green', 'pink', 'purple', 'red', 'undefined', 'white',
       'yellow'], dtype=object)
```

[157]:
```
# let's transform "undefined" in "gray"
undefinded_gray = SimpleImputer(missing_values = 'undefined', strategy =␣
 ↪'constant', \
                                fill_value = 'gray')

gray_column_array = undefinded_gray.fit_transform( GPD_dataset_subset2_0NaN.
 ↪loc[:,'colour'].to_numpy().reshape(-1,1) )

GPD_dataset_subset2_0NaN.loc[:,'colour']= gray_column_array.reshape(-1,1)
```

```
/tmp/ipykernel_34953/2547033298.py:7: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  GPD_dataset_subset2_0NaN.loc[:,'colour']= gray_column_array.reshape(-1,1)
```

[158]:
```
colour_encoder = LabelEncoder()
colour_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'colour'])
colour_encoder.classes_
```

[158]:
```
array(['blue', 'gray', 'green', 'pink', 'purple', 'red', 'white',
       'yellow'], dtype=object)
```

[101]:
```
season_encoder = LabelEncoder()
season_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'season'])
season_encoder.classes_
```

[101]:
```
array(['autspri', 'autumn', 'spriaut', 'spring', 'sprisum', 'sumaut',
       'summer', 'sumspri', 'undefined', 'winter', 'wispring', 'year'],
      dtype=object)
```

[103]:
```
s_pollination_encoder = LabelEncoder()
s_pollination_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'s.pollination'])
s_pollination_encoder.classes_
```

[103]:
```
array(['no', 'yes'], dtype=object)
```

[105]:
```
guild_encoder = LabelEncoder()
guild_encoder.fit(GPD_dataset_subset2_0NaN.loc[:,'guild'])
guild_encoder.classes_
```

```
[105]: array(['ANDRENIDAE', 'BUMBLEBEES', 'BUTTERFLIES', 'COLEOPTERA',
              'CUCKOO BEES', 'FLIES', 'HONEY BEES', 'MOTHS', 'OTHER',
              'OTHER BEES', 'STINGLESS BEES', 'SWEAT BEES', 'SYRPHIDS', 'WASPS'],
             dtype=object)
```

We want to use simbols to represent "guild", so duble encode it

```
[664]: guild_mark_list␣
        ↪=['o','v','<','_','3','s','p','*','|','x','d','$\\Omega$','$\\xi$','$\\aleph$']
       guild_mark_encoder = LabelEncoder()
       guild_mark_encoder.fit(guild_mark_list)
       guild_mark_encoder.classes_
```

```
[664]: array(['$\\Omega$', '$\\aleph$', '$\\xi$', '*', '3', '<', '_', 'd', 'o',
              'p', 's', 'v', 'x', '|'], dtype='<U8')
```

```
[632]: guild_encoder.transform( guild_encoder.classes_ )
```

```
[632]: array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13])
```

```
[119]: guild_mark_encoder.transform( guild_mark_encoder.classes_ )
```

```
[119]: array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13])
```

```
[124]: type(guild_encoder.transform( guild_encoder.classes_ )[0] )
```

```
[124]: numpy.int64
```

```
[665]: guild_mark_legend = dict(zip(guild_encoder.classes_ , \
                                    guild_mark_encoder.inverse_transform( \
                                       guild_encoder.transform( guild_encoder.classes_␣
        ↪) ) ) )

       guild_mark_legend
```

```
[665]: {'ANDRENIDAE': '$\\Omega$',
        'BUMBLEBEES': '$\\aleph$',
        'BUTTERFLIES': '$\\xi$',
        'COLEOPTERA': '*',
        'CUCKOO BEES': '3',
        'FLIES': '<',
        'HONEY BEES': '_',
        'MOTHS': 'd',
        'OTHER': 'o',
        'OTHER BEES': 'p',
        'STINGLESS BEES': 's',
        'SWEAT BEES': 'v',
        'SYRPHIDS': 'x',
        'WASPS': '|'}
```

[ ]:

```

```

we should to add some noise to limitate points overlapping and maybe reshape on higher values, ”or use size to plot less points but add the information of the number of points with that value combination. Maybe both

[666]:

```
#let's convert colours in matplotlib colour values
colours_list = []
for color_data in GPD_dataset_subset2_0NaN.loc[:,'colour']:
    colours_list.append(plt.colors.CSS4_COLORS[color_data])



GPD_dataset_subset2_0NaN_T = GPD_dataset_subset2_0NaN[['type', 'season', 's.
 ↪pollination']].copy()
GPD_dataset_subset2_0NaN_T.loc[:,'type'] = type_encoder.transform (␣
 ↪GPD_dataset_subset2_0NaN.loc[:,'type'] )
GPD_dataset_subset2_0NaN_T.loc[:,'season'] = season_encoder.transform (␣
 ↪GPD_dataset_subset2_0NaN.loc[:,'season'] )
GPD_dataset_subset2_0NaN_T.loc[:,'s.pollination'] = s_pollination_encoder.
 ↪transform ( GPD_dataset_subset2_0NaN.loc[:,'s.pollination'] )
GPD_dataset_subset2_0NaN_T.loc[:,'guild'] = guild_mark_encoder.
 ↪inverse_transform( \
                                guild_encoder.transform(␣
 ↪GPD_dataset_subset2_0NaN.loc[:,'guild'] ))

#let's add some noise
random.seed(6)
```

[431]:

```
GPD_dataset_subset2_0NaN_T.describe()
```

[431]:

```
             type      season  s.pollination
count  779.000000  779.000000     779.000000
mean     0.431322    4.668806       0.062901
std      0.495579    1.965170       0.242941
min      0.000000    0.000000       0.000000
25%      0.000000    3.000000       0.000000
50%      0.000000    4.000000       0.000000
75%      1.000000    6.000000       0.000000
max      1.000000   11.000000       1.000000
```

[669]:

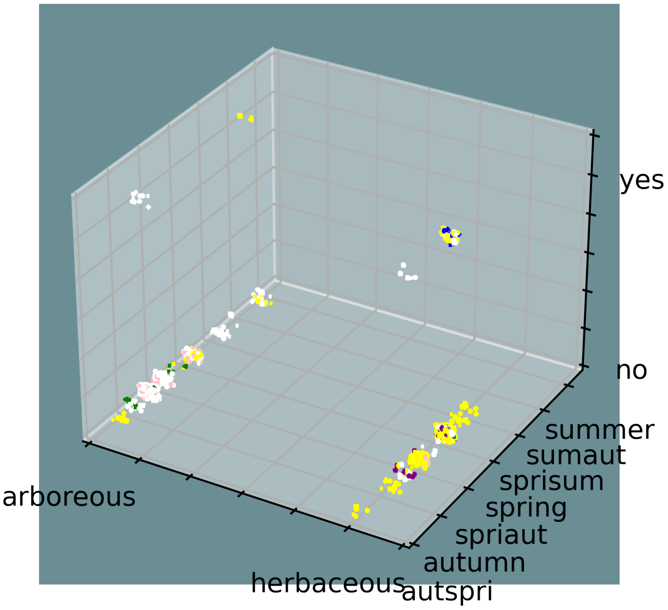
```
GPD_dataset_subset2_0NaN_T.describe
```

```
[669]: <bound method NDFrame.describe of      type  season  s.pollination     guild
       0       0       4              0  $\Omega$
       1       0       4              0  $\Omega$
       2       1       6              0  $\Omega$
       3       1       6              0  $\Omega$
       4       1       6              0  $\Omega$
       ..    …      …             …       …
       774     1       6              0         |
       775     0       2              0         |
       776     0       3              0         |
       777     1       6              0         |
       778     0       6              0         |

       [779 rows x 4 columns]>
```

```
[668]: fig = plt.pyplot.figure(dpi = 500)
       ax = fig.add_subplot( projection = '3d')

       ax.set_xlim(0,6)
       ax.set_ylim(0,13)
       ax.set_zlim(0,6)
       ax.set_xticklabels([type_encoder.inverse_transform([0])[0], '', '', '', '', \
                           type_encoder.inverse_transform([1])[0]])
       ax.set_yticklabels(season_encoder.
        ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]))
       ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '', '',␣
        ↪'', '', \
                           s_pollination_encoder.inverse_transform([1])[0]])
       ax.set_facecolor('#6b8e95')

       for i, ind in enumerate(GPD_dataset_subset2_0NaN_T.index):
           ax.scatter(xs = GPD_dataset_subset2_0NaN_T.loc[ind,'type']*5 + random.
        ↪randrange(0, 1000, )/3000 , \
                      ys = GPD_dataset_subset2_0NaN_T.loc[ind,'season'] + random.
        ↪randrange(0, 1000)/3000  , \
                      zs = GPD_dataset_subset2_0NaN_T.loc[ind,'s.pollination']*5 +␣
        ↪random.randrange(0, 1000)/3000 , \
                      c = colours_list[i],
                      sizes = [1.25], # markers dimension
                      marker = GPD_dataset_subset2_0NaN_T.loc[ind,'guild'])

       plt.pyplot.show()
```

```
/tmp/ipykernel_34953/1936832168.py:7: UserWarning:

FixedFormatter should only be used together with FixedLocator
```

```
/tmp/ipykernel_34953/1936832168.py:9: UserWarning:

FixedFormatter should only be used together with FixedLocator

/tmp/ipykernel_34953/1936832168.py:10: UserWarning:

FixedFormatter should only be used together with FixedLocator
```

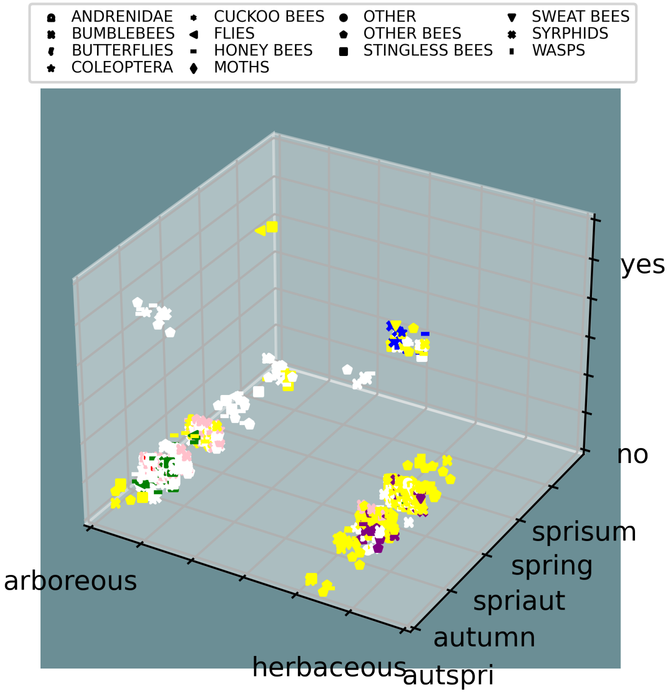


we need more space between season and bigger symbols

[730]:
```
%matplotlib inline
fig = plt.pyplot.figure(dpi = 500, figsize=(4,4))
ax = fig.add_subplot( projection = '3d')

ax.set_xlim(0,3)
ax.set_ylim(0,245)
ax.set_zlim(0,3)
ax.set_xticklabels([type_encoder.inverse_transform([0])[0], '', '', '', '', \
                    type_encoder.inverse_transform([1])[0]])
ax.set_yticklabels(season_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]))
ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '', '',␣
 ↪'', '', \
                    s_pollination_encoder.inverse_transform([1])[0]])
ax.set_facecolor('#6b8e95')
```

```
for i, ind in enumerate(GPD_dataset_subset2_0NaN_T.index):
    ax.scatter(xs = GPD_dataset_subset2_0NaN_T.loc[ind,'type']*2 + random.
 ↪randrange(0, 1000, )/3000 , \
               ys = GPD_dataset_subset2_0NaN_T.loc[ind,'season']*20 + random.
 ↪randrange(0, 1000)/3000  , \
               zs = GPD_dataset_subset2_0NaN_T.loc[ind,'s.pollination']*2 +␣
 ↪random.randrange(0, 1000)/3000 , \
               c = colours_list[i], \
               sizes = [10], # markers dimension \
               marker = GPD_dataset_subset2_0NaN_T.loc[ind,'guild'], \
               label = '_nolegend_')
# set legend
for i in guild_mark_legend:
        ax.scatter(xs = -20 , \
                   ys = -20  , \
                   zs = -20 , \
                   c = 'black', \
                   sizes = [5], # markers dimension \
                   marker = guild_mark_legend[i], \
                   label = i)

fig.legend(bbox_to_anchor=(0,1,0.92,0), labelspacing = 0.1, handletextpad = 0.
 ↪3, \
           columnspacing = 0.2, fontsize = 'xx-small', ncol = 4 )
plt.pyplot.show()
```

```
/tmp/ipykernel_34953/579580737.py:8: UserWarning:

FixedFormatter should only be used together with FixedLocator

/tmp/ipykernel_34953/579580737.py:10: UserWarning:

FixedFormatter should only be used together with FixedLocator

/tmp/ipykernel_34953/579580737.py:11: UserWarning:

FixedFormatter should only be used together with FixedLocator
```



Let’s use the size of the markers according to the number of occurrences and try to add noise to better distribute the binary groups

```
[671]: GPD_dataset_subset2_0NaN_T_colour = GPD_dataset_subset2_0NaN_T.copy()
       GPD_dataset_subset2_0NaN_T_colour['colour'] = colours_list
```

```
[734]: GPD_dataset_subset2_0NaN_T_colour.value_counts()
```

```
[734]: type  season  s.pollination  guild     colour
       0     3       0              p         #FFFFFF    33
       1     6       0              $\aleph$  #FFFF00    32
       0     3       0              $\Omega$  #FFFFFF    30
       1     4       0              p         #FFFF00    29
       0     4       0              p         #FFFFFF    25
                                                         ..
             1       0              _         #FFFF00     1
       1     0       0              _         #FFFF00     1
                                    $\aleph$  #FFFF00     1
       0     10      1              s         #FFFF00     1
       1     8       0              s         #FFFF00     1
       Length: 177, dtype: int64
```

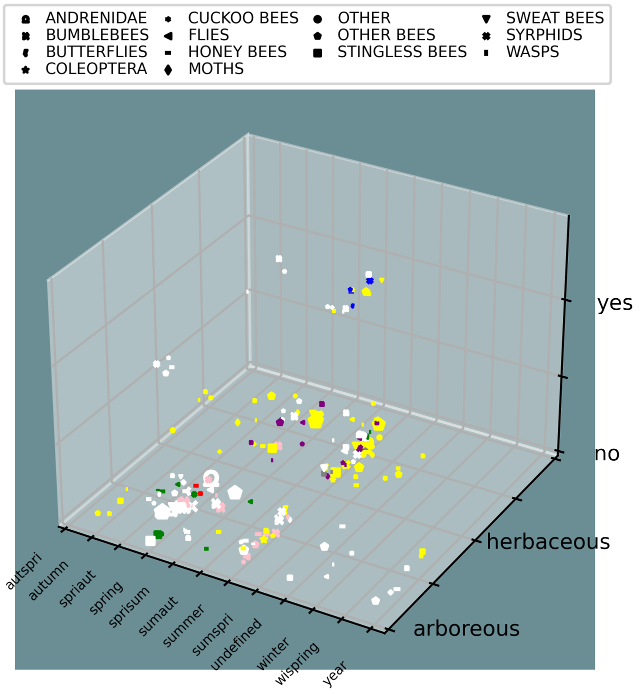
```
[649]: season_encoder.inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11])
```

[649]:

```
array(['autspri', 'autumn', 'spriaut', 'spring', 'sprisum', 'sumaut',
       'summer', 'sumspri', 'undefined', 'winter', 'wispring', 'year'],
      dtype=object)
```

[731]:

```
fig = plt.pyplot.figure(dpi = 500, figsize=(4,4))
ax = fig.add_subplot( projection = '3d')

ax.set_xlim(0,450)
ax.set_ylim(0,5)
ax.set_zlim(0,3)

x_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11])*40
ax.set_xticks(x_label_positions.tolist())
ax.set_xticklabels(season_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]), \
                   fontsize = 5, rotation = 45, ha="right", va="center")
ax.set_yticks([0,1.5,3,4.5,6])
ax.set_yticklabels(['', type_encoder.inverse_transform([0])[0], '',\
                    type_encoder.inverse_transform([1])[0], ''], fontsize = 8)
ax.set_zticks([0,1,2])
ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '',\
                    s_pollination_encoder.inverse_transform([1])[0]], fontsize␣
 ↪= 8)
ax.set_facecolor('#6b8e95')

for i, ind in enumerate(GPD_dataset_subset2_0NaN_T_colour.value_counts().index):
    ax.scatter(xs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][1]*40 + random.randrange(0, 100)/50   , \
               ys = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][0]*3 + random.randrange(0, 100)/50  , \
               zs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][2]*2 + random.randrange(0, 100)/300  , \
               marker = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][3],
               c = GPD_dataset_subset2_0NaN_T_colour.value_counts().index[i][4],
               sizes = [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪iloc[i]] # markers dimension
              )

# set legend
for i in guild_mark_legend:
        ax.scatter(xs = -20 , \
                   ys = -20  , \
                   zs = -20 , \
                   c = 'black', \
                   sizes = [5], # markers dimension \
                   marker = guild_mark_legend[i], \
                   label = i)

fig.legend(bbox_to_anchor=(0,1,0.92,0), labelspacing = 0.1, handletextpad = 0.3, \
           columnspacing = 0.2, fontsize = 'xx-small', ncol = 4 )


plt.pyplot.show()
```



[764]:
```
for i in type_encoder.inverse_transform([0,1]):
    print(i)
    print(type_encoder.transform([i])+3)
    print(guild_mark_encoder.inverse_transform(type_encoder.transform([i])+3))
```

```
arboreous
[3]
['*']
herbaceous
[4]
['3']
```

Let's make a rotating animation to show the graph from different point o views.

[ ]:

```
fig = plt.pyplot.figure(dpi = 500, figsize=(4,4))
ax = fig.add_subplot( projection = '3d')

ax.set_xlim(0,450)
ax.set_ylim(0,5)
ax.set_zlim(0,3)
x_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11])*40
ax.set_xticks(x_label_positions.tolist())
ax.set_xticklabels(season_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]), \
                   fontsize = 5, rotation = 45, ha="right", va="center")
ax.set_yticks([0,1.5,3,4.5,6])
ax.set_yticklabels(['', type_encoder.inverse_transform([0])[0], '',\
                    type_encoder.inverse_transform([1])[0], ''], fontsize = 8)
ax.set_zticks([0,1,2])
ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '',\
                    s_pollination_encoder.inverse_transform([1])[0]], fontsize␣
 ↪= 8)
ax.set_facecolor('#6b8e95')


for i, ind in enumerate(GPD_dataset_subset2_0NaN_T_colour.value_counts().index):
    ax.scatter(xs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][1]*40 + random.randrange(0, 100)/50  , \
               ys = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][0]*3 + random.randrange(0, 100)/50 , \
               zs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][2]*2 + random.randrange(0, 100)/300 , \
               marker = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][3],
               c = GPD_dataset_subset2_0NaN_T_colour.value_counts().index[i][4],
               sizes = [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪iloc[i]] # markers dimension
              )


fig.legend(bbox_to_anchor=(0,1,0.92,0), labelspacing = 0.1, handletextpad = 0.
 ↪3, \
           columnspacing = 0.2, fontsize = 'xx-small', ncol = 4 )

# define a function to call at each frame for view angle of the animation␣
 ↪movement
def update(frame, fig, ax):
    ax.view_init(elev = 20. , azim = frame)
    return fig, ax
```

```
# create the animation
anim = FuncAnimation(fig, update, frames = np.arange(0, 360, 2), repeat = True,␣
 ↪\
                     interval = 400, fargs = (fig, ax))
# save the animation in a gif file
#commented to pdf version - latex problems-  anim.save('Images/
 ↪GPD_subset_exploration.gif', dpi=180, writer='imagemagick', fps=8)
```

[ ]:

```

```

[675]:

```
#commented to pdf version - latex problems- anim.save('Images/
 ↪GPD_subset_exploration_slow.gif', dpi=150, writer='imagemagick', fps=5)
```

[ ]:

```
#Commented due to problems in insertion of gif in pdf via LaTeX
#![SegmentLocal](Images/GPD_subset_exploration.gif "segment")
```

Slower version

[742]:

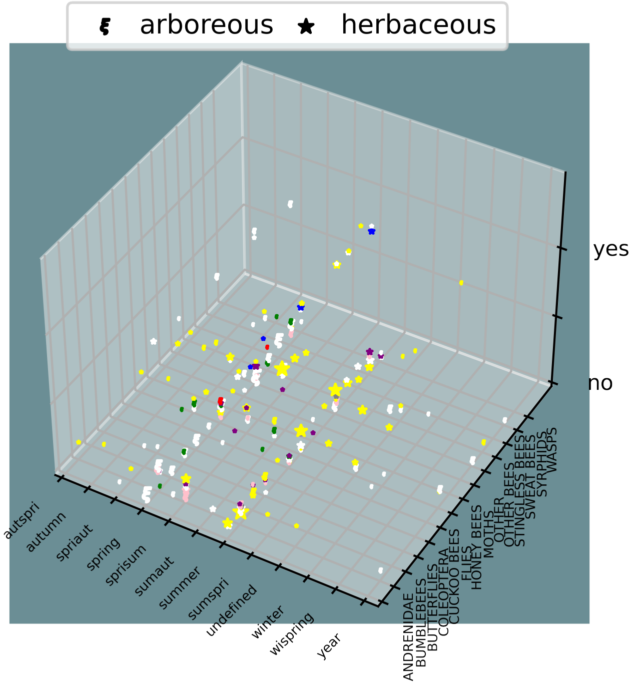
```
#Commented due to problems in insertion of gif in pdf via LaTeX
#![SegmentLocal](Images/GPD_subset_exploration_slow.gif "segment")
```

Maybe we can have a better visualization usign symbols for the type of plant

[822]:

```
%matplotlib inline
fig = plt.pyplot.figure(dpi = 800, figsize=(4,4))
ax = fig.add_subplot( projection = '3d')

ax.set_xlim(0,450)
ax.set_ylim(0,600)
ax.set_zlim(0,3)
x_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11])*40
ax.set_xticks(x_label_positions.tolist())
ax.set_xticklabels(season_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]), \
                   fontsize = 5, rotation = 45, ha="right", va="center")
y_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11,12,13])*40
ax.set_yticks(y_label_positions)
ax.set_yticklabels(guild_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11,12,13]), \
                    fontsize = 5, rotation = 90, ha="right", va="center")
ax.set_zticks([0,1,2])
ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '',\
                    s_pollination_encoder.inverse_transform([1])[0]], fontsize␣
 ↪= 8)
ax.set_facecolor('#6b8e95')
```

```
for i, ind in enumerate(GPD_dataset_subset2_0NaN_T_colour.value_counts().index):
    ax.scatter(xs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][1]*40 + \
                           random.randrange(0, 100)/50  , \
               ys = guild_mark_encoder.transform(\
                           [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][3]])*40 + \
                           random.randrange(0, 100)/50 , \
               zs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][2]*2 + \
                           random.randrange(0, 100)/300 , \
               marker = guild_mark_encoder.inverse_transform(\
                                [GPD_dataset_subset2_0NaN_T_colour.
 ↪value_counts().index[i][0]+2])[0],
               c = GPD_dataset_subset2_0NaN_T_colour.value_counts().index[i][4],
               sizes = [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪iloc[i]],
               label = '_nolegend_'
              )

# set legend
for i in type_encoder.inverse_transform([0,1]):
        ax.scatter(xs = -20 , \
                   ys = -20  , \
                   zs = -20 , \
                   c = 'black', \
                   sizes = [5], # markers dimension \
                   marker = guild_mark_encoder.inverse_transform(type_encoder.
 ↪transform([i])+2)[0], \
                   label = i)

fig.legend(bbox_to_anchor=(0,0.95,0.8,0), labelspacing = 0.1, handletextpad = 0.
 ↪3, \
           columnspacing = 0.2, ncol = 2, markerscale = 2.5 )

ax.view_init(elev = 40.)
```



```
[ ]: # create the animation
     anim = FuncAnimation(fig, update, frames = np.arange(0, 360, 2), repeat = True,␣
      ↪\
                          interval = 400, fargs = (fig, ax))
     # save the animation in a gif file
     #commented to pdf version - latex problems- anim.save('Images/
      ↪GPD_subset_exploration_2_slow.gif', dpi=150, writer='imagemagick', fps=6)
```

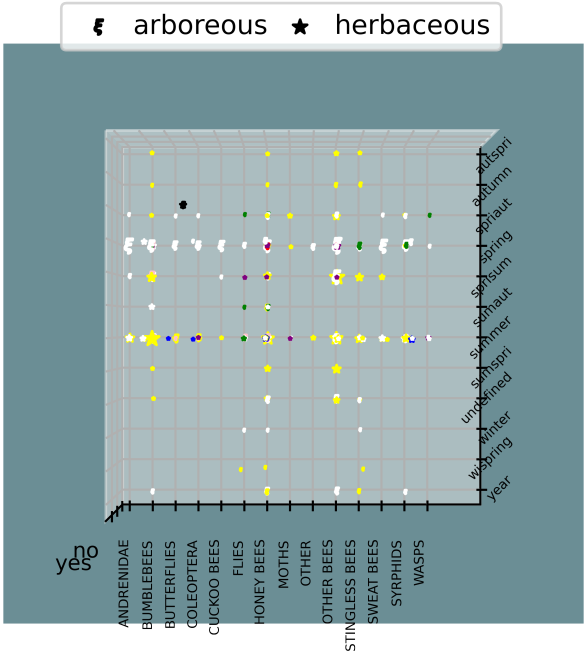
```
[ ]: #![SegmentLocal](Images/GPD_subset_exploration_2_slow.gif "segment")
```

Let’s reduce 1 dimension with a upper view

```
[833]: %matplotlib inline
       fig = plt.pyplot.figure(dpi = 800, figsize=(4,4))
       ax = fig.add_subplot( projection = '3d')

       ax.set_xlim(0,450)
       ax.set_ylim(0,600)
       ax.set_zlim(0,3)
       x_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11])*40
       ax.set_xticks(x_label_positions.tolist())
       ax.set_xticklabels(season_encoder.
        ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11]), \
                          fontsize = 5, rotation = 45, ha="right", va="center")
```

```
y_label_positions = np.array([0,1,2,3,4,5,6,7,8,9,10,11,12,13])*40
ax.set_yticks(y_label_positions)
ax.set_yticklabels(guild_encoder.
 ↪inverse_transform([0,1,2,3,4,5,6,7,8,9,10,11,12,13]), \
                    fontsize = 5, rotation = 90, ha="right", va="top")
ax.set_zticks([0,1,2])
ax.set_zticklabels([s_pollination_encoder.inverse_transform([0])[0], '',\
                    s_pollination_encoder.inverse_transform([1])[0]], fontsize␣
 ↪= 8)
ax.set_facecolor('#6b8e95')


for i, ind in enumerate(GPD_dataset_subset2_0NaN_T_colour.value_counts().index):
    ax.scatter(xs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][1]*40 + \
                           random.randrange(0, 100)/50  , \
               ys = guild_mark_encoder.transform(\
                           [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][3]])*40 + \
                           random.randrange(0, 100)/50 , \
               zs = GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪index[i][2]*2 + \
                           random.randrange(0, 100)/300 , \
               marker = guild_mark_encoder.inverse_transform(\
                                [GPD_dataset_subset2_0NaN_T_colour.
 ↪value_counts().index[i][0]+2])[0],
               c = GPD_dataset_subset2_0NaN_T_colour.value_counts().index[i][4],
               sizes = [GPD_dataset_subset2_0NaN_T_colour.value_counts().
 ↪iloc[i]],
               label = '_nolegend_'
              )

# set legend
for i in type_encoder.inverse_transform([0,1]):
        ax.scatter(xs = -20 , \
                   ys = -20  , \
                   zs = -20 , \
                   c = 'black', \
                   sizes = [5], # markers dimension \
                   marker = guild_mark_encoder.inverse_transform(type_encoder.
 ↪transform([i])+2)[0], \
                   label = i)

fig.legend(bbox_to_anchor=(0,0.95,0.8,0), labelspacing = 0.1, handletextpad = 0.
 ↪3, \
           columnspacing = 0.2, ncol = 2, markerscale = 2.5 )
```

```
ax.view_init(90, 0)
```



1.4.1 Year distribution

Let's focus on the distribution of flowers and pollinators during the year

[834]:
```
GPD_dataset_subset2_0NaN.describe()
```

[834]:
```
                crop        type  season corolla colour nectar b.system  \
count            779         779     779     779    779    779      779
unique            78           2      12       3      8      3        4
top     Prunus_avium  arboreous  summer    OPEN  white    yes  insects
freq              81         443     279     615    380    721      647

       s.pollination inflorescence composite         visitor       guild  \
count            779           779       779             779         779
unique             2             4         2             254          14
top               no           yes        no  Apis_mellifera  OTHER BEES
freq             730           611       745              67         193

       sociality    feeding
count        779        779
unique         3          4
top           no  polylectic
```

```
freq          379          696
```

[851]:
```
GPD_seasons = GPD_dataset_subset2_0NaN.season.unique()
#let's convert to list to print the complete list without "..."
GPD_seasons.to_list()
```

[851]:
```
['sprisum',
 'summer',
 'spriaut',
 'spring',
 'autspri',
 'sumspri',
 'autumn',
 'undefined',
 'year',
 'sumaut',
 'wispring',
 'winter']
```

mmm with “spriaut” it means between spring and autumn or in spring and in autumn but not in summer?

Notice that we have boht spri-sum and sum-spri so considering that seems the order count we shoud infer that spri-aut means between spring and autumn including summer.

So let’s convert these values in a more managable format and try to make a nice and useful plot

[852]:
```
def season_check(season, season_period):
    if season_period == 'undefined':
        return 0
    elif season_period == 'year':
        return 1
    elif season == 'spring':
        if season_period in ['sprisum', 'spriaut', 'sumspri', 'winspring',␣
 ↪'spring']:
            return 1
        else:
            return 0
    elif season == 'summer':
        if season_period in ['sprisum', 'spriaut', 'sumspri', 'sumaut',␣
 ↪'summer']:
            return 1
        else:
            return 0
    elif season == 'autumn':
        if season_period in ['spriaut', 'sumaut', 'sumspri', 'autspri',␣
 ↪'autumn']:
            return 1
        else:
            return 0
    elif season == 'winter':
        if season_period in ['winspring','sumspri', 'autspri', 'winter']:
            return 1
        else:
            return 0

    return 0
```

[853]:
```
GPD_seasons_dataset = GPD_dataset_subset2_0NaN
```

[858]:
```
GPD_seasons_dataset.columns
```

[858]:
```
Index(['crop', 'type', 'season', 'corolla', 'colour', 'nectar', 'b.system',
       's.pollination', 'inflorescence', 'composite', 'visitor', 'guild',
       'sociality', 'feeding'],
      dtype='object')
```

[859]:
```
for s in ['spring', 'summer', 'autumn', 'winter']:
    GPD_seasons_dataset[s] = GPD_seasons_dataset.apply(lambda row:␣
 ↪season_check(s, row.season), axis =1)
```

[865]:
```
GPD_seasons_dataset.describe()
```

[865]:
```
           spring      summer      autumn      winter
count  779.000000  779.000000  779.000000  779.000000
mean     0.575096    0.608472    0.112965    0.055199
std      0.494646    0.488406    0.316754    0.228515
min      0.000000    0.000000    0.000000    0.000000
25%      0.000000    0.000000    0.000000    0.000000
50%      1.000000    1.000000    0.000000    0.000000
75%      1.000000    1.000000    0.000000    0.000000
max      1.000000    1.000000    1.000000    1.000000
```

[866]:
```
GPD_seasons_dataset.columns
```

[866]:
```
Index(['crop', 'type', 'season', 'corolla', 'colour', 'nectar', 'b.system',
       's.pollination', 'inflorescence', 'composite', 'visitor', 'guild',
       'sociality', 'feeding', 'spring', 'summer', 'autumn', 'winter'],
      dtype='object')
```

[867]:
```
GPD_seasons_dataset.to_pickle(GPD_F_dataset_directory+"GPD_seasons_dataset.pkl")
```

1.4.2 Year distribution - Starting point

```
[80]: GPD_seasons_dataset = pd.
       ↪read_pickle(GPD_F_dataset_directory+"GPD_seasons_dataset.pkl")
```

```
[883]: GPD_crops = GPD_seasons_dataset.crop.unique()
       GPD_crops_seasons_dataset = pd.DataFrame()
       GPD_crops_seasons_dataset = GPD_crops_seasons_dataset.assign(crop = GPD_crops.
        ↪to_list())
       GPD_crops_seasons_dataset.describe()
```

```
[883]:                         crop
       count                     78
       unique                    78
       top     Vaccinium_corymbosum
       freq                       1
```

```
[899]: GPD_crops_seasons_dataset.describe()
```

```
[899]:                         crop
       count                     78
       unique                    78
       top     Vaccinium_corymbosum
       freq                       1
```

```
[939]: GPD_crops_seasons_dataset.columns
```

```
[939]: Index(['crop', 'herbaceous', 'arboreous', 'campanulate_corolla',
              'open_corolla', 'tubular_corolla', 'composite_flower',
              'self_pollination', 'nectar', 'spring', 'summer', 'autumn', 'winter'],
             dtype='object')
```

Let's assume that "type", "corolla", "nectar", "self pollination", "inflorescence", and "composite" are unique for crop.

```
[905]: GPD_seasons_dataset.corolla.unique().to_list()
```

```
[905]: ['CAMPANULATE', 'OPEN', 'TUBULAR']
```

```
[906]: GPD_seasons_dataset.inflorescence.unique().to_list()
```

```
[906]: ['yes', 'solitary', 'solitary/clusters', 'solitary/pairs']
```

mmm inflorescence values seems to indicate that it is not so much a valuable feature.

```
[ ]: """To do: insert the cited columns considering the firsth value of each crop,␣
      ↪maybe doing it we can also make a one hot encoding
     GPD_crops_seasons_dataset = GPD_crops_seasons_dataset.assign(herbaceous = \
                                                           ␣
 ↪GPD_seasons_dataset.loc[GPD_crops_seasons_dataset['crop'] == ,'type'])
"""
```

[907]:

```
GPD_crops_seasons_dataset = GPD_crops_seasons_dataset.assign(herbaceous =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            arboreous = ␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                           ␣
 ↪campanulate_corolla = [0]*len(GPD_crops_seasons_dataset.crop),
                                                            open_corolla =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            tubular_corolla =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            composite_flower =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            self_pollination =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            nectar =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            spring =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            summer =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            autumn =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop),
                                                            winter =␣
 ↪[0]*len(GPD_crops_seasons_dataset.crop))
GPD_crops_seasons_dataset.describe()
```

[907]:

```
       herbaceous  arboreous  campanulate_corolla  open_corolla  \
count        78.0       78.0                 78.0          78.0
mean          0.0        0.0                  0.0           0.0
std           0.0        0.0                  0.0           0.0
min           0.0        0.0                  0.0           0.0
25%           0.0        0.0                  0.0           0.0
50%           0.0        0.0                  0.0           0.0
75%           0.0        0.0                  0.0           0.0
max           0.0        0.0                  0.0           0.0

       tubular_corolla  composite_flower  self_pollination  nectar  spring  \
count             78.0              78.0              78.0    78.0    78.0
mean               0.0               0.0               0.0     0.0     0.0
std                0.0               0.0               0.0     0.0     0.0
min                0.0               0.0               0.0     0.0     0.0
25%                0.0               0.0               0.0     0.0     0.0
```

```
50%                 0.0                 0.0                 0.0      0.0      0.0
75%                 0.0                 0.0                 0.0      0.0      0.0
max                 0.0                 0.0                 0.0      0.0      0.0

       summer  autumn  winter
count    78.0    78.0    78.0
mean      0.0     0.0     0.0
std       0.0     0.0     0.0
min       0.0     0.0     0.0
25%       0.0     0.0     0.0
50%       0.0     0.0     0.0
75%       0.0     0.0     0.0
max       0.0     0.0     0.0
```

[913]:

```
GPD_crops_seasons_dataset.columns
```

[913]:

```
Index(['crop', 'herbaceous', 'arboreous', 'campanulate_corolla',
       'open_corolla', 'tubular_corolla', 'composite_flower',
       'self_pollination', 'nectar', 'spring', 'summer', 'autumn', 'winter'],
      dtype='object')
```

[940]:

```
#there is for sure a better way, but that's the easyest to think about for␣
 ↪today XD
for i in range(0, len(GPD_crops_seasons_dataset.crop)):
    GPD_crops_seasons_dataset.loc[i,'herbaceous'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'type'].to_list()[0] == 'herbaceous' else 0
    GPD_crops_seasons_dataset.loc[i,'arboreous'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'type'].to_list()[0] == 'arboreous' else 0
    GPD_crops_seasons_dataset.loc[i,'campanulate_corolla'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'corolla'].to_list()[0] == 'CAMPANULATE' else 0
    GPD_crops_seasons_dataset.loc[i,'open_corolla'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'corolla'].to_list()[0] == 'OPEN' else 0
    GPD_crops_seasons_dataset.loc[i,'tubular_corolla'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'corolla'].to_list()[0] == 'TUBULAR' else 0
    GPD_crops_seasons_dataset.loc[i,'composite_flower'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
 ↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'composite'].to_list()[0] == 'yes' else 0
    GPD_crops_seasons_dataset.loc[i,'self_pollination'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            's.pollination'].to_list()[0] == 'yes' else 0
    GPD_crops_seasons_dataset.loc[i,'self_pollination'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            's.pollination'].to_list()[0] == 'yes' else 0
    GPD_crops_seasons_dataset.loc[i,'nectar'] = 1 if  \
    GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                            'nectar'].to_list()[0] == 'yes' else 0
    GPD_crops_seasons_dataset.loc[i,'spring'] = \
        GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                                'spring'].sum()
    GPD_crops_seasons_dataset.loc[i,'summer'] = \
        GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                                'summer'].sum()
    GPD_crops_seasons_dataset.loc[i,'autumn'] = \
        GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                                'autumn'].sum()
    GPD_crops_seasons_dataset.loc[i,'winter'] = \
        GPD_seasons_dataset.loc[GPD_seasons_dataset.crop ==␣
↪GPD_crops_seasons_dataset.iloc[i,0] , \
                                'winter'].sum()
```

[941]:
```
GPD_crops_seasons_dataset.describe()
```

[941]:
```
       herbaceous  arboreous  campanulate_corolla  open_corolla  \
count   78.000000  78.000000            78.000000     78.000000
mean     0.435897   0.564103             0.141026      0.756410
std      0.499083   0.499083             0.350301      0.432026
min      0.000000   0.000000             0.000000      0.000000
25%      0.000000   0.000000             0.000000      1.000000
50%      0.000000   1.000000             0.000000      1.000000
75%      1.000000   1.000000             0.000000      1.000000
max      1.000000   1.000000             1.000000      1.000000

       tubular_corolla  composite_flower  self_pollination     nectar  \
count        78.000000         78.000000         78.000000  78.000000
```

```
mean          0.102564          0.025641          0.076923  0.910256
std           0.305352          0.159085          0.268194  0.287664
min           0.000000          0.000000          0.000000  0.000000
25%           0.000000          0.000000          0.000000  1.000000
50%           0.000000          0.000000          0.000000  1.000000
75%           0.000000          0.000000          0.000000  1.000000
max           1.000000          1.000000          1.000000  1.000000

          spring     summer     autumn     winter
count  78.000000  78.000000  78.000000  78.000000
mean    5.743590   6.076923   1.128205   0.551282
std    11.843608   8.338254   2.769776   2.055385
min     0.000000   0.000000   0.000000   0.000000
25%     0.000000   0.000000   0.000000   0.000000
50%     1.500000   4.000000   0.000000   0.000000
75%     6.000000   6.750000   0.000000   0.000000
max    81.000000  44.000000  14.000000  14.000000
```

```
[942]: GPD_crops_seasons_dataset.
        ↪to_pickle(GPD_F_dataset_directory+"GPD_crops_seasons_dataset.pkl")
```

1.4.3 Year distribution - Starting point

```
[4]: GPD_crops_seasons_dataset = pd.
      ↪read_pickle(GPD_F_dataset_directory+"GPD_crops_seasons_dataset.pkl")
```

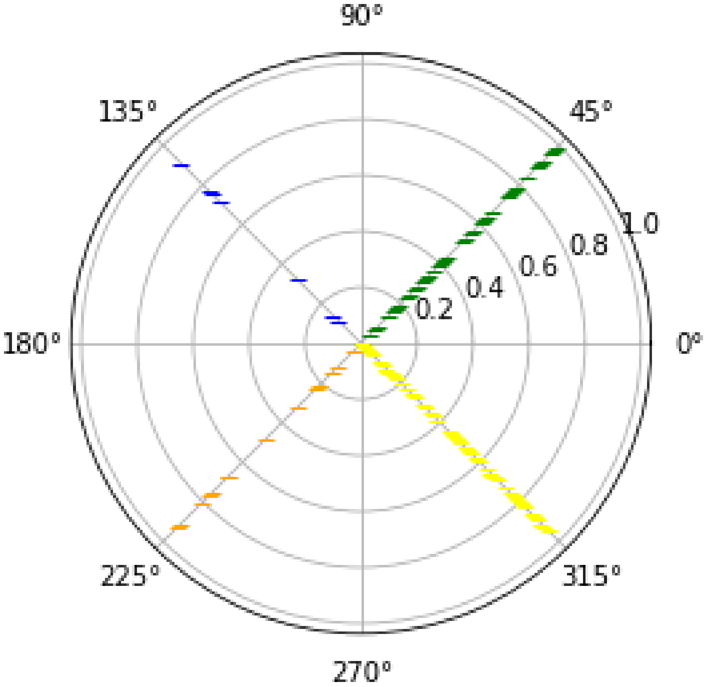
```
[5]: GPD_crops_seasons_dataset.describe()
```

```
[5]:        herbaceous  arboreous  campanulate_corolla  open_corolla  \
     count   78.000000  78.000000            78.000000     78.000000
     mean     0.435897   0.564103             0.141026      0.756410
     std      0.499083   0.499083             0.350301      0.432026
     min      0.000000   0.000000             0.000000      0.000000
     25%      0.000000   0.000000             0.000000      1.000000
     50%      0.000000   1.000000             0.000000      1.000000
     75%      1.000000   1.000000             0.000000      1.000000
     max      1.000000   1.000000             1.000000      1.000000

            tubular_corolla  composite_flower  self_pollination    nectar  \
     count        78.000000         78.000000         78.000000  78.000000
     mean          0.102564          0.025641          0.076923   0.910256
     std           0.305352          0.159085          0.268194   0.287664
     min           0.000000          0.000000          0.000000   0.000000
     25%           0.000000          0.000000          0.000000   1.000000
     50%           0.000000          0.000000          0.000000   1.000000
     75%           0.000000          0.000000          0.000000   1.000000
     max           1.000000          1.000000          1.000000   1.000000
```

```
          spring     summer     autumn     winter
count  78.000000  78.000000  78.000000  78.000000
mean    5.743590   6.076923   1.128205   0.551282
std    11.843608   8.338254   2.769776   2.055385
min     0.000000   0.000000   0.000000   0.000000
25%     0.000000   0.000000   0.000000   0.000000
50%     1.500000   4.000000   0.000000   0.000000
75%     6.000000   6.750000   0.000000   0.000000
max    81.000000  44.000000  14.000000  14.000000
```

[962]:

```
plt.pyplot.axes(projection = 'polar')
for i in range(0, len(GPD_crops_seasons_dataset.crop)):
    if GPD_crops_seasons_dataset.loc[i,'spring'] > 0:
        plt.pyplot.polar(np.pi/4, i/78, color = 'green', marker = '_')
    if GPD_crops_seasons_dataset.loc[i,'summer'] > 0:
        plt.pyplot.polar(7*np.pi/4, i/78, color = 'yellow', marker = '_')
    if GPD_crops_seasons_dataset.loc[i,'autumn'] > 0:
        plt.pyplot.polar(5*np.pi/4, i/78, color = 'orange', marker = '_')
    if GPD_crops_seasons_dataset.loc[i,'winter'] > 0:
        plt.pyplot.polar(3*np.pi/4, i/78, color = 'blue', marker = '_')
plt.pyplot.show()
```



[ ]:

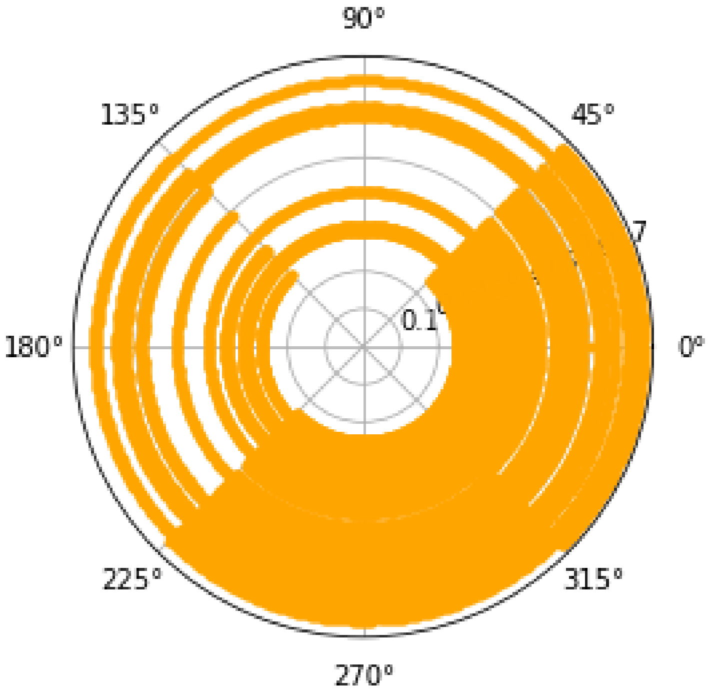
```
#To do: make understandable the complete period for each flower,
#maybe we should came back to the categorical variable to correctly identify␣
 ↪the starting and ending period
```

[ ]:

```
"""
plt.pyplot.axes(projection = 'polar')
for unique_crop_index in range(0, len(GPD_crops_seasons_dataset.crop)):
    crop = GPD_crops_seasons_dataset.loc[unique_crop_index,'crop']
    for full_crop_index in range(0, len(GPD_dataset_subset2_0NaN.
 ↪loc[GPD_dataset_subset2_0NaN['crop'] == crop, 'season'])):
        angle_range = [0]
        season_period = GPD_dataset_subset2_0NaN.loc[\
            GPD_dataset_subset2_0NaN['crop'] == crop 'season'].
 ↪to_list()[full_crop_index]
        if season_period == 'year':
            angle_range = np.arange(0, (2 * np.pi), 0.01)
        elif season_period == 'spring':
            angle_range = np.arange(np.pi/4, -np.pi/4, -0.01)
        elif season_period == 'sprisum':
            angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.01)
        elif season_period == 'spriaut':
            angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.01)
        elif season_period == 'winspring':
            angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.01)
        elif season_period == 'sumspri': #is not year?
            angle_range = np.arange(0, 6*np.pi/4, 0.01)
        elif season_period == 'summer':
            angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.01)
        elif season_period == 'sumaut':
            angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.01)
        elif season_period == 'autumn':
            angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.01)
        elif season_period == 'autspri':
            angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.01)
        elif season_period == 'winter':
            angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.01)
        for angle in angle_range:
            plt.pyplot.polar(angle, (0.5 + unique_crop_index/(78*2)), \
                                 color = 'orange', marker = '.')

plt.pyplot.show()
"""
```

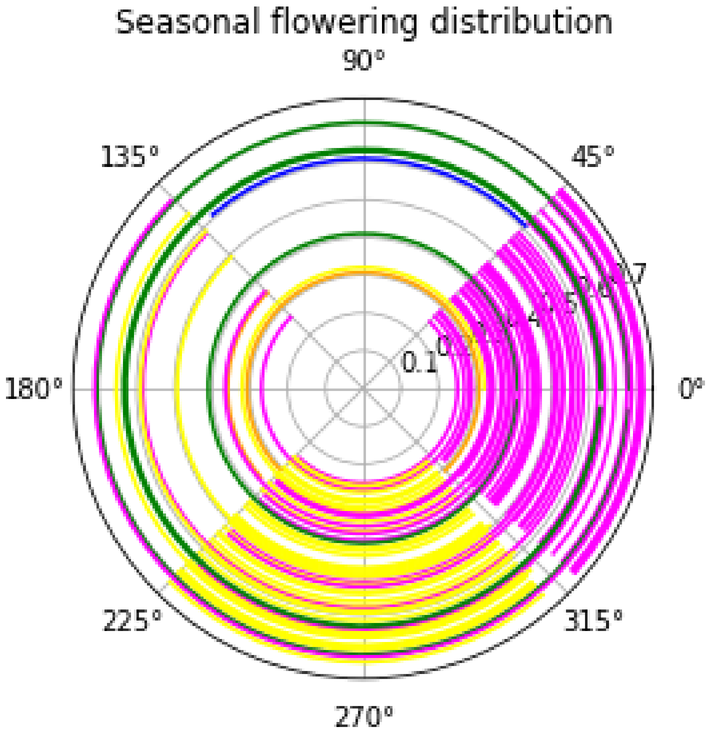
[27]:

```
plt.pyplot.axes(projection = 'polar')
for unique_crop_index in range(0, len(GPD_crops_seasons_dataset.crop)):
    crop = GPD_crops_seasons_dataset.loc[unique_crop_index,'crop']
    season_period = GPD_dataset_subset2_0NaN.loc[\
                        GPD_dataset_subset2_0NaN['crop'] == crop, 'season'].
↪to_list()[0]
    angle_range = [0]
    if season_period == 'year':
        angle_range = np.arange(0, (2 * np.pi), 0.01)
    elif season_period == 'spring':
        angle_range = np.arange(np.pi/4, -np.pi/4, -0.01)
    elif season_period == 'sprisum':
        angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.01)
    elif season_period == 'spriaut':
        angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.01)
    elif season_period == 'winspring':
        angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.01)
    elif season_period == 'sumspri': #is not year?
        angle_range = np.arange(0, 6*np.pi/4, 0.01)
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.01)
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.01)
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.01)
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.01)
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.01)

    if season_period != 'undefined':
        for angle in angle_range:
            plt.pyplot.polar(angle, (0.25 + unique_crop_index/(78*2)), \
                         color = 'orange', marker = '.')

plt.pyplot.show()
```



```
[35]: plt.pyplot.axes(projection = 'polar')
      for unique_crop_index in range(0, len(GPD_crops_seasons_dataset.crop)):
          crop = GPD_crops_seasons_dataset.loc[unique_crop_index,'crop']
          season_period = GPD_dataset_subset2_0NaN.loc[\
                                  GPD_dataset_subset2_0NaN['crop'] == crop, 'season'].
       ↪to_list()[0]
          angle_range = np.zeros(1)
          season_color = 'gray'
          if season_period == 'year':
              angle_range = np.arange(0, (2 * np.pi), 0.1)
              season_color = 'green'
          elif season_period == 'spring':
              angle_range = np.arange(np.pi/4, -np.pi/4, -0.1)
              season_color = 'magenta'
          elif season_period == 'sprisum':
              angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.1)
              season_color = 'magenta'
          elif season_period == 'spriaut':
              angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.1)
              season_color = 'magenta'
          elif season_period == 'winspring':
              angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.1)
              season_color = 'blue'
          elif season_period == 'sumspri': #is not year?
```

```
        angle_range = np.arange(0, 6*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.1)
        season_color = 'blue'

    if season_period != 'undefined':
        positions = np.full(shape = angle_range.shape, \
                           fill_value = (0.25 + unique_crop_index/(78*2)))
        plt.pyplot.polar(angle_range, positions, color = season_color)

plt.pyplot.title('Seasonal flowering distribution')
plt.pyplot.show()
```

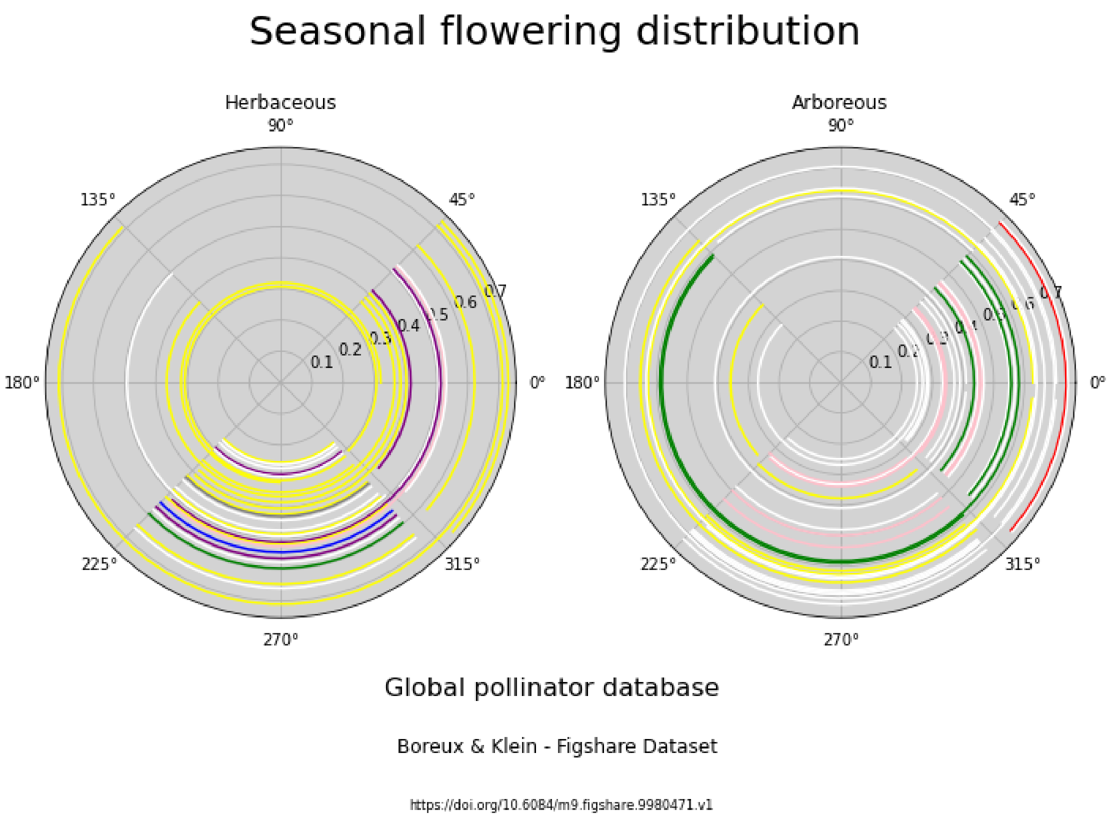


[21]:

```
#let's convert colours in matplotlib colour values
colours_list = []
for color_data in GPD_dataset_subset2_0NaN.loc[:,'colour']:
    if color_data == 'undefined':
        color_data = 'gray'
    colours_list.append(plt.colors.CSS4_COLORS[color_data])
```

[62]:

```
fig, (ax1, ax2) = plt.pyplot.subplots(1, 2, subplot_kw = dict(polar = True), ␣
 ↪figsize=(10,10))

#flowering cicles differentiated by the type of plant (herbaceous or arboreous)
for unique_crop_index in range(0, len(GPD_crops_seasons_dataset.crop)):
    crop = GPD_crops_seasons_dataset.loc[unique_crop_index,'crop']
    season_period = GPD_dataset_subset2_0NaN.loc[\
                        GPD_dataset_subset2_0NaN['crop'] == crop, 'season'].
 ↪to_list()[0]
    first_element_index = GPD_dataset_subset2_0NaN.loc[\
                        GPD_dataset_subset2_0NaN['crop'] == crop, :].index.
 ↪to_list()[0]

    angle_range = np.zeros(1)
    season_color = 'gray'
    if season_period == 'year':
        angle_range = np.arange(0, (2 * np.pi), 0.1)
    elif season_period == 'spring':
        angle_range = np.arange(np.pi/4, -np.pi/4, -0.1)
    elif season_period == 'sprisum':
        angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.1)
    elif season_period == 'spriaut':
        angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.1)
    elif season_period == 'winspring':
        angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.1)
    elif season_period == 'sumspri': #is not year?
        angle_range = np.arange(0, 6*np.pi/4, 0.1)
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.1)
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.1)
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.1)
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.1)
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.1)
    if season_period != 'undefined':
        positions = np.full(shape = angle_range.shape, \
                           fill_value = (0.25 + unique_crop_index/(78*2)))
        if GPD_crops_seasons_dataset.loc[unique_crop_index,'herbaceous'] == 1:
            ax1.plot(angle_range, positions, color =␣
 ↪colours_list[first_element_index] )
        else:
            ax2.plot(angle_range, positions, color =␣
 ↪colours_list[first_element_index] )

ax1.set_title('Herbaceous')
ax1.set_facecolor('#D3D3D3')
ax2.set_title('Arboreous')
ax2.set_facecolor('#D3D3D3')

fig.suptitle('Seasonal flowering distribution', fontsize=25, y=0.8)
fig.text(0.35, 0.2, 'Global pollinator database', fontsize=16)
fig.text(0.36, 0.15, 'Boreux & Klein - Figshare Dataset', fontsize=12)
fig.text(0.37, 0.1, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=8)

#set spacing between plots
fig.tight_layout()

plt.pyplot.savefig('Images/Seasonal flowering distribution.png', dpi=150)
plt.pyplot.savefig('Images/Seasonal flowering distribution.jpg', dpi=150)

plt.pyplot.show()
```



Global pollinator database

Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

So now we should check the seasonal distibution of pollinators, maybe it's better looking for pollinator's guild

[87]:
```
GPD_pollinators_guilds = GPD_seasons_dataset.guild.unique()
GPD_pollinators_guilds_seasons_dataset = pd.DataFrame()
GPD_pollinators_guilds_seasons_dataset = GPD_pollinators_guilds_seasons_dataset.
  ↪assign(guild = GPD_pollinators_guilds.to_list())
GPD_pollinators_guilds_seasons_dataset.describe()
```

[87]:
```
             guild
count           14
unique          14
top     ANDRENIDAE
freq             1
```

[95]:
```
GPD_pollinators_guilds_seasons_dataset.describe
```

[95]:
```
<bound method NDFrame.describe of              guild
0       ANDRENIDAE
1       BUMBLEBEES
2      BUTTERFLIES
```

```
3       COLEOPTERA
4      CUCKOO BEES
5            FLIES
6       HONEY BEES
7            MOTHS
8            OTHER
9       OTHER BEES
10  STINGLESS BEES
11      SWEAT BEES
12        SYRPHIDS
13           WASPS>
```

[97]:
```
GPD_seasons_dataset.guild.value_counts()
```

[97]:
```
OTHER BEES        193
BUMBLEBEES        147
HONEY BEES        145
SYRPHIDS           63
ANDRENIDAE         47
STINGLESS BEES     44
SWEAT BEES         36
COLEOPTERA         27
BUTTERFLIES        24
FLIES              19
CUCKOO BEES        16
OTHER               7
WASPS               6
MOTHS               5
Name: guild, dtype: int64
```

[91]:
```
GPD_pollinators = GPD_seasons_dataset.visitor.unique()
GPD_pollinators_seasons_dataset = pd.DataFrame()
GPD_pollinators_seasons_dataset = GPD_pollinators_seasons_dataset.
 ↪assign(pollinator = GPD_pollinators.to_list())
GPD_pollinators_seasons_dataset.describe()
```

[91]:
```
              pollinator
count                254
unique               254
top     Andrena_wilkella
freq                   1
```

[92]:
```
GPD_pollinators.describe
```

[92]:
```
<bound method Categorical.describe of ['Andrena_wilkella',
'Andrena_barbilabris', 'Andrena_cineraria', 'Andrena_flavipes',
'Andrena_gravida', …, 'Dolichovespula_norwegica', 'Dolichovespula_saxonica',
'Bembecinus_tridens', 'Vespula_vulgaris', 'Philanthus_triangulum']
Length: 254
Categories (254, object): ['Adalia_decempunctata',
'Agapanthia_villosoviridescens', 'Agapostemon_virescens', 'Aglais_urticae', …,
'Xylocopa_hottentotta', 'Xylocopa_valga', 'Xylocopa_violacea',
'Xylocopa_virginica']>
```

[90]:

```
GPD_seasons_dataset.describe
```

[90]:

```
<bound method NDFrame.describe of                      crop        type   season
corolla  colour nectar  \
0    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
1    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
2          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
3          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
4          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
..                    …         …      …          …     …    …
774      Allium_oleraceum  herbaceous   summer  CAMPANULATE  purple    yes
775       Jatropha_curcas   arboreous  spriaut         OPEN   green    yes
776       Malus_domestica   arboreous   spring         OPEN   white    yes
777   Phaseolus_coccineus  herbaceous   summer         OPEN   white    yes
778      Capparis_spinosa   arboreous   summer         OPEN   white    yes

         b.system s.pollination inflorescence composite  \
0         insects            no           yes        no
1         insects            no           yes        no
2    wind/insects            no           yes        no
3    wind/insects            no           yes        no
4    wind/insects            no           yes        no
..            …           …           …       …
774       insects            no           yes        no
775       insects            no           yes        no
776       insects            no           yes        no
777       insects            no           yes        no
778       insects            no      solitary        no

                     visitor       guild sociality      feeding  spring  \
0           Andrena_wilkella  ANDRENIDAE        no  oligolectic       1
1        Andrena_barbilabris  ANDRENIDAE        no   polylectic       1
2          Andrena_cineraria  ANDRENIDAE        no   polylectic       0
3           Andrena_flavipes  ANDRENIDAE        no   polylectic       0
4            Andrena_gravida  ANDRENIDAE        no   polylectic       0
..                       …         …       …          …     …
774  Dolichovespula_saxonica       WASPS       yes   polylectic       0
775       Bembecinus_tridens       WASPS        no    undefined       1
776         Vespula_vulgaris       WASPS       yes   polylectic       1
777    Philanthus_triangulum       WASPS        no   polylectic       0
```

```
778       Bembecinus_tridens       WASPS        no    undefined       0

     summer  autumn  winter
0         1       0       0
1         1       0       0
2         1       0       0
3         1       0       0
4         1       0       0
..      …     …     …
774       1       0       0
775       1       1       0
776       0       0       0
777       1       0       0
778       1       0       0

[779 rows x 18 columns]>
```

[98]:
```
GPD_seasons_dataset.visitor.value_counts()
```

[98]:
```
Apis_mellifera            67
Apis_dorsata              22
Apis_florea               20
Apis_cerana               20
Bombus_terrestris         20
                          ..
Leucozona_lucorum          1
Calliphora_vicina          1
Calliphora_vomitoria       1
Lasioglossum_subhirtum     1
Adalia_decempunctata       1
Name: visitor, Length: 254, dtype: int64
```

Let's check the number of pollinators for each season and the guild distribution

[105]:
```
GPD_seasons_dataset.loc[GPD_seasons_dataset['spring'] == 1, 'visitor'].
 ↪value_counts().sum()
```

[105]:
```
448
```

[106]:
```
GPD_seasons_dataset.loc[GPD_seasons_dataset['summer'] == 1, 'visitor'].
 ↪value_counts().sum()
```

[106]:
```
474
```

[107]:
```
GPD_seasons_dataset.loc[GPD_seasons_dataset['autumn'] == 1, 'visitor'].
 ↪value_counts().sum()
```

```
[107]: 88
```

```
[108]: GPD_seasons_dataset.loc[GPD_seasons_dataset['winter'] == 1, 'visitor'].
         ↪value_counts().sum()
```

```
[108]: 43
```

```
[111]: GPD_seasons_dataset.loc[GPD_seasons_dataset['spring'] == 1, 'guild'].
         ↪value_counts()
```

```
[111]: OTHER BEES        127
       BUMBLEBEES         79
       HONEY BEES         74
       ANDRENIDAE         33
       SYRPHIDS           31
       SWEAT BEES         27
       STINGLESS BEES     23
       CUCKOO BEES        15
       COLEOPTERA         14
       BUTTERFLIES        10
       FLIES               5
       OTHER               5
       MOTHS               3
       WASPS               2
       Name: guild, dtype: int64
```

```
[112]: GPD_seasons_dataset.loc[GPD_seasons_dataset['summer'] == 1, 'guild'].
         ↪value_counts()
```

```
[112]: OTHER BEES        130
       BUMBLEBEES        105
       HONEY BEES         94
       SYRPHIDS           37
       STINGLESS BEES     22
       ANDRENIDAE         17
       BUTTERFLIES        15
       COLEOPTERA         14
       FLIES              14
       SWEAT BEES         13
       WASPS               5
       MOTHS               4
       CUCKOO BEES         2
       OTHER               2
       Name: guild, dtype: int64
```

```
[113]: GPD_seasons_dataset.loc[GPD_seasons_dataset['autumn'] == 1, 'guild'].
         ↪value_counts()
```

```
[113]: HONEY BEES        32
       OTHER BEES        28
       BUMBLEBEES         9
       STINGLESS BEES     5
       SYRPHIDS           5
       FLIES              2
       MOTHS              2
       ANDRENIDAE         1
       BUTTERFLIES        1
       COLEOPTERA         1
       SWEAT BEES         1
       WASPS              1
       CUCKOO BEES        0
       OTHER              0
       Name: guild, dtype: int64
```

```
[114]: GPD_seasons_dataset.loc[GPD_seasons_dataset['winter'] == 1, 'guild'].
         ↪value_counts()
```

```
[114]: OTHER BEES        17
       HONEY BEES        15
       BUMBLEBEES         4
       STINGLESS BEES     4
       SYRPHIDS           2
       FLIES              1
       ANDRENIDAE         0
       BUTTERFLIES        0
       COLEOPTERA         0
       CUCKOO BEES        0
       MOTHS              0
       OTHER              0
       SWEAT BEES         0
       WASPS              0
       Name: guild, dtype: int64
```

Let's check how many different kinds of pollinators we can find in each season. The precedent count of single pollinators could be not so usefull because could be strongly biased by the sampling. Note that also this new count could be biased but should be a bit less biased.

```
[140]: GPD_pollinators_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['spring'] == 1, 'visitor'].value_counts()
       len(GPD_pollinators_count_serie[GPD_pollinators_count_serie != 0].to_list())
```

```
[140]: 212
```

```
[141]: GPD_pollinators_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['summer'] == 1, 'visitor'].value_counts()
```

```
len(GPD_pollinators_count_serie[GPD_pollinators_count_serie != 0].to_list())
```

[141]: 168

```
[142]: GPD_pollinators_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['autumn'] == 1, 'visitor'].value_counts()
       len(GPD_pollinators_count_serie[GPD_pollinators_count_serie != 0].to_list())
```

[142]: 50

```
[143]: GPD_pollinators_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['winter'] == 1, 'visitor'].value_counts()
       len(GPD_pollinators_count_serie[GPD_pollinators_count_serie != 0].to_list())
```

[143]: 31

Let's check if in each season there is only one record for each couple of crop and visitor

```
[146]: GPD_pollinators_crop_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['spring'] == 1, ['visitor','crop']].value_counts()
       len(GPD_pollinators_crop_count_serie[GPD_pollinators_crop_count_serie > 1 ].
         ↪to_list())
```

[146]: 0

```
[147]: GPD_pollinators_crop_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['summer'] == 1, ['visitor','crop']].value_counts()
       len(GPD_pollinators_crop_count_serie[GPD_pollinators_crop_count_serie > 1 ].
         ↪to_list())
```

[147]: 0

```
[148]: GPD_pollinators_crop_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['autumn'] == 1, ['visitor','crop']].value_counts()
       len(GPD_pollinators_crop_count_serie[GPD_pollinators_crop_count_serie > 1 ].
         ↪to_list())
```

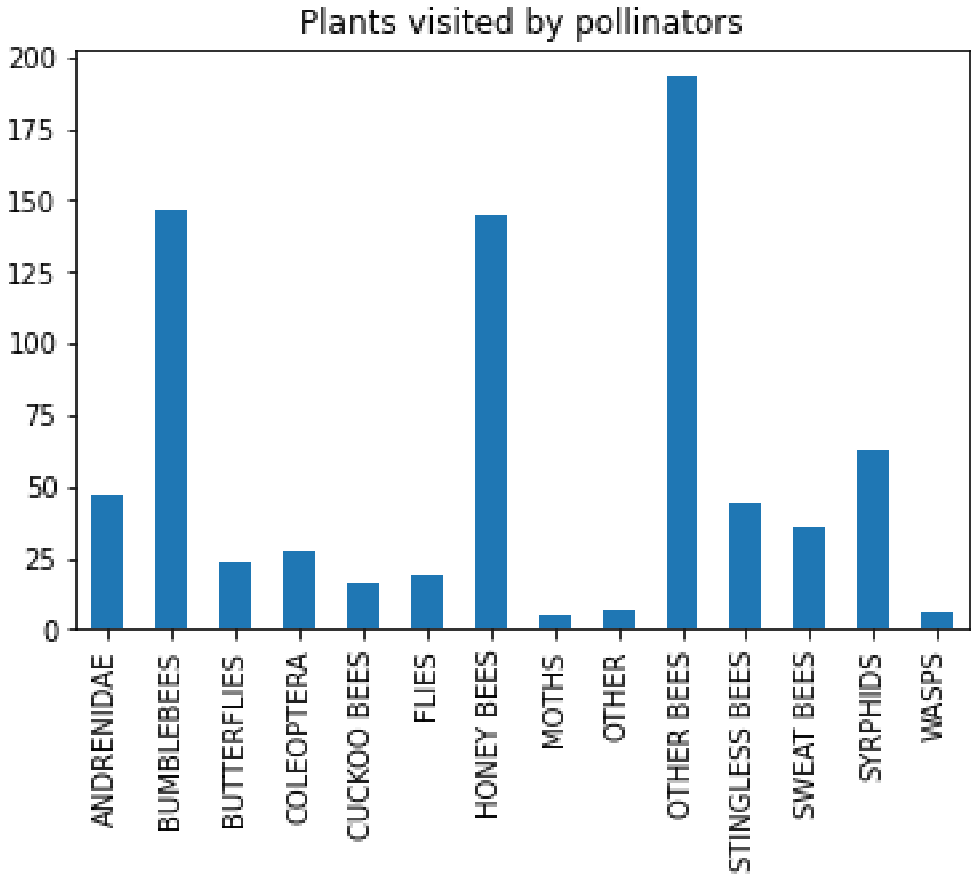
[148]: 0

```
[149]: GPD_pollinators_crop_count_serie = GPD_seasons_dataset.
         ↪loc[GPD_seasons_dataset['winter'] == 1, ['visitor','crop']].value_counts()
       len(GPD_pollinators_crop_count_serie[GPD_pollinators_crop_count_serie > 1 ].
         ↪to_list())
```

[149]: 0

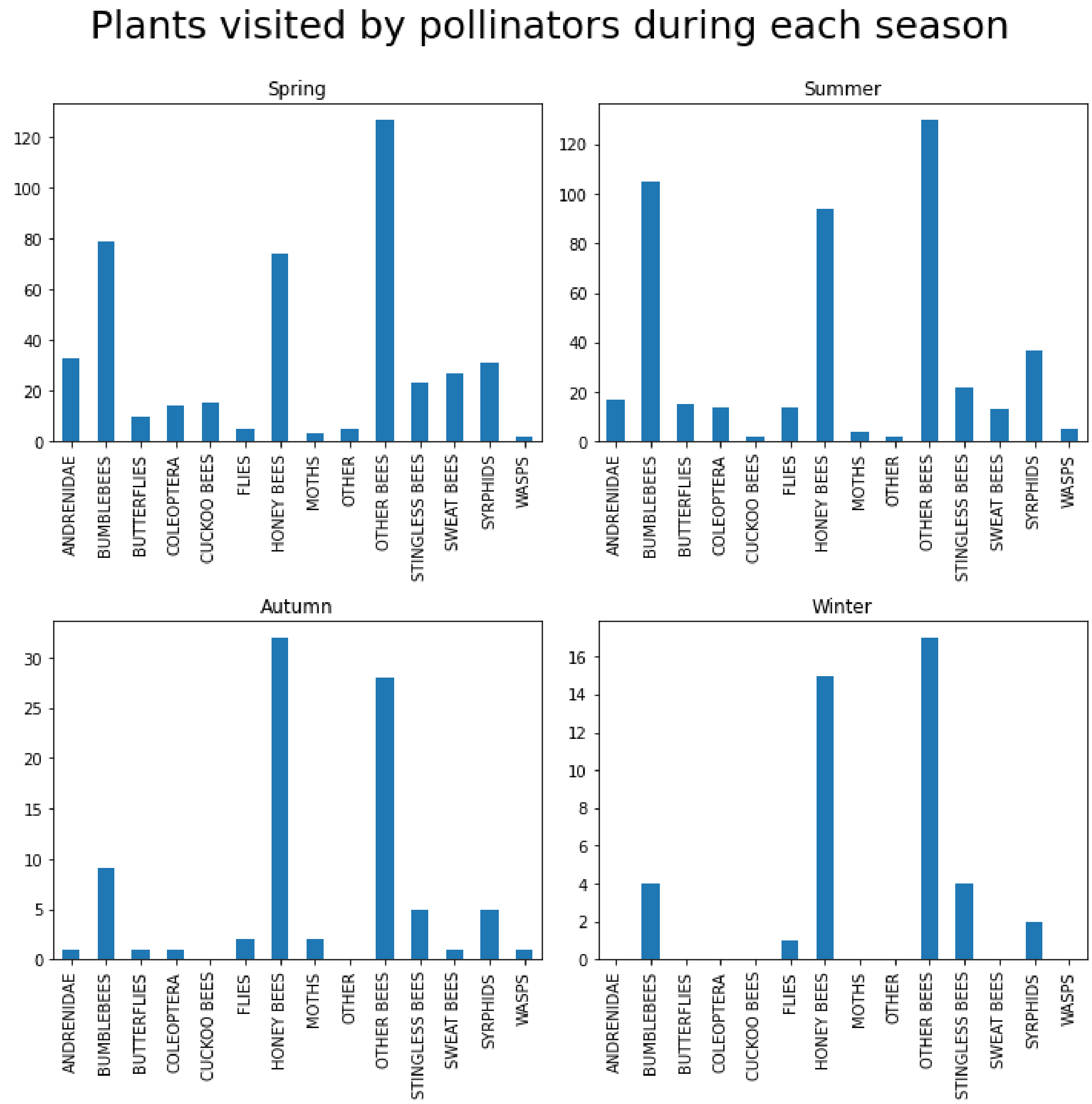
OK, so we have confirmed that the observers declared one record for each different kind of visitor for each crop, so we do not have information of how much frequently a kind of visitor visit a crop but whe have information on how many kind of crops visit each visitor

[170]:
```
''' wrong plot title - see below '''
'''
plt.pyplot.figure()
plt.pyplot.title('Plants visited by pollinators')
GPD_seasons_dataset['guild'].value_counts(sort=False).plot(kind = 'bar')

plt.pyplot.savefig('Images/Plants for pollinators.png', dpi=150)
plt.pyplot.savefig('Images/Plants for pollinators.jpg', dpi=150)
'''
```



[168]:
```
''' wrong plot title - see below '''
'''
fig, ((ax1, ax2), (ax3, ax4)) = plt.pyplot.subplots(2, 2, figsize=(10,10))

fig.suptitle('Plants visited by pollinators during each season', fontsize=25,␣
 ↪y=1)
```

```
ax1.set_title('Spring')
ax2.set_title('Summer')
ax3.set_title('Autumn')
ax4.set_title('Winter')

GPD_seasons_dataset.loc[GPD_seasons_dataset['spring'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False).plot(kind = 'bar', ax=ax1)
GPD_seasons_dataset.loc[GPD_seasons_dataset['summer'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False).plot(kind = 'bar', ax=ax2)
GPD_seasons_dataset.loc[GPD_seasons_dataset['autumn'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False).plot(kind = 'bar', ax=ax3)
GPD_seasons_dataset.loc[GPD_seasons_dataset['winter'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False).plot(kind = 'bar', ax=ax4)

fig.tight_layout()

plt.pyplot.savefig('Images/Seasonal plants for pollinators.png', dpi=150)
plt.pyplot.savefig('Images/Seasonal plants for pollinators.jpg', dpi=150)


plt.pyplot.show()
'''
```


Plants visited by pollinators during each season

Spring

Summer

Autumn

Winter

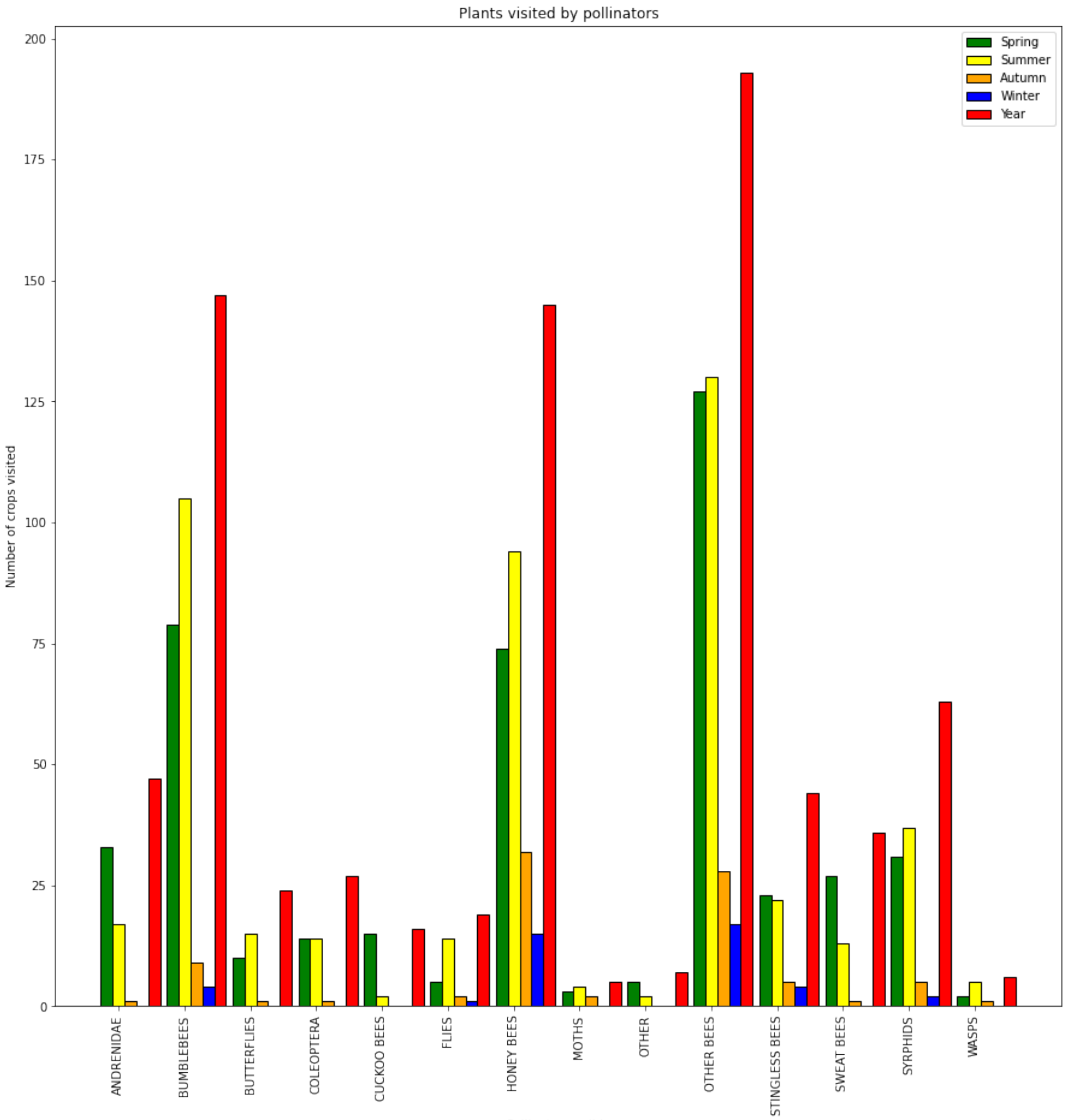
Pay attention at the y scale! Maybe we should make a unique graph with the seasonal differentiation by colours

[173]:
```
GPD_seasons_dataset['guild'].unique().to_list()
```

[173]:
```
['ANDRENIDAE',
 'BUMBLEBEES',
 'BUTTERFLIES',
 'COLEOPTERA',
 'CUCKOO BEES',
 'FLIES',
 'HONEY BEES',
 'MOTHS',
 'OTHER',
 'OTHER BEES',
 'STINGLESS BEES',
 'SWEAT BEES',
 'SYRPHIDS',
 'WASPS']
```

[196]:

```
''' wrong plot title - see below '''
'''
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.18

spring = GPD_seasons_dataset.loc[GPD_seasons_dataset['spring'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False)
summer = GPD_seasons_dataset.loc[GPD_seasons_dataset['summer'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False)
autumn = GPD_seasons_dataset.loc[GPD_seasons_dataset['autumn'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False)
winter = GPD_seasons_dataset.loc[GPD_seasons_dataset['winter'] == 1, 'guild'].
 ↪value_counts(\
                        sort = False)
total = GPD_seasons_dataset['guild'].value_counts(sort = False)


plt.pyplot.bar(x_range , spring, color = 'green',
        width = width, edgecolor = 'black',
        label='Spring')
plt.pyplot.bar(x_range + width, summer, color = 'yellow',
        width = width, edgecolor = 'black',
        label='Summer')
plt.pyplot.bar(x_range + 2*width, autumn, color = 'orange',
        width = width, edgecolor = 'black',
        label='Autumn')
plt.pyplot.bar(x_range +  3*width, winter, color = 'blue',
        width = width, edgecolor = 'black',
        label='Winter')
plt.pyplot.bar(x_range + 4*width, total, color = 'red',
        width = width, edgecolor = 'black',
        label='Year')

plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of crops visited")
plt.pyplot.title("Plants visited by pollinators")

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.savefig('Images/Plants visited by pollinators.png', dpi=150)
plt.pyplot.savefig('Images/Plants visited by pollinators.jpg', dpi=150)


plt.pyplot.show()
'''
```



1.5 Previous plots on pollinators are wrong

That wasn't the number of plants for pollinators. We have used the guilds so, as example, we can have 3 values in a guild because we have 3 species in that guild and not 3 different crops

[273]:

```
spring_guild_crop_serie = GPD_seasons_dataset.loc[GPD_seasons_dataset['spring']␣
 ↪== 1, \
                                                    ['guild', 'crop']].
 ↪value_counts()
```

[270]:

```
spring_guild_crop_serie
```

```
[270]: guild        crop
       ANDRENIDAE   Prunus_avium              25
       SWEAT BEES   Prunus_avium              23
       OTHER BEES   Vaccinium_corymbosum      22
                    Citrullus_lanatus         19
                    Malus_domestica           15
                                              ..
       HONEY BEES   Sambucus_racemosa          1
                    Prunus_avium               1
                    Persea_americana           1
                    Cyphomandra_betacea        1
       WASPS        Malus_domestica            1
       Length: 128, dtype: int64
```

```
[279]: spring_guild_crop_serie.unstack(level = 0)
```

```
[279]: guild                       ANDRENIDAE  BUMBLEBEES  BUTTERFLIES  COLEOPTERA  \
       crop
       Prunus_avium                      25.0         7.0          NaN         NaN
       Vaccinium_corymbosum               2.0         5.0          NaN         NaN
       Citrullus_lanatus                  NaN         5.0          NaN         NaN
       Malus_domestica                    5.0         5.0          2.0         3.0
       Cucumis_sativus                    NaN         5.0          NaN         NaN
       Vaccinium_myrtillus                NaN         9.0          NaN         NaN
       Vaccinium_uliginosum               NaN         9.0          NaN         NaN
       Cucurbita_pepo                     NaN         1.0          NaN         NaN
       Coffea_arabica                     NaN         NaN          NaN         NaN
       Castanea_crenata                   NaN         2.0          7.0         6.0
       Trifolium_pratense                 NaN         6.0          NaN         NaN
       Persea_americana                   NaN         1.0          NaN         NaN
       Glycine_max                        NaN         1.0          NaN         NaN
       Vicia_faba                         NaN         5.0          NaN         1.0
       Anacardium_occidentale             NaN         NaN          NaN         NaN
       Vaccinium_angustifolium            NaN         4.0          NaN         NaN
       Coriandrum_sativum                 1.0         NaN          1.0         1.0
       Litchi_chinensis                   NaN         NaN          NaN         1.0
       Coffea_canephora                   NaN         NaN          NaN         NaN
       Jatropha_curcas                    NaN         NaN          NaN         NaN
       Brassica_rapa                      NaN         1.0          NaN         NaN
       Dimocarpus_longan                  NaN         NaN          NaN         NaN
       Sambucus_simpsonii                 NaN         NaN          NaN         NaN
       Cocos_nucifera                     NaN         NaN          NaN         NaN
       Sambucus_racemosa                  NaN         NaN          NaN         NaN
       Prunus_dulcis                      NaN         2.0          NaN         NaN
       Vicia_faba_major                   NaN         3.0          NaN         NaN
       Brassica_juncea                    NaN         NaN          NaN         NaN
       Vitis_vinifera                     NaN         NaN          NaN         2.0
```

```
Citrus_paradisi                 NaN         1.0          NaN         NaN
Cyphomandra_betacea             NaN         2.0          NaN         NaN
Vigna_unguiculata               NaN         2.0          NaN         NaN
Citrus_reticulata               NaN         NaN          NaN         NaN
Sinapis_alba                    NaN         NaN          NaN         NaN
Prunus_domestica                NaN         NaN          NaN         NaN
Pyrus_communis                  NaN         1.0          NaN         NaN
Prunus_persica                  NaN         1.0          NaN         NaN
Prunus_cerasus                  NaN         1.0          NaN         NaN
Amomum_subulatum                NaN         NaN          NaN         NaN

guild                    CUCKOO BEES  FLIES  HONEY BEES  MOTHS  OTHER  \
crop
Prunus_avium                    14.0    NaN         1.0    NaN    NaN
Vaccinium_corymbosum             1.0    NaN         1.0    NaN    NaN
Citrullus_lanatus                NaN    NaN         3.0    NaN    NaN
Malus_domestica                  NaN    2.0         2.0    NaN    4.0
Cucumis_sativus                  NaN    NaN         3.0    NaN    NaN
Vaccinium_myrtillus              NaN    NaN         1.0    NaN    NaN
Vaccinium_uliginosum             NaN    NaN         NaN    NaN    NaN
Cucurbita_pepo                   NaN    NaN         4.0    NaN    NaN
Coffea_arabica                   NaN    NaN         4.0    NaN    NaN
Castanea_crenata                 NaN    NaN         1.0    NaN    NaN
Trifolium_pratense               NaN    NaN         NaN    NaN    NaN
Persea_americana                 NaN    NaN         1.0    NaN    NaN
Glycine_max                      NaN    NaN         2.0    NaN    NaN
Vicia_faba                       NaN    NaN         NaN    NaN    1.0
Anacardium_occidentale           NaN    NaN         4.0    NaN    NaN
Vaccinium_angustifolium          NaN    NaN         1.0    NaN    NaN
Coriandrum_sativum               NaN    NaN         4.0    NaN    NaN
Litchi_chinensis                 NaN    NaN         4.0    NaN    NaN
Coffea_canephora                 NaN    NaN         4.0    NaN    NaN
Jatropha_curcas                  NaN    1.0         4.0    NaN    NaN
Brassica_rapa                    NaN    NaN         NaN    NaN    NaN
Dimocarpus_longan                NaN    NaN         3.0    NaN    NaN
Sambucus_simpsonii               NaN    NaN         1.0    NaN    NaN
Cocos_nucifera                   NaN    NaN         3.0    NaN    NaN
Sambucus_racemosa                NaN    NaN         1.0    NaN    NaN
Prunus_dulcis                    NaN    NaN         2.0    NaN    NaN
Vicia_faba_major                 NaN    NaN         1.0    NaN    NaN
Brassica_juncea                  NaN    NaN         3.0    NaN    NaN
Vitis_vinifera                   NaN    NaN         1.0    NaN    NaN
Citrus_paradisi                  NaN    NaN         2.0    NaN    NaN
Cyphomandra_betacea              NaN    NaN         1.0    NaN    NaN
Vigna_unguiculata                NaN    1.0         1.0    NaN    NaN
Citrus_reticulata                NaN    1.0         2.0    NaN    NaN
Sinapis_alba                     NaN    NaN         1.0    2.0    NaN
```

```
Prunus_domestica                 NaN    NaN         1.0    NaN    NaN
Pyrus_communis                   NaN    NaN         2.0    NaN    NaN
Prunus_persica                   NaN    NaN         2.0    NaN    NaN
Prunus_cerasus                   NaN    NaN         2.0    NaN    NaN
Amomum_subulatum                 NaN    NaN         1.0    1.0    NaN

guild                    OTHER BEES  STINGLESS BEES  SWEAT BEES  SYRPHIDS  \
crop
Prunus_avium                   11.0             NaN        23.0       NaN
Vaccinium_corymbosum           22.0             NaN         NaN       NaN
Citrullus_lanatus              19.0             4.0         NaN       NaN
Malus_domestica                15.0             NaN         NaN       9.0
Cucumis_sativus                10.0             3.0         3.0       NaN
Vaccinium_myrtillus             NaN             NaN         NaN       NaN
Vaccinium_uliginosum            NaN             NaN         NaN       NaN
Cucurbita_pepo                  9.0             NaN         NaN       NaN
Coffea_arabica                  2.0             7.0         NaN       NaN
Castanea_crenata                1.0             NaN         NaN       NaN
Trifolium_pratense              NaN             NaN         NaN       NaN
Persea_americana                NaN             5.0         NaN       NaN
Glycine_max                     5.0             NaN         NaN       NaN
Vicia_faba                      2.0             NaN         NaN       NaN
Anacardium_occidentale          NaN             1.0         NaN       NaN
Vaccinium_angustifolium         3.0             NaN         NaN       NaN
Coriandrum_sativum              3.0             NaN         1.0       2.0
Litchi_chinensis                3.0             NaN         NaN       4.0
Coffea_canephora                3.0             NaN         NaN       NaN
Jatropha_curcas                 NaN             NaN         NaN       NaN
Brassica_rapa                   4.0             NaN         NaN       1.0
Dimocarpus_longan               NaN             NaN         NaN       NaN
Sambucus_simpsonii              3.0             NaN         NaN       2.0
Cocos_nucifera                  NaN             2.0         NaN       NaN
Sambucus_racemosa               3.0             NaN         NaN       2.0
Prunus_dulcis                   3.0             NaN         NaN       2.0
Vicia_faba_major                1.0             NaN         NaN       NaN
Brassica_juncea                 NaN             NaN         NaN       NaN
Vitis_vinifera                  NaN             NaN         NaN       3.0
Citrus_paradisi                 NaN             1.0         NaN       NaN
Cyphomandra_betacea             NaN             NaN         NaN       NaN
Vigna_unguiculata               1.0             NaN         NaN       NaN
Citrus_reticulata               NaN             NaN         NaN       1.0
Sinapis_alba                    2.0             NaN         NaN       NaN
Prunus_domestica                NaN             NaN         NaN       2.0
Pyrus_communis                  1.0             NaN         NaN       NaN
Prunus_persica                  NaN             NaN         NaN       2.0
Prunus_cerasus                  NaN             NaN         NaN       NaN
Amomum_subulatum                1.0             NaN         NaN       1.0
```

```
guild                      WASPS
crop
Prunus_avium                 NaN
Vaccinium_corymbosum         NaN
Citrullus_lanatus            NaN
Malus_domestica              1.0
Cucumis_sativus              NaN
Vaccinium_myrtillus          NaN
Vaccinium_uliginosum         NaN
Cucurbita_pepo               NaN
Coffea_arabica               NaN
Castanea_crenata             NaN
Trifolium_pratense           NaN
Persea_americana             NaN
Glycine_max                  NaN
Vicia_faba                   NaN
Anacardium_occidentale       NaN
Vaccinium_angustifolium      NaN
Coriandrum_sativum           NaN
Litchi_chinensis             NaN
Coffea_canephora             NaN
Jatropha_curcas              1.0
Brassica_rapa                NaN
Dimocarpus_longan            NaN
Sambucus_simpsonii           NaN
Cocos_nucifera               NaN
Sambucus_racemosa            NaN
Prunus_dulcis                NaN
Vicia_faba_major             NaN
Brassica_juncea              NaN
Vitis_vinifera               NaN
Citrus_paradisi              NaN
Cyphomandra_betacea          NaN
Vigna_unguiculata            NaN
Citrus_reticulata            NaN
Sinapis_alba                 NaN
Prunus_domestica             NaN
Pyrus_communis               NaN
Prunus_persica               NaN
Prunus_cerasus               NaN
Amomum_subulatum             NaN
```

[309]:

```
spring_guild_crop_dataset = GPD_seasons_dataset.
 ↪loc[GPD_seasons_dataset['spring'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
summer_guild_crop_dataset = GPD_seasons_dataset.
 ↪loc[GPD_seasons_dataset['summer'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
autumn_guild_crop_dataset = GPD_seasons_dataset.
 ↪loc[GPD_seasons_dataset['autumn'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
winter_guild_crop_dataset = GPD_seasons_dataset.
 ↪loc[GPD_seasons_dataset['winter'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
year_guild_crop_dataset = GPD_seasons_dataset[['guild', 'crop']].value_counts(\
                                    sort = False).unstack(level = 0)
```

[310]:

```
print(len(spring_guild_crop_dataset.count()))
print(len(summer_guild_crop_dataset.count()))
print(len(autumn_guild_crop_dataset.count()))
print(len(winter_guild_crop_dataset.count()))
print(len(year_guild_crop_dataset.count()))
```

```
14
14
12
6
14
```

Mmm whe have a problem of dimensions

[ ]:

```
winter_guild_crop_serie = year_guild_crop_dataset.count().apply(\
                            lambda x: df1.loc[x['Year'] == df1['Year'],␣
 ↪x['State']].reset_index(drop=True), axis=1)
```

[311]:

```
spring_guild_crop_dataset.count().index
```

[311]:

```
CategoricalIndex(['ANDRENIDAE', 'BUMBLEBEES', 'BUTTERFLIES', 'COLEOPTERA',
                  'CUCKOO BEES', 'FLIES', 'HONEY BEES', 'MOTHS', 'OTHER',
                  'OTHER BEES', 'STINGLESS BEES', 'SWEAT BEES', 'SYRPHIDS',
                  'WASPS'],
                 categories=['ANDRENIDAE', 'BUMBLEBEES', 'BUTTERFLIES',
'COLEOPTERA', 'CUCKOO BEES', 'FLIES', 'HONEY BEES', 'MOTHS', …],
ordered=False, dtype='category', name='guild')
```

```
[312]: winter_guild_crop_dataset.count().index
```

```
[312]: CategoricalIndex(['BUMBLEBEES', 'FLIES', 'HONEY BEES', 'OTHER BEES',
                          'STINGLESS BEES', 'SYRPHIDS'],
                         categories=['ANDRENIDAE', 'BUMBLEBEES', 'BUTTERFLIES',
        'COLEOPTERA', 'CUCKOO BEES', 'FLIES', 'HONEY BEES', 'MOTHS', …],
        ordered=False, dtype='category', name='guild')
```

```
[324]: winter_guild_crop_dataset_full = year_guild_crop_dataset*0 +␣
        ↪winter_guild_crop_dataset
```

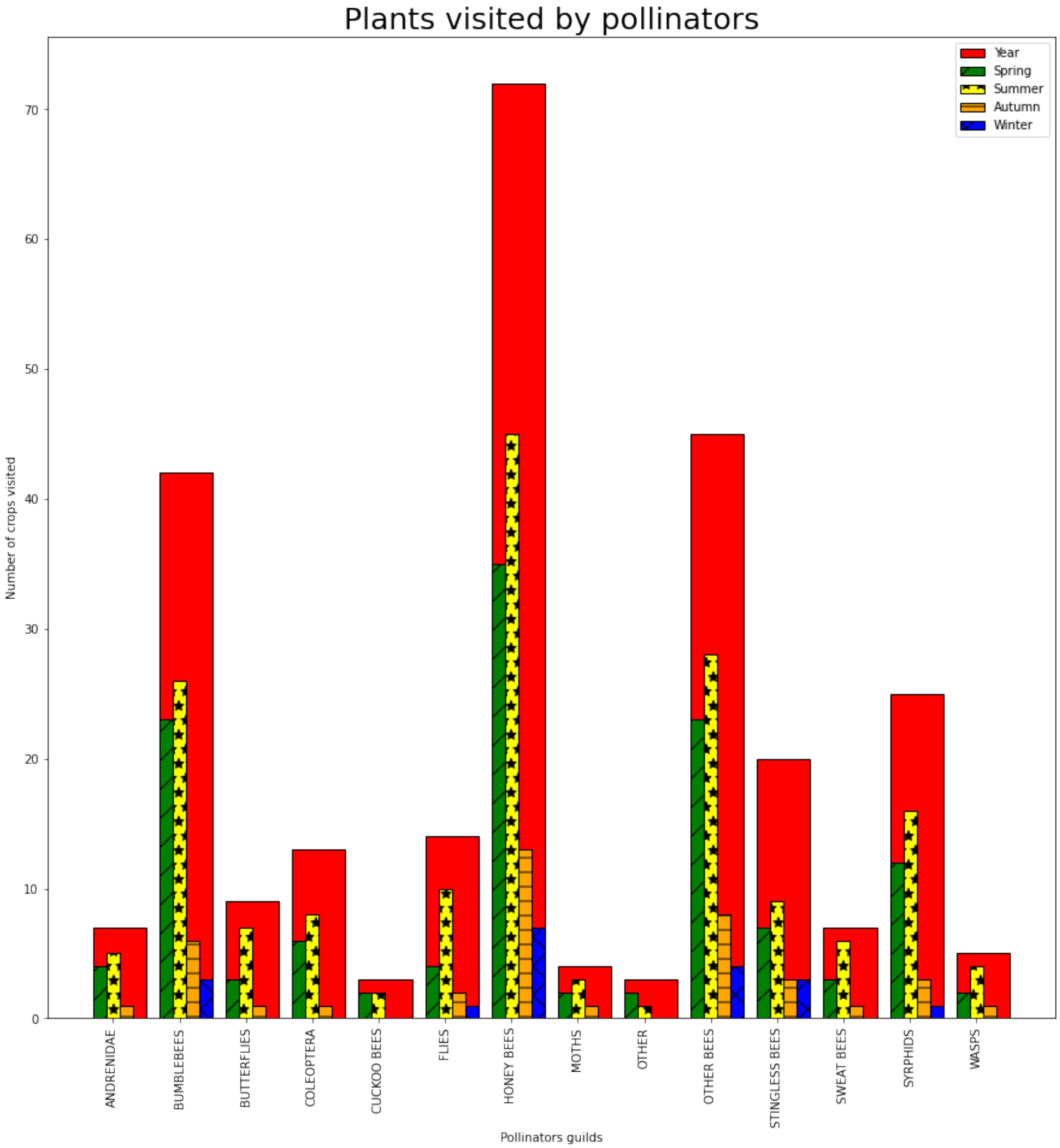
```
[328]: winter_guild_crop_dataset_full.count()
```

```
[328]: guild
       ANDRENIDAE        0
       BUMBLEBEES        3
       BUTTERFLIES       0
       COLEOPTERA        0
       CUCKOO BEES       0
       FLIES             1
       HONEY BEES        7
       MOTHS             0
       OTHER             0
       OTHER BEES        4
       STINGLESS BEES    3
       SWEAT BEES        0
       SYRPHIDS          1
       WASPS             0
       dtype: int64
```

```
[329]: autumn_guild_crop_dataset_full = year_guild_crop_dataset*0 +␣
        ↪autumn_guild_crop_dataset
```

```
[342]: plt.pyplot.figure(figsize=(15,15))

       bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())
       x_range = np.arange(bar_number)
       width = 0.20

       plt.pyplot.bar(x_range + 1.5*width, year_guild_crop_dataset.count(), color =␣
        ↪'red',
               width = 4*width, edgecolor = 'black', label='Year')
       plt.pyplot.bar(x_range , spring_guild_crop_dataset.count(), color = 'green',
               width = width, edgecolor = 'black', hatch='/', label='Spring')
       plt.pyplot.bar(x_range + width, summer_guild_crop_dataset.count(), color =␣
        ↪'yellow',
               width = width, edgecolor = 'black', hatch= '*', label='Summer')
```

```
plt.pyplot.bar(x_range + 2*width, autumn_guild_crop_dataset_full.count(), color␣
 ↪= 'orange',
        width = width, edgecolor = 'black', hatch='-', label='Autumn')
plt.pyplot.bar(x_range +  3*width, winter_guild_crop_dataset_full.count(),␣
 ↪color = 'blue',
        width = width, edgecolor = 'black', hatch='x', label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of crops visited")
plt.pyplot.title("Plants visited by pollinators", fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.savefig('Images/Plants visited by pollinators.png', dpi=150)
plt.pyplot.savefig('Images/Plants visited by pollinators.jpg', dpi=150)


plt.pyplot.show()
```



Could be interesting watch the same graph differentiated by herbaceous and arboreous plants

[348]:

```
GPD_arboreous_seasons_dataset = GPD_seasons_dataset.loc[\
                                GPD_seasons_dataset['type'] == 'arboreous',]
GPD_herbaceous_seasons_dataset = GPD_seasons_dataset.loc[\
                                GPD_seasons_dataset['type'] == 'herbaceous',]
```

[390]:

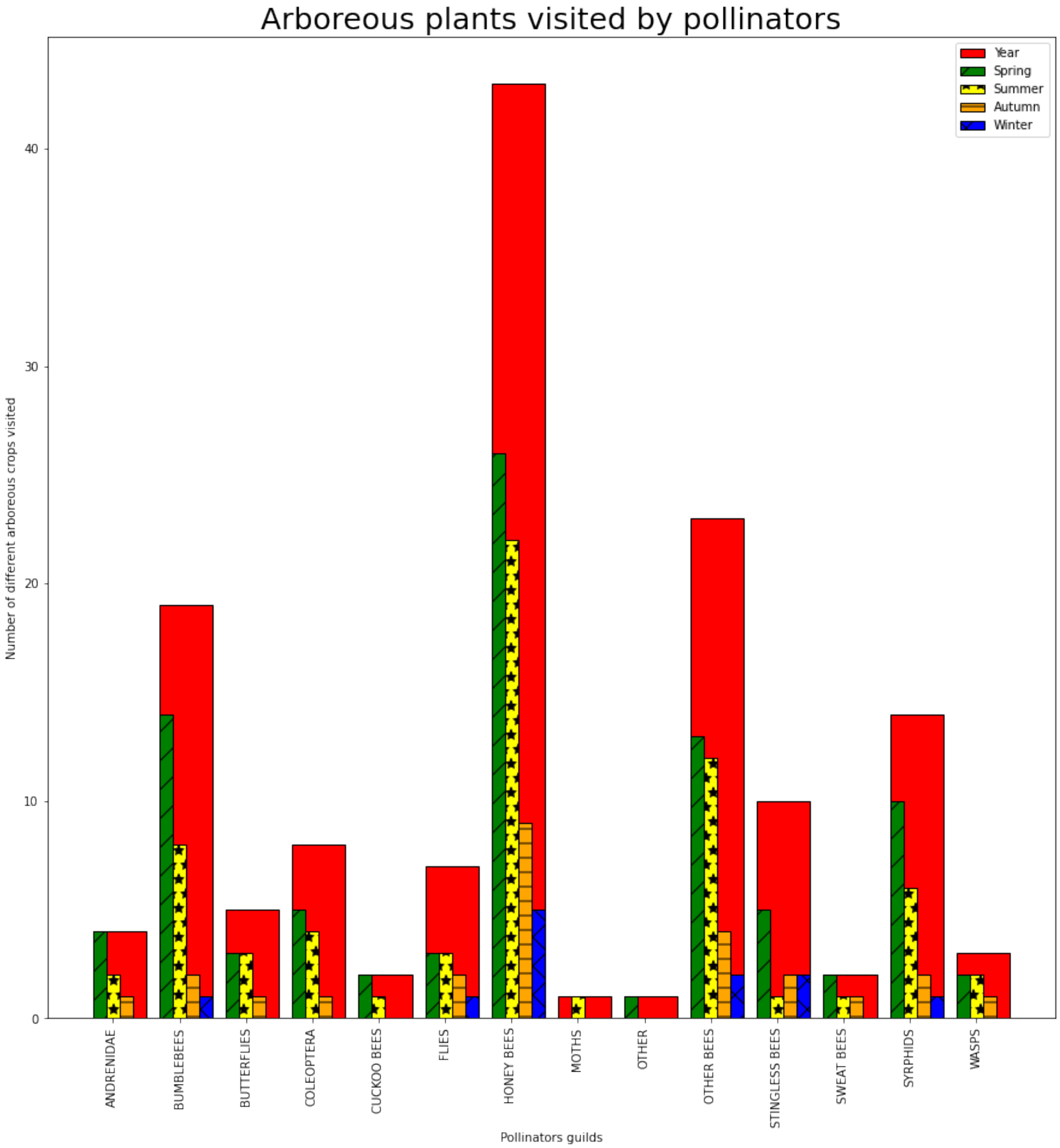
```
arboreous_spring_guild_crop_dataset = GPD_arboreous_seasons_dataset.
 ↪loc[GPD_arboreous_seasons_dataset['spring'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
arboreous_summer_guild_crop_dataset = GPD_arboreous_seasons_dataset.
 ↪loc[GPD_arboreous_seasons_dataset['summer'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
arboreous_autumn_guild_crop_dataset = GPD_arboreous_seasons_dataset.
 ↪loc[GPD_arboreous_seasons_dataset['autumn'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
arboreous_winter_guild_crop_dataset = GPD_arboreous_seasons_dataset.
 ↪loc[GPD_arboreous_seasons_dataset['winter'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
arboreous_year_guild_crop_dataset = GPD_arboreous_seasons_dataset[['guild',␣
 ↪'crop']].value_counts(\
                                    sort = False).unstack(level = 0)

herbaceous_spring_guild_crop_dataset = GPD_herbaceous_seasons_dataset.
 ↪loc[GPD_herbaceous_seasons_dataset['spring'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
herbaceous_summer_guild_crop_dataset = GPD_herbaceous_seasons_dataset.
 ↪loc[GPD_herbaceous_seasons_dataset['summer'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
herbaceous_autumn_guild_crop_dataset = GPD_herbaceous_seasons_dataset.
 ↪loc[GPD_herbaceous_seasons_dataset['autumn'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
herbaceous_winter_guild_crop_dataset = GPD_herbaceous_seasons_dataset.
 ↪loc[GPD_herbaceous_seasons_dataset['winter'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
herbaceous_year_guild_crop_dataset = GPD_herbaceous_seasons_dataset[['guild',␣
 ↪'crop']].value_counts(\
                                    sort = False).unstack(level = 0)
```

[391]:

```
arboreous_spring_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_spring_guild_crop_dataset
arboreous_summer_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_summer_guild_crop_dataset
arboreous_autumn_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_autumn_guild_crop_dataset
arboreous_winter_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_winter_guild_crop_dataset
arboreous_year_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_year_guild_crop_dataset

herbaceous_spring_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_spring_guild_crop_dataset
herbaceous_summer_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_summer_guild_crop_dataset
herbaceous_autumn_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_autumn_guild_crop_dataset
herbaceous_winter_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_winter_guild_crop_dataset
herbaceous_year_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_year_guild_crop_dataset
```

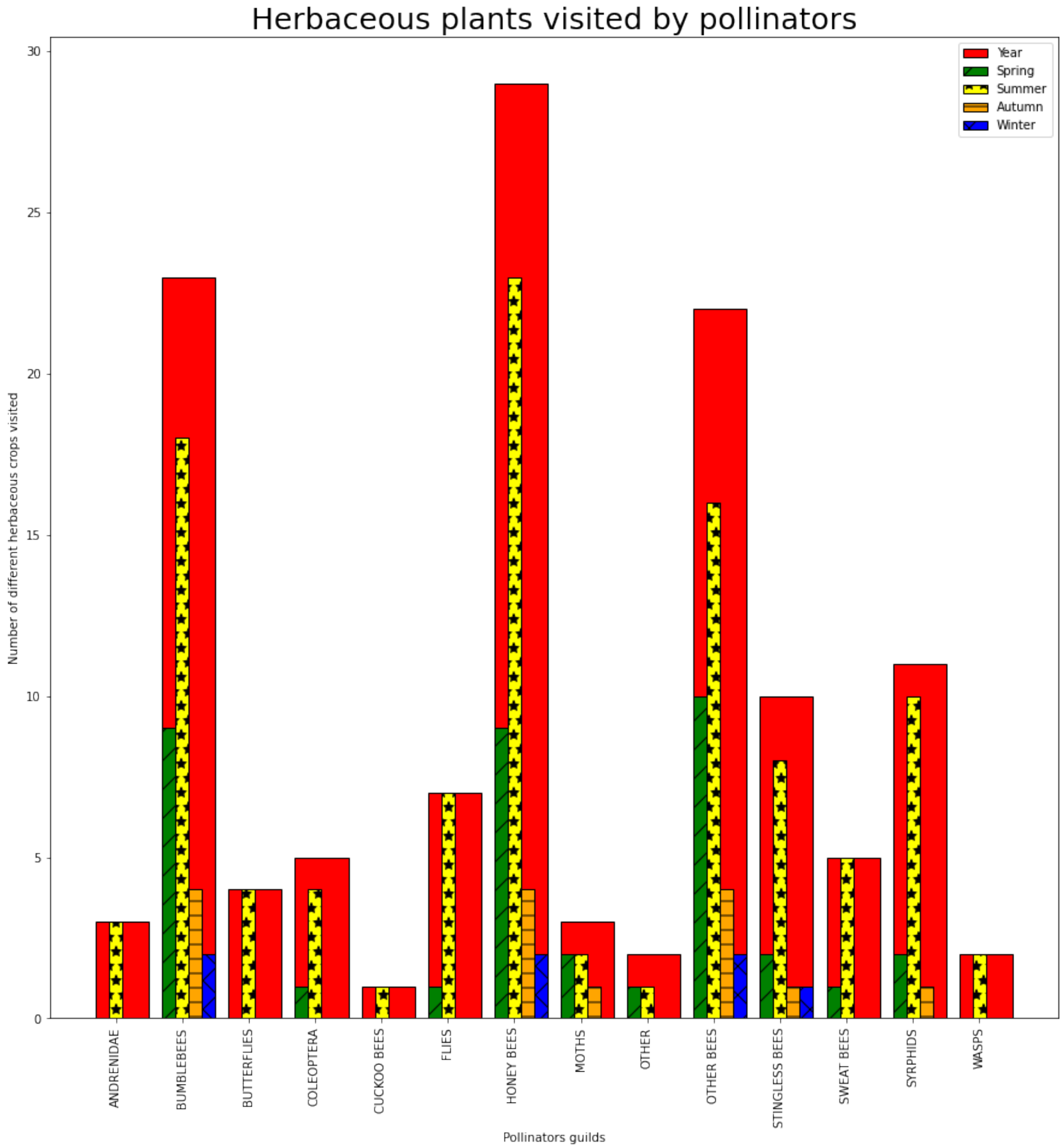
[354]:

```
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.20

plt.pyplot.bar(x_range + 1.5*width, arboreous_year_guild_crop_dataset_full.
  ↪count(), \
               color = 'red', width = 4*width, edgecolor = 'black',␣
  ↪label='Year')
plt.pyplot.bar(x_range , arboreous_spring_guild_crop_dataset_full.count(), \
               color = 'green', width = width, edgecolor = 'black', hatch='/',␣
  ↪label='Spring')
plt.pyplot.bar(x_range + width, arboreous_summer_guild_crop_dataset_full.
  ↪count(), \
               color = 'yellow', width = width, edgecolor = 'black', hatch=␣
  ↪'*', label='Summer')
plt.pyplot.bar(x_range + 2*width, arboreous_autumn_guild_crop_dataset_full.
  ↪count(), \
               color = 'orange', width = width, edgecolor = 'black', hatch='-',␣
  ↪label='Autumn')
plt.pyplot.bar(x_range +  3*width, arboreous_winter_guild_crop_dataset_full.
  ↪count(), \
               color = 'blue', width = width, edgecolor = 'black', hatch='x',␣
 ↪label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of different arboreous crops visited")
plt.pyplot.title("Arboreous plants visited by pollinators", fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.savefig('Images/Arboreous plants visited by pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Arboreous plants visited by pollinators.jpg',␣
 ↪dpi=150)


plt.pyplot.show()
```



[355]:
```
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.20

plt.pyplot.bar(x_range + 1.5*width, herbaceous_year_guild_crop_dataset_full.
 ↪count(), \
               color = 'red', width = 4*width, edgecolor = 'black',␣
 ↪label='Year')
```

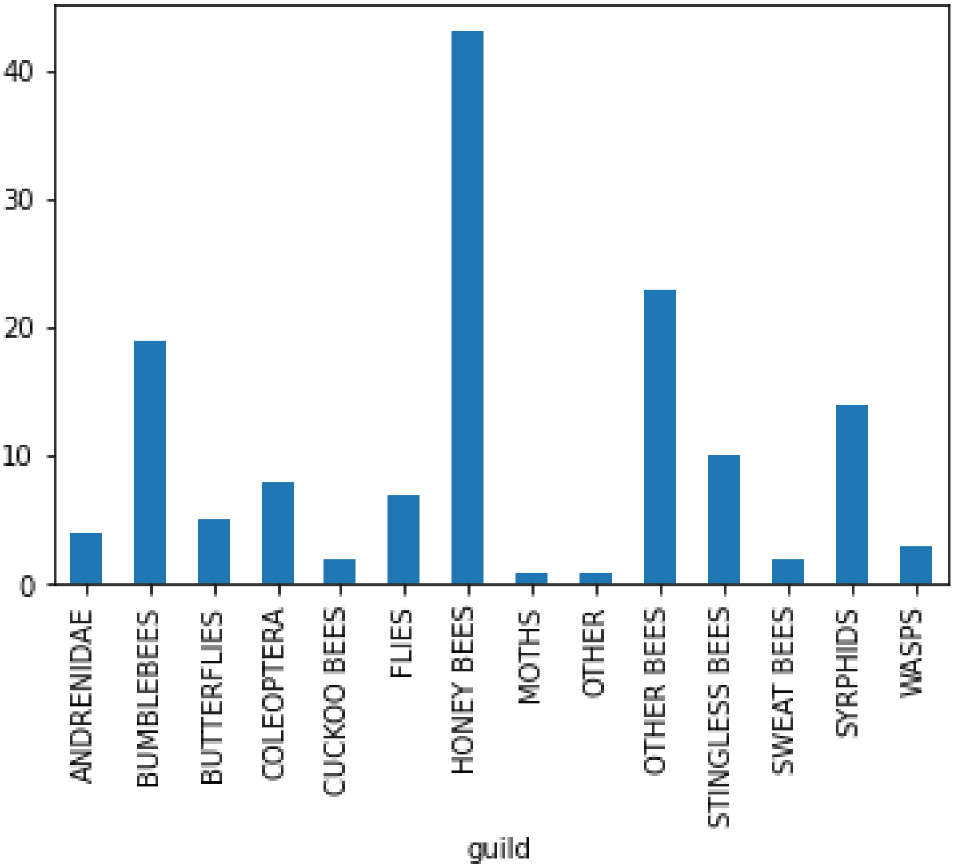
```
plt.pyplot.bar(x_range , herbaceous_spring_guild_crop_dataset_full.count(), \
               color = 'green', width = width, edgecolor = 'black', hatch='/',␣
 ↪label='Spring')
plt.pyplot.bar(x_range + width, herbaceous_summer_guild_crop_dataset_full.
 ↪count(),\
               color = 'yellow', width = width, edgecolor = 'black', hatch=␣
 ↪'*', label='Summer')
plt.pyplot.bar(x_range + 2*width, herbaceous_autumn_guild_crop_dataset_full.
 ↪count(), color = 'orange',
        width = width, edgecolor = 'black', hatch='-', label='Autumn')
plt.pyplot.bar(x_range +  3*width, herbaceous_winter_guild_crop_dataset_full.
 ↪count(), color = 'blue',
        width = width, edgecolor = 'black', hatch='x', label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of different herbaceous crops visited")
plt.pyplot.title("Herbaceous plants visited by pollinators", fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.savefig('Images/Herbaceous plants visited by pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Herbaceous plants visited by pollinators.jpg',␣
 ↪dpi=150)


plt.pyplot.show()
```



Maybe we should add the total amount of different crops visited by pollinators in each season, it will evidence if honeybees are able to visit all the crops in the dataset or there are some crops wich are visited only by certain pollinators. Let's make a different graph for each season

```
[359]: arboreous_year_guild_crop_dataset_full.count().plot( kind = 'bar')
```

```
[359]: <AxesSubplot:xlabel='guild'>
```



```
[368]: len(herbaceous_year_guild_crop_dataset_full.index.to_list())
```

```
[368]: 78
```

```
[387]: GPD_arboreous_seasons_dataset.loc[GPD_arboreous_seasons_dataset['spring'] == 1,␣
         ↪\
                                          ['guild', 'crop']].value_counts(sort =␣
         ↪False\
                                          ).unstack(level = 1)
```

```
[387]: guild                    ANDRENIDAE  BUMBLEBEES  BUTTERFLIES  COLEOPTERA  \
       crop
       Coriandrum_sativum              1.0         NaN          1.0         1.0
       Malus_domestica                 5.0         5.0          2.0         3.0
       Prunus_avium                   25.0         7.0          NaN         NaN
       Vaccinium_corymbosum            2.0         5.0          NaN         NaN
       Castanea_crenata                NaN         2.0          7.0         6.0
       Citrus_paradisi                 NaN         1.0          NaN         NaN
       Cyphomandra_betacea             NaN         2.0          NaN         NaN
```

```
Persea_americana                NaN         1.0          NaN         NaN
Prunus_cerasus                  NaN         1.0          NaN         NaN
Prunus_dulcis                   NaN         2.0          NaN         NaN
Prunus_persica                  NaN         1.0          NaN         NaN
Pyrus_communis                  NaN         1.0          NaN         NaN
Vaccinium_angustifolium         NaN         4.0          NaN         NaN
Vaccinium_myrtillus             NaN         9.0          NaN         NaN
Vaccinium_uliginosum            NaN         9.0          NaN         NaN
Litchi_chinensis                NaN         NaN          NaN         1.0
Vitis_vinifera                  NaN         NaN          NaN         2.0
Citrus_reticulata               NaN         NaN          NaN         NaN
Jatropha_curcas                 NaN         NaN          NaN         NaN
Anacardium_occidentale          NaN         NaN          NaN         NaN
Cocos_nucifera                  NaN         NaN          NaN         NaN
Coffea_arabica                  NaN         NaN          NaN         NaN
Coffea_canephora                NaN         NaN          NaN         NaN
Dimocarpus_longan               NaN         NaN          NaN         NaN
Prunus_domestica                NaN         NaN          NaN         NaN
Sambucus_racemosa               NaN         NaN          NaN         NaN
Sambucus_simpsonii              NaN         NaN          NaN         NaN

guild                    CUCKOO BEES  FLIES  HONEY BEES  OTHER  OTHER BEES  \
crop
Coriandrum_sativum               NaN    NaN         4.0    NaN         3.0
Malus_domestica                  NaN    2.0         2.0    4.0        15.0
Prunus_avium                    14.0    NaN         1.0    NaN        11.0
Vaccinium_corymbosum             1.0    NaN         1.0    NaN        22.0
Castanea_crenata                 NaN    NaN         1.0    NaN         1.0
Citrus_paradisi                  NaN    NaN         2.0    NaN         NaN
Cyphomandra_betacea              NaN    NaN         1.0    NaN         NaN
Persea_americana                 NaN    NaN         1.0    NaN         NaN
Prunus_cerasus                   NaN    NaN         2.0    NaN         NaN
Prunus_dulcis                    NaN    NaN         2.0    NaN         3.0
Prunus_persica                   NaN    NaN         2.0    NaN         NaN
Pyrus_communis                   NaN    NaN         2.0    NaN         1.0
Vaccinium_angustifolium          NaN    NaN         1.0    NaN         3.0
Vaccinium_myrtillus              NaN    NaN         1.0    NaN         NaN
Vaccinium_uliginosum             NaN    NaN         NaN    NaN         NaN
Litchi_chinensis                 NaN    NaN         4.0    NaN         3.0
Vitis_vinifera                   NaN    NaN         1.0    NaN         NaN
Citrus_reticulata                NaN    1.0         2.0    NaN         NaN
Jatropha_curcas                  NaN    1.0         4.0    NaN         NaN
Anacardium_occidentale           NaN    NaN         4.0    NaN         NaN
Cocos_nucifera                   NaN    NaN         3.0    NaN         NaN
Coffea_arabica                   NaN    NaN         4.0    NaN         2.0
Coffea_canephora                 NaN    NaN         4.0    NaN         3.0
Dimocarpus_longan                NaN    NaN         3.0    NaN         NaN
```

```
Prunus_domestica                 NaN    NaN         1.0    NaN         NaN
Sambucus_racemosa                NaN    NaN         1.0    NaN         3.0
Sambucus_simpsonii               NaN    NaN         1.0    NaN         3.0

guild                    STINGLESS BEES  SWEAT BEES  SYRPHIDS  WASPS
crop
Coriandrum_sativum                  NaN         1.0       2.0    NaN
Malus_domestica                     NaN         NaN       9.0    1.0
Prunus_avium                        NaN        23.0       NaN    NaN
Vaccinium_corymbosum                NaN         NaN       NaN    NaN
Castanea_crenata                    NaN         NaN       NaN    NaN
Citrus_paradisi                     1.0         NaN       NaN    NaN
Cyphomandra_betacea                 NaN         NaN       NaN    NaN
Persea_americana                    5.0         NaN       NaN    NaN
Prunus_cerasus                      NaN         NaN       NaN    NaN
Prunus_dulcis                       NaN         NaN       2.0    NaN
Prunus_persica                      NaN         NaN       2.0    NaN
Pyrus_communis                      NaN         NaN       NaN    NaN
Vaccinium_angustifolium             NaN         NaN       NaN    NaN
Vaccinium_myrtillus                 NaN         NaN       NaN    NaN
Vaccinium_uliginosum                NaN         NaN       NaN    NaN
Litchi_chinensis                    NaN         NaN       4.0    NaN
Vitis_vinifera                      NaN         NaN       3.0    NaN
Citrus_reticulata                   NaN         NaN       1.0    NaN
Jatropha_curcas                     NaN         NaN       NaN    1.0
Anacardium_occidentale              1.0         NaN       NaN    NaN
Cocos_nucifera                      2.0         NaN       NaN    NaN
Coffea_arabica                      7.0         NaN       NaN    NaN
Coffea_canephora                    NaN         NaN       NaN    NaN
Dimocarpus_longan                   NaN         NaN       NaN    NaN
Prunus_domestica                    NaN         NaN       2.0    NaN
Sambucus_racemosa                   NaN         NaN       2.0    NaN
Sambucus_simpsonii                  NaN         NaN       2.0    NaN
```

[393]:
```
len(GPD_arboreous_seasons_dataset.loc[GPD_arboreous_seasons_dataset['spring']␣
 ↪== 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 1).count())
```

[393]:
```
27
```

[394]:
```
len(GPD_arboreous_seasons_dataset.loc[GPD_arboreous_seasons_dataset['summer']␣
 ↪== 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 1).count())
```

```
[394]: 22
```

```
[395]: len(GPD_arboreous_seasons_dataset.loc[GPD_arboreous_seasons_dataset['autumn']␣
        ↪== 1, \
                                            ['guild', 'crop']].value_counts(sort =␣
        ↪False\
                                            ).unstack(level = 1).count())
```

```
[395]: 9
```

```
[ ]: len(GPD_arboreous_seasons_dataset.loc[GPD_arboreous_seasons_dataset['winter']␣
      ↪== 1, \
                                          ['guild', 'crop']].value_counts(sort =␣
      ↪False\
                                          ).unstack(level = 1).count())
```

```
[371]: total_pollinated_plants_array = np.ones([len(GPD_seasons_dataset['guild'].
        ↪unique().to_list())])*len(herbaceous_year_guild_crop_dataset_full.index.
        ↪to_list())
```

```
[357]: plt.pyplot.bar(x_range + 1.5*width, herbaceous_year_guild_crop_dataset_full.
        ↪count(), \
                       color = 'red', width = 4*width, edgecolor = 'black',␣
        ↪label='Year')
```

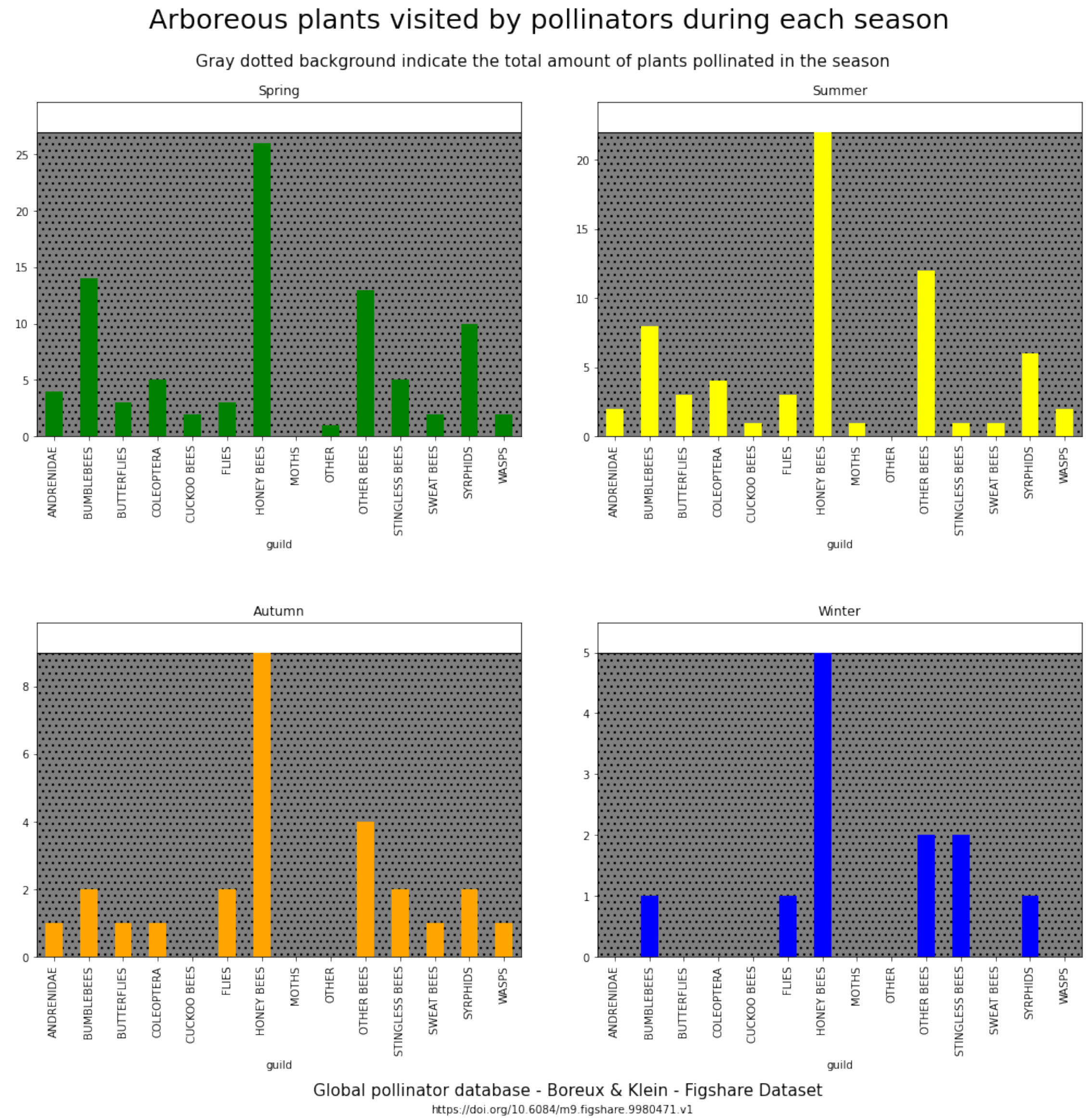
```
[357]: guild
       ANDRENIDAE          0
       BUMBLEBEES          9
       BUTTERFLIES         0
       COLEOPTERA          1
       CUCKOO BEES         0
       FLIES               1
       HONEY BEES          9
       MOTHS               2
       OTHER               1
       OTHER BEES         10
       STINGLESS BEES      2
       SWEAT BEES          1
       SYRPHIDS            2
       WASPS               0
       dtype: int64
```

```
[437]: fig, ((ax1, ax2), (ax3, ax4)) = plt.pyplot.subplots(2, 2, figsize=(15,15))

       fig.suptitle('Arboreous plants visited by pollinators during each season',␣
        ↪fontsize=25, y=0.95)
       ax1.set_title('Spring')
```

```
ax2.set_title('Summer')
ax3.set_title('Autumn')
ax4.set_title('Winter')

total_spring_pollinated_crops = len(GPD_arboreous_seasons_dataset.loc[\
                                    GPD_arboreous_seasons_dataset['spring']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_summer_pollinated_crops = len(GPD_arboreous_seasons_dataset.loc[\
                                    GPD_arboreous_seasons_dataset['summer']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_autumn_pollinated_crops = len(GPD_arboreous_seasons_dataset.loc[\
                                    GPD_arboreous_seasons_dataset['autumn']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_winter_pollinated_crops = len(GPD_arboreous_seasons_dataset.loc[\
                                    GPD_arboreous_seasons_dataset['winter']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())

ax1.set_ylim(ymax= total_spring_pollinated_crops +␣
 ↪total_spring_pollinated_crops/10 )
ax2.set_ylim(ymax= total_summer_pollinated_crops +␣
 ↪total_summer_pollinated_crops/10 )
ax3.set_ylim(ymax= total_autumn_pollinated_crops +␣
 ↪total_autumn_pollinated_crops/10 )
ax4.set_ylim(ymax= total_winter_pollinated_crops +␣
 ↪total_winter_pollinated_crops/10 )


bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())

width = 0.10

plt.pyplot.axes(ax1)
plt.pyplot.bar((bar_number-1)/2, total_spring_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_spring_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax1,␣
 ↪color = 'green')
```

```
plt.pyplot.axes(ax2)
plt.pyplot.bar((bar_number-1)/2, total_summer_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_summer_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax2,␣
 ↪color = 'yellow')

plt.pyplot.axes(ax3)
plt.pyplot.bar((bar_number-1)/2, total_autumn_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_autumn_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax3,␣
 ↪color = 'orange')

plt.pyplot.axes(ax4)
plt.pyplot.bar((bar_number-1)/2, total_winter_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_winter_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax4,␣
 ↪color = 'blue')

#plt.pyplot.legend()


fig.text(0.20, 0.90, 'Gray dotted background indicate the total amount of␣
 ↪plants pollinated in the season',\
         fontsize=15)

fig.text(0.30, 0.025, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
fig.text(0.40, 0.01, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)

fig.tight_layout(pad=5)
#plt.pyplot.margins(2000)


plt.pyplot.savefig('Images/Seasonal arboreous plants for pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Seasonal arboreous plants for pollinators.jpg',␣
 ↪dpi=150)
```

```
plt.pyplot.show()
```



Arboreous plants visited by pollinators during each season

Gray dotted background indicate the total amount of plants pollinated in the season

Spring

Summer

Autumn

Winter

Global pollinator database - Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

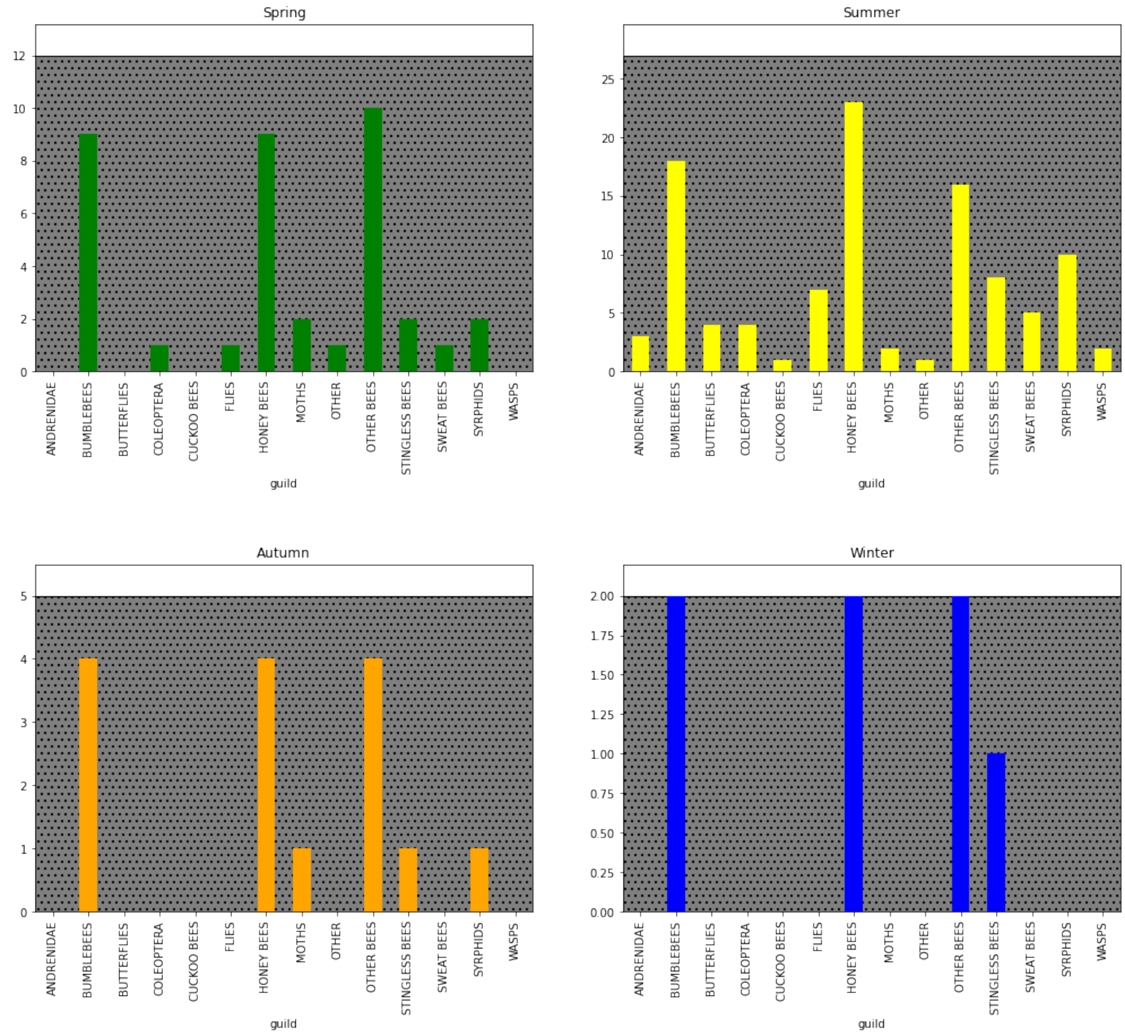
```
[491]: fig, ((ax1, ax2), (ax3, ax4)) = plt.pyplot.subplots(2, 2, figsize=(15,15))

fig.suptitle('Herbaceous plants visited by pollinators during each season', fontsize=25, y=0.95)
ax1.set_title('Spring')
ax2.set_title('Summer')
ax3.set_title('Autumn')
```

```
ax4.set_title('Winter')

total_spring_pollinated_crops = len(GPD_herbaceous_seasons_dataset.loc[\
                                    GPD_herbaceous_seasons_dataset['spring']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_summer_pollinated_crops = len(GPD_herbaceous_seasons_dataset.loc[\
                                    GPD_herbaceous_seasons_dataset['summer']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_autumn_pollinated_crops = len(GPD_herbaceous_seasons_dataset.loc[\
                                    GPD_herbaceous_seasons_dataset['autumn']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_winter_pollinated_crops = len(GPD_herbaceous_seasons_dataset.loc[\
                                    GPD_herbaceous_seasons_dataset['winter']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())

ax1.set_ylim(ymax= total_spring_pollinated_crops +␣
  ↪total_spring_pollinated_crops/10 )
ax2.set_ylim(ymax= total_summer_pollinated_crops +␣
  ↪total_summer_pollinated_crops/10 )
ax3.set_ylim(ymax= total_autumn_pollinated_crops +␣
  ↪total_autumn_pollinated_crops/10 )
ax4.set_ylim(ymax= total_winter_pollinated_crops +␣
  ↪total_winter_pollinated_crops/10 )


bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())

width = 0.10

plt.pyplot.axes(ax1)
plt.pyplot.bar((bar_number-1)/2, total_spring_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
  ↪label='Total',\
               hatch='..')
herbaceous_spring_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax1,␣
  ↪color = 'green')

plt.pyplot.axes(ax2)
plt.pyplot.bar((bar_number-1)/2, total_summer_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_summer_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax2,␣
 ↪color = 'yellow')

plt.pyplot.axes(ax3)
plt.pyplot.bar((bar_number-1)/2, total_autumn_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_autumn_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax3,␣
 ↪color = 'orange')

plt.pyplot.axes(ax4)
plt.pyplot.bar((bar_number-1)/2, total_winter_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_winter_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax4,␣
 ↪color = 'blue')

#plt.pyplot.legend()


fig.text(0.20, 0.90, 'Gray dotted background indicate the total amount of␣
 ↪plants pollinated in the season',\
         fontsize=15)

fig.text(0.30, 0.025, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
fig.text(0.40, 0.01, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)

fig.tight_layout(pad=5)
#plt.pyplot.margins(2000)


plt.pyplot.savefig('Images/Seasonal herbaceous plants for pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Seasonal herbaceous plants for pollinators.jpg',␣
 ↪dpi=150)
```

```
plt.pyplot.show()
```

Herbaceous plants visited by pollinators during each season

Gray dotted background indicate the total amount of plants pollinated in the season



Global pollinator database - Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

```
[482]: GPD_seasons_dataset.loc[GPD_seasons_dataset['spring'] == 1, \
                                                  'guild'].unique().to_list()
```

```
[482]: ['ANDRENIDAE',
        'BUMBLEBEES',
        'BUTTERFLIES',
        'COLEOPTERA',
        'CUCKOO BEES',
        'FLIES',
        'HONEY BEES',
        'MOTHS',
        'OTHER',
        'OTHER BEES',
        'STINGLESS BEES',
        'SWEAT BEES',
        'SYRPHIDS',
        'WASPS']
```

```
[489]: GPD_honeybees_count_serie = GPD_seasons_dataset.
        ↪loc[(GPD_seasons_dataset['spring'] == 1) & \
                                (GPD_seasons_dataset['guild'] == 'HONEY BEES') , \
                                                      'visitor'].value_counts()
```

```
[484]: len(GPD_honeybees_count_serie[GPD_honeybees_count_serie != 0].to_list())
```

```
[484]: 8
```

```
[488]: GPD_honeybees_count_serie[GPD_honeybees_count_serie != 0]
```

```
[488]: Apis_mellifera                 30
       Apis_cerana                    12
       Apis_florea                    11
       Apis_dorsata                   11
       Apis_cerana_indica              4
       Apis_mellifera_scutellata       4
       Apis_mellifera_ligustica        1
       Apis_mellifera_carnica          1
       Name: visitor, dtype: int64
```

OK… we have a problem: seems that the authors put toghether different datasets without check for uniformity of data. We have the same pollinators named in different way and that alterate the meaning of the previous plots

```
[493]: GPD_bumblebees_count_serie = GPD_seasons_dataset.
        ↪loc[(GPD_seasons_dataset['spring'] == 1) & \
                                (GPD_seasons_dataset['guild'] == 'BUMBLEBEES') , \
                                                      'visitor'].value_counts()
       GPD_bumblebees_count_serie[GPD_bumblebees_count_serie != 0]
```

```
[493]: Bombus_terrestris        12
       Bombus_pascuorum          8
       Bombus_impatiens          6
       Bombus_pratorum           5
       Bombus_hortorum           4
       Bombus_vagans             4
       Bombus_lapidarius         4
       Bombus_griseocollis       3
```

```
Bombus_fervidus         3
Bombus_lucorum          3
Bombus_lapponicus       2
Bombus_balteatus        2
Bombus_bimaculatus      2
Bombus_vestalis         2
Bombus_hyperboreus      2
Bombus_hypnorum         2
Bombus_jonellus         2
Bombus_alpinus          2
Bombus_terricola        2
Bombus_ternarius        2
Bombus_hypocrita        1
Bombus_pensylvanicus    1
Bombus_sylvarum         1
Bombus_bohemicus        1
Bombus_sylvestris       1
Bombus_atratus          1
Bombus_vosnesenskii     1
Name: visitor, dtype: int64
```

[496]:

```
GPD_otherbees_count_serie = GPD_seasons_dataset.
 ↪loc[(GPD_seasons_dataset['spring'] == 1) & \
                        (GPD_seasons_dataset['guild'] == 'OTHER BEES') , \
                                                'visitor'].value_counts()
GPD_otherbees_count_serie[GPD_otherbees_count_serie != 0]
```

[496]:

```
Osmia_lignaria             7
Halictus_rubicundus        6
Osmia_cornuta              5
Melissodes_bimaculata      5
Halictus_confusus          5
Ceratina_dupla             4
Osmia_cornifrons           4
Lasioglossum_coriaceum     4
Ceratina_smaragdula        4
Lasioglossum_versatum      4
Xylocopa_virginica         3
Augochlorella_aurata       3
Augochlora_pura            3
Megachile_lanata           3
Peponapis_pruinosa         3
Halictus_ligatus           3
Megachile_rotundata        3
Agapostemon_virescens      3
Xylocopa_fenestrata        3
Lasioglossum_pilosum       3
```

```
Lasioglossum_cressonii      3
Xylocopa_aestuans           3
Anthophora_plumipes         2
Nomioides                   2
Xylocopa_violacea           2
Augochloropsis_metallica    2
Osmia_lignaria_propinqua    2
Osmia_rufa                  2
Megachile_frontalis         2
Megachile_centuncularis     2
Megachile_brevis            2
Anthidium_manicatum         2
Osmia_bicornis              2
Macropis_fulvipes           2
Megachile_mendica           2
Ceratina_cucurbitina        2
Osmia_bicolor               1
Ceratina_chalcites          1
Osmia_gallarum              1
Xylocopa_valga              1
Halictus_tripartitus        1
Melissodes_agilis           1
Megachile_ligniseca         1
Colletes_cunicularius       1
Megachile_pilidens          1
Megachile_apicalis          1
Osmia_aurulenta             1
Megachile_alpicola          1
Megachile_versicolor        1
Megachile_addenda           1
Heriades_truncorum          1
Name: visitor, dtype: int64
```

[495]:

```
GPD_stinglessbees_count_serie = GPD_seasons_dataset.
 ↪loc[(GPD_seasons_dataset['spring'] == 1) & \
                        (GPD_seasons_dataset['guild'] == 'STINGLESS BEES') , \
                                                'visitor'].value_counts()
GPD_stinglessbees_count_serie[GPD_stinglessbees_count_serie != 0]
```

[495]:

```
Trigona_fulviventris          5
Partamona_bilineata           4
Nannotrigona_perilampoides    4
Plebeia_frontalis             3
Trigona_nigerrima             2
Tetragonisca_angustula        2
Trigona_spinipes              1
Trigona_amalthea              1
```

```
Melipona_quadrifasciata       1
Name: visitor, dtype: int64
```

[498]:

```
GPD_sweatbees_count_serie = GPD_seasons_dataset.
 ↪loc[(GPD_seasons_dataset['spring'] == 1) & \
                        (GPD_seasons_dataset['guild'] == 'SWEAT BEES') , \
                                                'visitor'].value_counts()
GPD_sweatbees_count_serie[GPD_sweatbees_count_serie != 0]
```

[498]:

```
Lasioglossum_puncticolle       2
Halictus_scabiosae             2
Lasioglossum_reticulatum       1
Lasioglossum_parvulum          1
Sphecodes_niger                1
Lasioglossum_subhirtum         1
Sphecodes_monilicornis         1
Lasioglossum_pygmaeum          1
Lasioglossum_punctatissimum    1
Lasioglossum_politum           1
Sphecodes_majalis              1
Lasioglossum_pauxillum         1
Lasioglossum_pauperatum        1
Lasioglossum_morio             1
Lasioglossum_minutulum         1
Lasioglossum_minutissimum      1
Lasioglossum_malachurum        1
Lasioglossum_lineare           1
Halictus_tumulorum             1
Lasioglossum_laticeps          1
Lasioglossum_glabriusculum     1
Sphecodes_longulus             1
Sphecodes_albilabris           1
Lasioglossum_calceatum         1
Lasioglossum_xanthopus         1
Name: visitor, dtype: int64
```

So let’s now chek for the pollinators with at least 2 “ ” *and then wi will check if exist the less specific definition with only one* ””

[591]:

```
visitor_subsp_check_list = GPD_seasons_dataset.visitor.str.contains(r".*_.*_.
 ↪*").to_list()
visitor_subsp_indexes = []
for index, check in enumerate(visitor_subsp_check_list):
    if check:
        visitor_subsp_indexes.append(index)
len(visitor_subsp_indexes)
```

[591]:
```
19
```

Apparently we have 19 visitor that could be considered as duplicated values. To be honest seems not such a big alteration of the results of the previous plots… Let's check over if that is the situation: for each of these 19 we also have its generic definition in the dataset?

[657]:
```
visitor_subsp_list = GPD_seasons_dataset.iloc[visitor_subsp_indexes,].visitor
visitor_subsp_list
```

[657]:
```
296              Apis_cerana_indica
315       Apis_mellifera_scutellata
320       Apis_mellifera_scutellata
322              Apis_cerana_indica
347       Apis_mellifera_scutellata
355        Apis_mellifera_ligustica
360              Apis_cerana_indica
376          Apis_mellifera_carnica
377              Apis_cerana_indica
378              Apis_cerana_indica
380              Apis_cerana_indica
381        Apis_mellifera_ligustica
399       Apis_mellifera_scutellata
406              Apis_cerana_indica
416              Apis_cerana_indica
421       Apis_mellifera_scutellata
567        Osmia_lignaria_propinqua
587        Osmia_lignaria_propinqua
638    Trigona_fulviventris_guianae
Name: visitor, dtype: category
Categories (254, object): ['Adalia_decempunctata',
'Agapanthia_villosoviridescens', 'Agapostemon_virescens', 'Aglais_urticae', …,
'Xylocopa_hottentotta', 'Xylocopa_valga', 'Xylocopa_violacea',
'Xylocopa_virginica']
```

[663]:
```
# now let's remove duplicated values
visitor_subsp_list = pd.DataFrame(visitor_subsp_list).visitor.unique().tolist()
visitor_subsp_list
```

[663]:
```
['Apis_cerana_indica',
 'Apis_mellifera_scutellata',
 'Apis_mellifera_ligustica',
 'Apis_mellifera_carnica',
 'Osmia_lignaria_propinqua',
 'Trigona_fulviventris_guianae']
```

[622]:
```
# Let's create a list removing characters from the last '_' to the end for each␣
 ↪element in
```

```
# the visitor subspecies's list
visitor_rel_sp_list=[]
for visitor in visitor_subsp_list:
    visitor_rel_sp_list.append(re.search('.*_.*_', visitor).group()[:-1])
# now let's remove duplicated values
visitor_rel_sp_list = pd.DataFrame(visitor_rel_sp_list)[0].unique().tolist()
visitor_rel_sp_list
```

```
[622]: ['Apis_cerana', 'Apis_mellifera', 'Osmia_lignaria', 'Trigona_fulviventris']
```

```
[643]: #Now let's check that the species related to the selected subspecies are in the␣
         ↪dataset

        for specie in visitor_rel_sp_list:
            print(specie)
            check_list = GPD_seasons_dataset.visitor.str.contains(fr"{specie}")
            print(check_list[check_list != False].count())
```

```
Apis_cerana
28
Apis_mellifera
75
Osmia_lignaria
10
Trigona_fulviventris
7
```

We shoudl check also the crops

```
[648]: crop_subsp_check_list = GPD_seasons_dataset.crop.str.contains(r".*_.*_.*").
         ↪to_list()
        crop_subsp_indexes = []
        for index, check in enumerate(crop_subsp_check_list):
            if check:
                crop_subsp_indexes.append(index)
        len(crop_subsp_indexes)
```

```
[648]: 5
```

```
[649]: crop_subsp_list = GPD_seasons_dataset.iloc[crop_subsp_indexes,].crop
        crop_subsp_list
```

```
[649]: 191    Vicia_faba_major
        192    Vicia_faba_major
        193    Vicia_faba_major
        423    Vicia_faba_major
        629    Vicia_faba_major
        Name: crop, dtype: category
```

```
Categories (78, object): ['Allium_cepa', 'Allium_oleraceum', 'Amomum_subulatum',
'Anacardium_occidentale', …, 'Vicia_faba_major', 'Vigna_unguiculata',
'Vitis_vinifera', 'Ziziphus_mauritiana']
```

[651]:

```
crop_rel_sp = re.search('.*_.*_', crop_subsp_list[191]).group()[:-1]
crop_rel_sp
```

[651]:

```
'Vicia_faba'
```

[652]:

```
check_list = GPD_seasons_dataset.crop.str.contains(fr"{crop_rel_sp}")
check_list[check_list != False].count()
```

[652]:

```
14
```

Let's uniform the data overriding the subspecies values with related species values

[655]:

```
# replace crop
GPD_seasons_dataset_sp = GPD_seasons_dataset.replace(crop_subsp_list[191],␣
 ↪crop_rel_sp)
check_list = GPD_seasons_dataset_sp.crop.str.
 ↪contains(fr"{crop_subsp_list[191]}")
check_list[check_list != False].count()
```

[655]:

```
0
```

[665]:

```
# replace visitor
for subsp in visitor_subsp_list:
    GPD_seasons_dataset_sp = GPD_seasons_dataset_sp.replace(subsp ,\
                                    re.search('.*_.*_', subsp).group()[:-1])
    print(subsp)
    print(re.search('.*_.*_', subsp).group()[:-1])
    check_list = GPD_seasons_dataset_sp.visitor.str.contains(fr"{subsp}")
    print(check_list[check_list != False].count())
```

```
Apis_cerana_indica
Apis_cerana
0
Apis_mellifera_scutellata
Apis_mellifera
0
Apis_mellifera_ligustica
Apis_mellifera
0
Apis_mellifera_carnica
Apis_mellifera
0
Osmia_lignaria_propinqua
```

```
Osmia_lignaria
0
Trigona_fulviventris_guianae
Trigona_fulviventris
0
```

```
[675]: GPD_seasons_dataset_sp.
        ↪to_pickle(GPD_F_dataset_directory+"GPD_seasons_dataset_sp.pkl")
```

1.5.1 Year distribution - post subspecies uniformation - Starting point

```
[676]: GPD_seasons_dataset_sp =  pd.
        ↪read_pickle(GPD_F_dataset_directory+"GPD_seasons_dataset_sp.pkl")
```

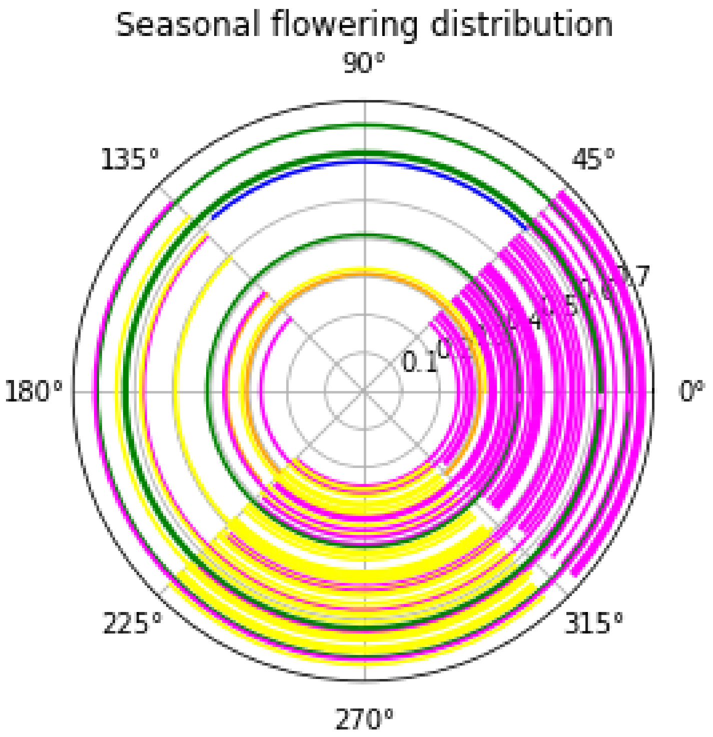
```
[679]: GPD_seasons_dataset_sp.describe
```

```
[679]: <bound method NDFrame.describe of                      crop        type   season
       corolla  colour nectar  \
       0    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
       1    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
       2          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
       3          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
       4          Brassica_napus  herbaceous   summer         OPEN  yellow    yes
       ..                    …         …      …          …     …    …
       774      Allium_oleraceum  herbaceous   summer  CAMPANULATE  purple    yes
       775       Jatropha_curcas   arboreous  spriaut         OPEN   green    yes
       776       Malus_domestica   arboreous   spring         OPEN   white    yes
       777   Phaseolus_coccineus  herbaceous   summer         OPEN   white    yes
       778      Capparis_spinosa   arboreous   summer         OPEN   white    yes

                b.system s.pollination inflorescence composite  \
       0         insects            no           yes        no
       1         insects            no           yes        no
       2    wind/insects            no           yes        no
       3    wind/insects            no           yes        no
       4    wind/insects            no           yes        no
       ..            …           …           …       …
       774       insects            no           yes        no
       775       insects            no           yes        no
       776       insects            no           yes        no
       777       insects            no           yes        no
       778       insects            no      solitary        no

                            visitor       guild sociality      feeding  spring  \
       0           Andrena_wilkella  ANDRENIDAE        no  oligolectic       1
       1        Andrena_barbilabris  ANDRENIDAE        no   polylectic       1
       2          Andrena_cineraria  ANDRENIDAE        no   polylectic       0
```

```
3           Andrena_flavipes  ANDRENIDAE        no   polylectic       0
4            Andrena_gravida  ANDRENIDAE        no   polylectic       0
..                        …         …       …          …     …
774  Dolichovespula_saxonica       WASPS       yes   polylectic       0
775        Bembecinus_tridens       WASPS        no    undefined       1
776          Vespula_vulgaris       WASPS       yes   polylectic       1
777     Philanthus_triangulum       WASPS        no   polylectic       0
778        Bembecinus_tridens       WASPS        no    undefined       0

     summer  autumn  winter
0         1       0       0
1         1       0       0
2         1       0       0
3         1       0       0
4         1       0       0
..      …     …     …
774       1       0       0
775       1       1       0
776       0       0       0
777       1       0       0
778       1       0       0

[779 rows x 18 columns]>
```

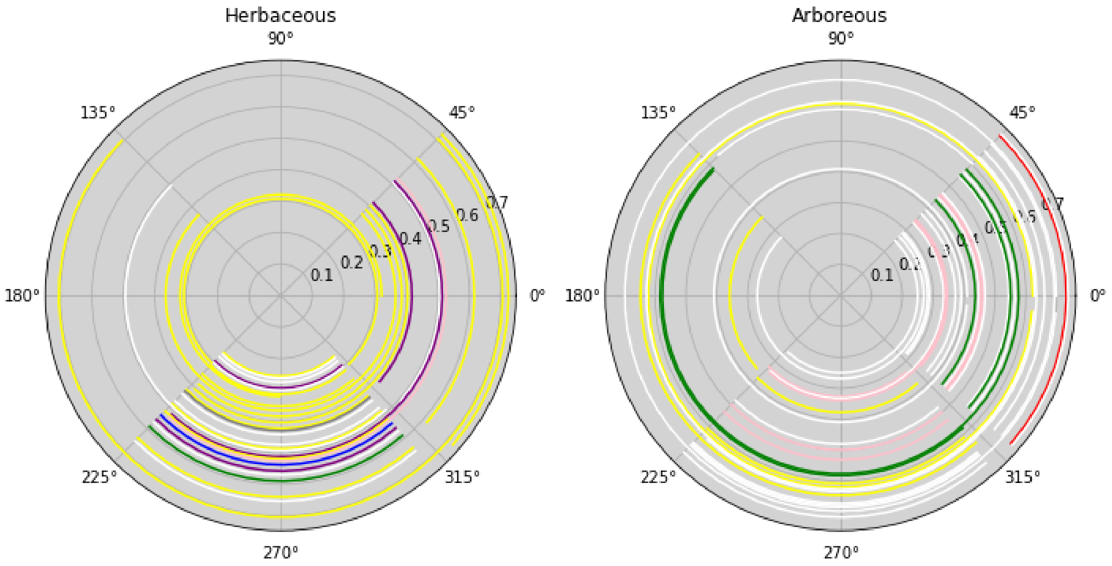
OK, now let's reproduce the previous plots

[669]:
```
plt.pyplot.axes(projection = 'polar')
for unique_crop_index in range(0, len(GPD_seasons_dataset_sp.crop.unique())):
    crop = GPD_seasons_dataset_sp.crop.unique()[unique_crop_index]
    season_period = GPD_seasons_dataset_sp.loc[\
                        GPD_seasons_dataset_sp['crop'] == crop, 'season'].
 ↪to_list()[0]
    angle_range = np.zeros(1)
    season_color = 'gray'
    if season_period == 'year':
        angle_range = np.arange(0, (2 * np.pi), 0.1)
        season_color = 'green'
    elif season_period == 'spring':
        angle_range = np.arange(np.pi/4, -np.pi/4, -0.1)
        season_color = 'magenta'
    elif season_period == 'sprisum':
        angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.1)
        season_color = 'magenta'
    elif season_period == 'spriaut':
        angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.1)
        season_color = 'magenta'
    elif season_period == 'winspring':
        angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.1)
        season_color = 'blue'
    elif season_period == 'sumspri': #is not year?
        angle_range = np.arange(0, 6*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.1)
        season_color = 'blue'

    if season_period != 'undefined':
        positions = np.full(shape = angle_range.shape, \
                           fill_value = (0.25 + unique_crop_index/(78*2)))
        plt.pyplot.polar(angle_range, positions, color = season_color)

plt.pyplot.title('Seasonal flowering distribution')
plt.pyplot.show()
```



[672]:
```python
fig, (ax1, ax2) = plt.pyplot.subplots(1, 2, subplot_kw = dict(polar = True), figsize=(10,10))

#flowering cicles differentiated by the type of plant (herbaceous or arboreous)
for unique_crop_index in range(0, len(GPD_seasons_dataset_sp.crop.unique())):
    crop = GPD_seasons_dataset_sp.crop.unique()[unique_crop_index]
    season_period = GPD_seasons_dataset_sp.loc[\
                        GPD_seasons_dataset_sp['crop'] == crop, 'season'].to_list()[0]
    first_element_index = GPD_seasons_dataset_sp.loc[\
                        GPD_seasons_dataset_sp['crop'] == crop, :].index.to_list()[0]

    angle_range = np.zeros(1)
    season_color = 'gray'
    if season_period == 'year':
        angle_range = np.arange(0, (2 * np.pi), 0.1)
    elif season_period == 'spring':
        angle_range = np.arange(np.pi/4, -np.pi/4, -0.1)
    elif season_period == 'sprisum':
        angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.1)
    elif season_period == 'spriaut':
        angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.1)
    elif season_period == 'winspring':
        angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.1)
    elif season_period == 'sumspri': #is not year?
        angle_range = np.arange(0, 6*np.pi/4, 0.1)
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.1)
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.1)
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.1)
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.1)
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.1)

    if season_period != 'undefined':
        positions = np.full(shape = angle_range.shape, \
                           fill_value = (0.25 + unique_crop_index/(78*2)))
        if GPD_seasons_dataset_sp.loc[first_element_index,'type'] ==␣
 ↪'herbaceous':
            ax1.plot(angle_range, positions, color =␣
 ↪colours_list[first_element_index] )
        else:
            ax2.plot(angle_range, positions, color =␣
 ↪colours_list[first_element_index] )

ax1.set_title('Herbaceous')
ax1.set_facecolor('#D3D3D3')
ax2.set_title('Arboreous')
ax2.set_facecolor('#D3D3D3')

fig.suptitle('Seasonal flowering distribution', fontsize=25, y=0.8)
fig.text(0.35, 0.2, 'Global pollinator database', fontsize=16)
fig.text(0.36, 0.15, 'Boreux & Klein - Figshare Dataset', fontsize=12)
fig.text(0.37, 0.1, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=8)

#set spacing between plots
fig.tight_layout()

plt.pyplot.savefig('Images/Seasonal flowering distribution.png', dpi=150)
plt.pyplot.savefig('Images/Seasonal flowering distribution.jpg', dpi=150)

plt.pyplot.show()
```

Seasonal flowering distribution



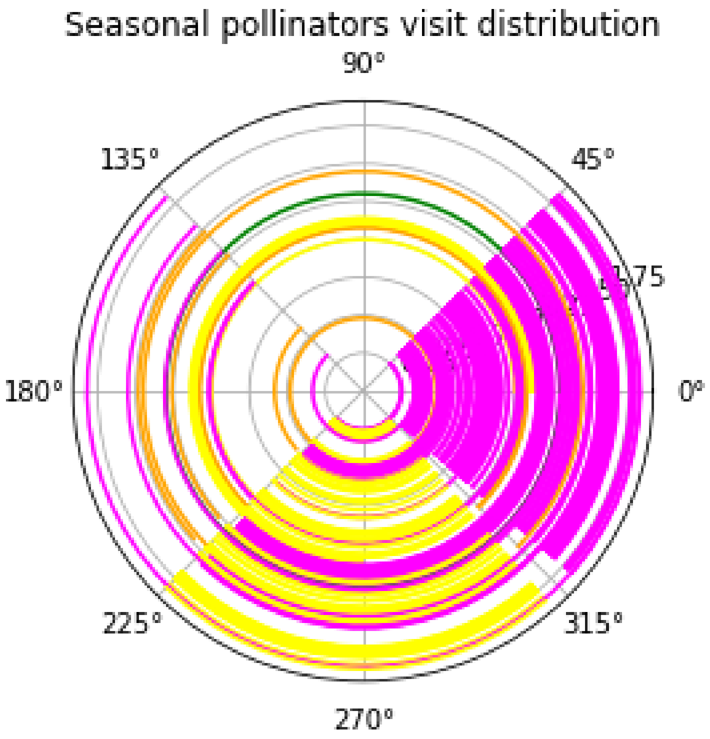
Global pollinator database

Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

```
[674]: plt.pyplot.axes(projection = 'polar')
       for unique_visitor_index in range(0, len(GPD_seasons_dataset_sp.visitor.
        ↪unique())):
           visitor = GPD_seasons_dataset_sp.visitor.unique()[unique_visitor_index]
           season_period = GPD_seasons_dataset_sp.loc[\
                               GPD_seasons_dataset_sp['visitor'] == visitor, 'season'].
        ↪to_list()[0]
           angle_range = np.zeros(1)
           season_color = 'gray'
           if season_period == 'year':
               angle_range = np.arange(0, (2 * np.pi), 0.1)
               season_color = 'green'
           elif season_period == 'spring':
               angle_range = np.arange(np.pi/4, -np.pi/4, -0.1)
               season_color = 'magenta'
           elif season_period == 'sprisum':
               angle_range = np.arange(np.pi/4, -3*np.pi/4, -0.1)
               season_color = 'magenta'
           elif season_period == 'spriaut':
               angle_range = np.arange(np.pi/4, -5*np.pi/4, -0.1)
               season_color = 'magenta'
```

```
    elif season_period == 'winspring':
        angle_range = np.arange(np.pi/4, 3*np.pi/4, 0.1)
        season_color = 'blue'
    elif season_period == 'sumspri': #is not year?
        angle_range = np.arange(0, 6*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'summer':
        angle_range = np.arange(5*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'sumaut':
        angle_range = np.arange(3*np.pi/4, 7*np.pi/4, 0.1)
        season_color = 'yellow'
    elif season_period == 'autumn':
        angle_range = np.arange(3*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'autspri':
        angle_range = np.arange(-1*np.pi/4, 5*np.pi/4, 0.1)
        season_color = 'orange'
    elif season_period == 'winter':
        angle_range = np.arange(1*np.pi/4, 3*np.pi/4, 0.1)
        season_color = 'blue'

    if season_period != 'undefined':
        positions = np.full(shape = angle_range.shape, \
                           fill_value = (0.25 + unique_visitor_index/(78*2)))
        plt.pyplot.polar(angle_range, positions, color = season_color)

plt.pyplot.title('Seasonal pollinators visit distribution')
plt.pyplot.show()
```



```
[693]: GPD_herbaceous_seasons_dataset_sp = GPD_seasons_dataset_sp.loc[ \
                                    GPD_seasons_dataset_sp['type'] ==␣
        ↪'herbaceous', : ]
       GPD_arboreous_seasons_dataset_sp = GPD_seasons_dataset_sp.loc[ \
                                    GPD_seasons_dataset_sp['type'] ==␣
        ↪'arboreous', : ]
```

```
[695]: spring_guild_crop_dataset = GPD_seasons_dataset_sp.
        ↪loc[GPD_seasons_dataset_sp['spring'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
        ↪False\
                                    ).unstack(level = 0)
       summer_guild_crop_dataset = GPD_seasons_dataset_sp.
        ↪loc[GPD_seasons_dataset_sp['summer'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
        ↪False\
                                    ).unstack(level = 0)
       autumn_guild_crop_dataset = GPD_seasons_dataset_sp.
        ↪loc[GPD_seasons_dataset_sp['autumn'] == 1, \
                                    ['guild', 'crop']].value_counts(sort =␣
        ↪False\
                                    ).unstack(level = 0)
```

```
winter_guild_crop_dataset = GPD_seasons_dataset_sp.
 ↪loc[GPD_seasons_dataset_sp['winter'] == 1, \
                  ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                  ).unstack(level = 0)
year_guild_crop_dataset = GPD_seasons_dataset_sp[['guild', 'crop']].
 ↪value_counts(\
                  sort = False).unstack(level = 0)



print(len(spring_guild_crop_dataset.count()))
print(len(summer_guild_crop_dataset.count()))
print(len(autumn_guild_crop_dataset.count()))
print(len(winter_guild_crop_dataset.count()))
print(len(year_guild_crop_dataset.count()))
```

```
14
14
12
6
14
```

[696]:

```
arboreous_spring_guild_crop_dataset = GPD_arboreous_seasons_dataset_sp.loc[\
                   ␣
 ↪GPD_arboreous_seasons_dataset_sp['spring'] == 1, \
                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                  ).unstack(level = 0)
arboreous_summer_guild_crop_dataset = GPD_arboreous_seasons_dataset_sp.loc[\
                   ␣
 ↪GPD_arboreous_seasons_dataset_sp['summer'] == 1, \
                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                  ).unstack(level = 0)
arboreous_autumn_guild_crop_dataset = GPD_arboreous_seasons_dataset_sp.loc[\
                   ␣
 ↪GPD_arboreous_seasons_dataset_sp['autumn'] == 1, \
                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                  ).unstack(level = 0)
arboreous_winter_guild_crop_dataset = GPD_arboreous_seasons_dataset_sp.loc[\
                   ␣
 ↪GPD_arboreous_seasons_dataset_sp['winter'] == 1, \
                    ['guild', 'crop']].value_counts(sort =␣
 ↪False\
                                    ).unstack(level = 0)
arboreous_year_guild_crop_dataset = GPD_arboreous_seasons_dataset_sp[['guild',␣
  ↪'crop']].value_counts(\
                                    sort = False).unstack(level = 0)

herbaceous_spring_guild_crop_dataset = GPD_herbaceous_seasons_dataset_sp.loc[\
                                       ␣
  ↪GPD_herbaceous_seasons_dataset_sp['spring'] == 1, \
                                        ['guild', 'crop']].value_counts(sort =␣
  ↪False\
                                    ).unstack(level = 0)
herbaceous_summer_guild_crop_dataset = GPD_herbaceous_seasons_dataset_sp.loc[\
                                       ␣
  ↪GPD_herbaceous_seasons_dataset_sp['summer'] == 1, \
                                        ['guild', 'crop']].value_counts(sort =␣
  ↪False\
                                    ).unstack(level = 0)
herbaceous_autumn_guild_crop_dataset = GPD_herbaceous_seasons_dataset_sp.loc[\
                                       ␣
  ↪GPD_herbaceous_seasons_dataset_sp['autumn'] == 1, \
                                        ['guild', 'crop']].value_counts(sort =␣
  ↪False\
                                    ).unstack(level = 0)
herbaceous_winter_guild_crop_dataset = GPD_herbaceous_seasons_dataset_sp.loc[\
                                       ␣
  ↪GPD_herbaceous_seasons_dataset['winter'] == 1, \
                                        ['guild', 'crop']].value_counts(sort =␣
  ↪False\
                                    ).unstack(level = 0)
herbaceous_year_guild_crop_dataset = GPD_herbaceous_seasons_dataset_sp[\
                                        ['guild', 'crop']].value_counts(\
                                    sort = False).unstack(level = 0)
```

[694]:

```
year_guild_crop_dataset
```

[694]:

```
guild                    ANDRENIDAE  BUMBLEBEES  BUTTERFLIES  COLEOPTERA  \
crop
Allium_cepa                     NaN         NaN          1.0         1.0
Allium_oleraceum                NaN         1.0          1.0         NaN
Amomum_subulatum                NaN         NaN          NaN         NaN
Anacardium_occidentale          NaN         NaN          NaN         NaN
Arachis_hypogaea                NaN         1.0          NaN         NaN
…                             …         …           …          …
Vicia_faba                      NaN         5.0          NaN         1.0
Vicia_faba_major                NaN         3.0          NaN         NaN
Vigna_unguiculata               NaN         2.0          NaN         NaN
```

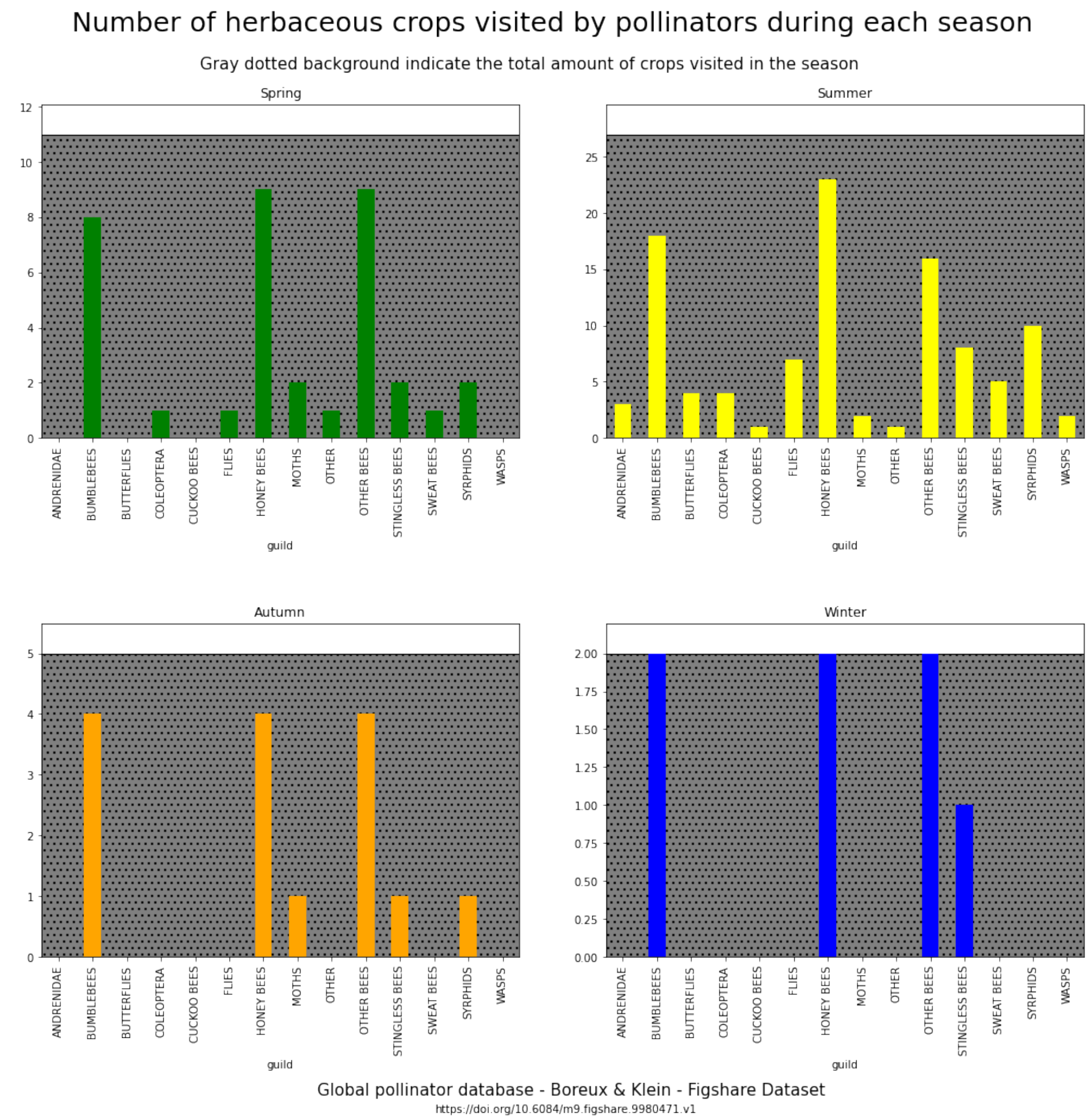
```
Vitis_vinifera                 NaN         NaN          NaN         2.0
Ziziphus_mauritiana            NaN         NaN          NaN         NaN

guild                   CUCKOO BEES  FLIES  HONEY BEES  MOTHS  OTHER  \
crop
Allium_cepa                     NaN    4.0         4.0    NaN    NaN
Allium_oleraceum                NaN    NaN         NaN    1.0    NaN
Amomum_subulatum                NaN    NaN         1.0    1.0    NaN
Anacardium_occidentale          NaN    NaN         4.0    NaN    NaN
Arachis_hypogaea                NaN    NaN         2.0    NaN    NaN
…                             …    …         …    …    …
Vicia_faba                      NaN    NaN         NaN    NaN    1.0
Vicia_faba_major                NaN    NaN         1.0    NaN    NaN
Vigna_unguiculata               NaN    1.0         1.0    NaN    NaN
Vitis_vinifera                  NaN    NaN         1.0    NaN    NaN
Ziziphus_mauritiana             NaN    1.0         3.0    NaN    NaN

guild                   OTHER BEES  STINGLESS BEES  SWEAT BEES  SYRPHIDS  \
crop
Allium_cepa                    3.0             NaN         NaN       4.0
Allium_oleraceum               NaN             NaN         NaN       4.0
Amomum_subulatum               1.0             NaN         NaN       1.0
Anacardium_occidentale         NaN             1.0         NaN       NaN
Arachis_hypogaea               6.0             1.0         1.0       NaN
…                            …             …         …       …
Vicia_faba                     2.0             NaN         NaN       NaN
Vicia_faba_major               1.0             NaN         NaN       NaN
Vigna_unguiculata              1.0             NaN         NaN       NaN
Vitis_vinifera                 NaN             NaN         NaN       3.0
Ziziphus_mauritiana            NaN             NaN         NaN       NaN

guild                   WASPS
crop
Allium_cepa               NaN
Allium_oleraceum          2.0
Amomum_subulatum          NaN
Anacardium_occidentale    NaN
Arachis_hypogaea          NaN
…                       …
Vicia_faba                NaN
Vicia_faba_major          NaN
Vigna_unguiculata         NaN
Vitis_vinifera            NaN
Ziziphus_mauritiana       NaN

[78 rows x 14 columns]
```

[697]:

```
arboreous_spring_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_spring_guild_crop_dataset
arboreous_summer_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_summer_guild_crop_dataset
arboreous_autumn_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_autumn_guild_crop_dataset
arboreous_winter_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_winter_guild_crop_dataset
arboreous_year_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            arboreous_year_guild_crop_dataset

herbaceous_spring_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_spring_guild_crop_dataset
herbaceous_summer_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_summer_guild_crop_dataset
herbaceous_autumn_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_autumn_guild_crop_dataset
herbaceous_winter_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_winter_guild_crop_dataset
herbaceous_year_guild_crop_dataset_full = year_guild_crop_dataset*0 + \
                                            herbaceous_year_guild_crop_dataset
```

[737]:

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.pyplot.subplots(2, 2, figsize=(15,15))

fig.suptitle('Number of herbaceous crops visited by pollinators during each␣
 ↪season', fontsize=25, y=0.95)
ax1.set_title('Spring')
ax2.set_title('Summer')
ax3.set_title('Autumn')
ax4.set_title('Winter')

total_spring_pollinated_crops = len(GPD_herbaceous_seasons_dataset_sp.loc[\
                                    GPD_herbaceous_seasons_dataset_sp['spring']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_summer_pollinated_crops = len(GPD_herbaceous_seasons_dataset_sp.loc[\
                                    GPD_herbaceous_seasons_dataset_sp['summer']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_autumn_pollinated_crops = len(GPD_herbaceous_seasons_dataset_sp.loc[\
                                    GPD_herbaceous_seasons_dataset_sp['autumn']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())
total_winter_pollinated_crops = len(GPD_herbaceous_seasons_dataset_sp.loc[\
                                    GPD_herbaceous_seasons_dataset_sp['winter']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
 ↪= False \
                                    ).unstack(level = 1).count())

ax1.set_ylim(ymax= total_spring_pollinated_crops +␣
 ↪total_spring_pollinated_crops/10 )
ax2.set_ylim(ymax= total_summer_pollinated_crops +␣
 ↪total_summer_pollinated_crops/10 )
ax3.set_ylim(ymax= total_autumn_pollinated_crops +␣
 ↪total_autumn_pollinated_crops/10 )
ax4.set_ylim(ymax= total_winter_pollinated_crops +␣
 ↪total_winter_pollinated_crops/10 )


bar_number = len(GPD_seasons_dataset_sp['guild'].unique().to_list())

width = 0.10

plt.pyplot.axes(ax1)
plt.pyplot.bar((bar_number-1)/2, total_spring_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_spring_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax1,␣
 ↪color = 'green')

plt.pyplot.axes(ax2)
plt.pyplot.bar((bar_number-1)/2, total_summer_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_summer_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax2,␣
 ↪color = 'yellow')

plt.pyplot.axes(ax3)
plt.pyplot.bar((bar_number-1)/2, total_autumn_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_autumn_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax3,␣
 ↪color = 'orange')

plt.pyplot.axes(ax4)
plt.pyplot.bar((bar_number-1)/2, total_winter_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
herbaceous_winter_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax4,␣
 ↪color = 'blue')

#plt.pyplot.legend()


fig.text(0.20, 0.90, 'Gray dotted background indicate the total amount of crops␣
 ↪visited in the season',\
         fontsize=15)

fig.text(0.30, 0.025, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
fig.text(0.40, 0.01, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)

fig.tight_layout(pad=5)
#plt.pyplot.margins(2000)


plt.pyplot.savefig('Images/Seasonal herbaceous plants for pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Seasonal herbaceous plants for pollinators.jpg',␣
 ↪dpi=150)


plt.pyplot.show()
```



Number of herbaceous crops visited by pollinators during each season

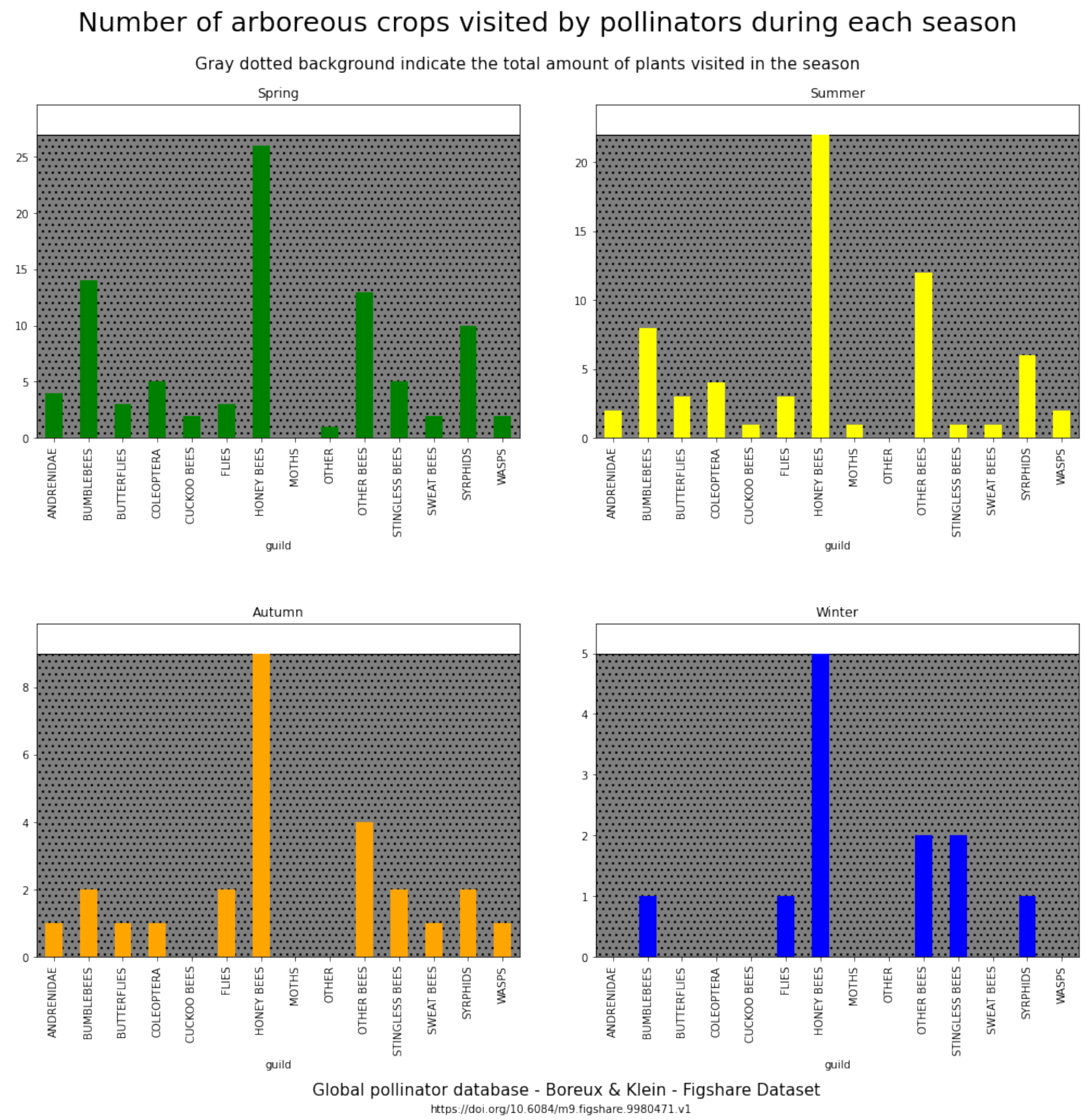
Gray dotted background indicate the total amount of crops visited in the season

Global pollinator database - Boreux & Klein - Figshare Dataset
https://doi.org/10.6084/m9.figshare.9980471.v1

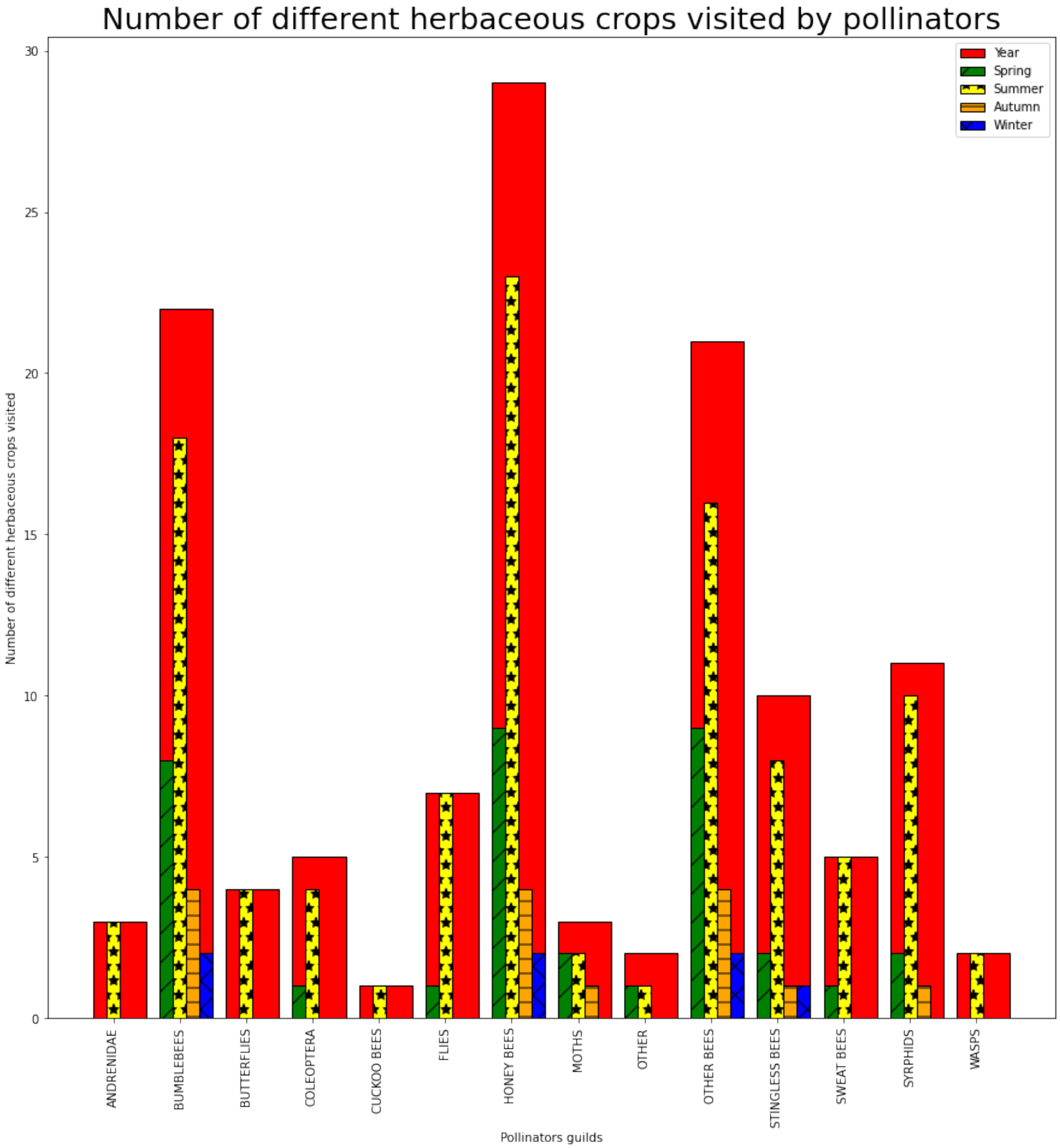
[738]:

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.pyplot.subplots(2, 2, figsize=(15,15))

fig.suptitle('Number of arboreous crops visited by pollinators during each␣
 ↪season', fontsize=25, y=0.95)
ax1.set_title('Spring')
ax2.set_title('Summer')
ax3.set_title('Autumn')
ax4.set_title('Winter')

total_spring_pollinated_crops = len(GPD_arboreous_seasons_dataset_sp.loc[\
                                    GPD_arboreous_seasons_dataset_sp['spring']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_summer_pollinated_crops = len(GPD_arboreous_seasons_dataset_sp.loc[\
                                    GPD_arboreous_seasons_dataset_sp['summer']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_autumn_pollinated_crops = len(GPD_arboreous_seasons_dataset_sp.loc[\
                                    GPD_arboreous_seasons_dataset_sp['autumn']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())
total_winter_pollinated_crops = len(GPD_arboreous_seasons_dataset_sp.loc[\
                                    GPD_arboreous_seasons_dataset_sp['winter']\
                                    == 1, ['guild', 'crop']].value_counts(sort␣
  ↪= False \
                                    ).unstack(level = 1).count())

ax1.set_ylim(ymax= total_spring_pollinated_crops +␣
  ↪total_spring_pollinated_crops/10 )
ax2.set_ylim(ymax= total_summer_pollinated_crops +␣
  ↪total_summer_pollinated_crops/10 )
ax3.set_ylim(ymax= total_autumn_pollinated_crops +␣
  ↪total_autumn_pollinated_crops/10 )
ax4.set_ylim(ymax= total_winter_pollinated_crops +␣
  ↪total_winter_pollinated_crops/10 )


bar_number = len(GPD_seasons_dataset['guild'].unique().to_list())

width = 0.10

plt.pyplot.axes(ax1)
plt.pyplot.bar((bar_number-1)/2, total_spring_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
  ↪label='Total',\
               hatch='..')
arboreous_spring_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax1,␣
  ↪color = 'green')

plt.pyplot.axes(ax2)
plt.pyplot.bar((bar_number-1)/2, total_summer_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
  ↪label='Total',\
               hatch='..')
```

```
arboreous_summer_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax2,␣
 ↪color = 'yellow')

plt.pyplot.axes(ax3)
plt.pyplot.bar((bar_number-1)/2, total_autumn_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_autumn_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax3,␣
 ↪color = 'orange')

plt.pyplot.axes(ax4)
plt.pyplot.bar((bar_number-1)/2, total_winter_pollinated_crops, \
               color = 'gray', width = bar_number, edgecolor = 'black',␣
 ↪label='Total',\
               hatch='..')
arboreous_winter_guild_crop_dataset_full.count().plot(kind = 'bar', ax=ax4,␣
 ↪color = 'blue')

#plt.pyplot.legend()


fig.text(0.20, 0.90, 'Gray dotted background indicate the total amount of␣
 ↪plants visited in the season',\
         fontsize=15)

fig.text(0.30, 0.025, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
fig.text(0.40, 0.01, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)

fig.tight_layout(pad=5)
#plt.pyplot.margins(2000)


plt.pyplot.savefig('Images/Seasonal arboreous plants for pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Seasonal arboreous plants for pollinators.jpg',␣
 ↪dpi=150)


plt.pyplot.show()
```



[759]:
```
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset_sp['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.20

plt.pyplot.bar(x_range + 1.5*width, herbaceous_year_guild_crop_dataset_full.
  ↪count(), \
                color = 'red', width = 4*width, edgecolor = 'black',␣
  ↪label='Year')
plt.pyplot.bar(x_range , herbaceous_spring_guild_crop_dataset_full.count(), \
               color = 'green', width = width, edgecolor = 'black', hatch='/',␣
 ↪label='Spring')
plt.pyplot.bar(x_range + width, herbaceous_summer_guild_crop_dataset_full.
 ↪count(),\
               color = 'yellow', width = width, edgecolor = 'black', hatch=␣
 ↪'*', label='Summer')
plt.pyplot.bar(x_range + 2*width, herbaceous_autumn_guild_crop_dataset_full.
 ↪count(), color = 'orange',
        width = width, edgecolor = 'black', hatch='-', label='Autumn')
plt.pyplot.bar(x_range +  3*width, herbaceous_winter_guild_crop_dataset_full.
 ↪count(), color = 'blue',
        width = width, edgecolor = 'black', hatch='x', label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of different herbaceous crops visited")
plt.pyplot.title("Number of different herbaceous crops visited by pollinators",␣
 ↪fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset_sp['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.text(3, -6, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
plt.pyplot.text(5, -7.5, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)


plt.pyplot.savefig('Images/Herbaceous plants visited by pollinators.png',␣
 ↪dpi=150)
plt.pyplot.savefig('Images/Herbaceous plants visited by pollinators.jpg',␣
 ↪dpi=150)


plt.pyplot.show()
```



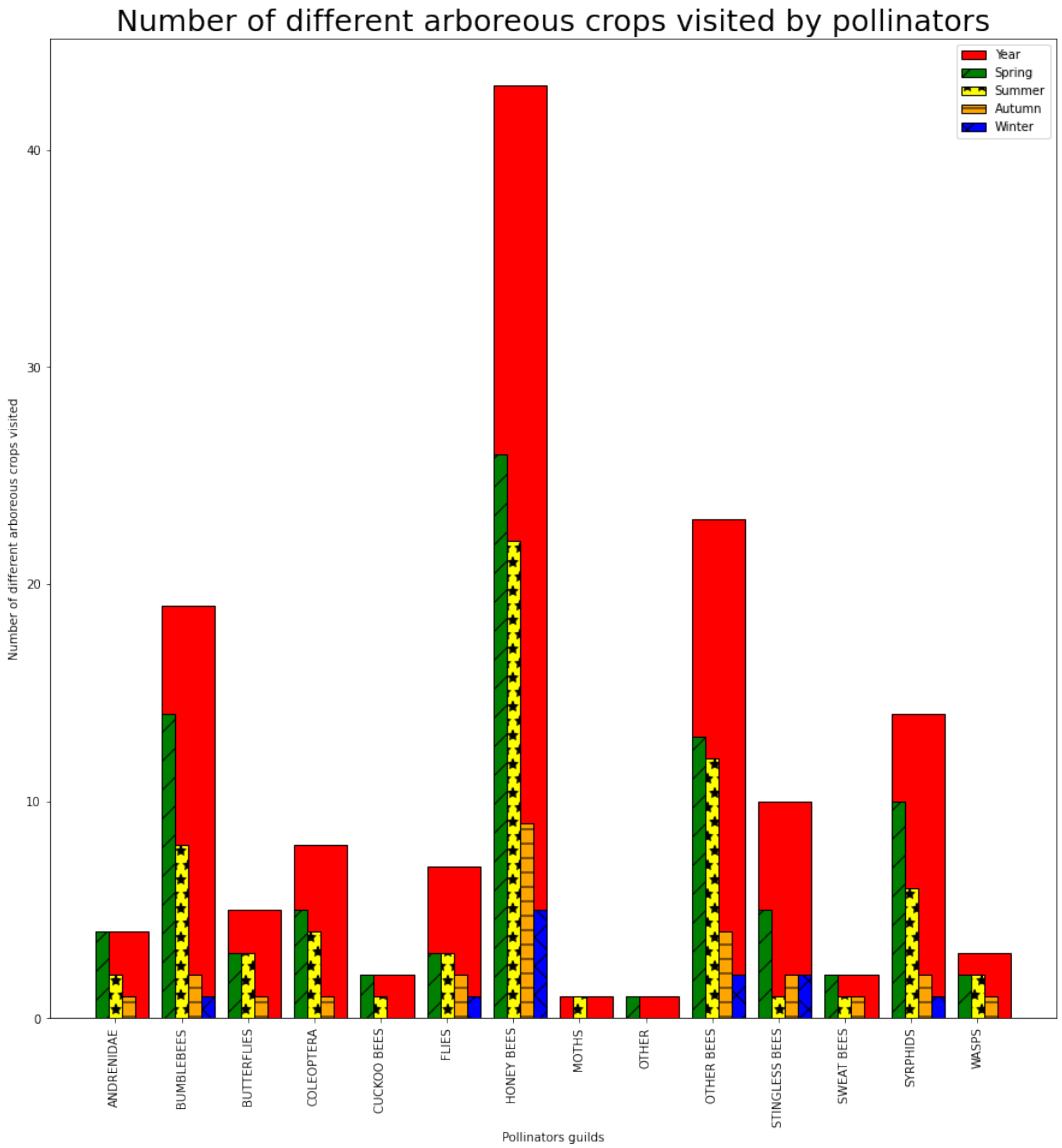
Global pollinator database - Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

[761]:

```
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset_sp['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.20
```

```
plt.pyplot.bar(x_range + 1.5*width, arboreous_year_guild_crop_dataset_full.
  ↪count(), \
               color = 'red', width = 4*width, edgecolor = 'black',␣
  ↪label='Year')
plt.pyplot.bar(x_range , arboreous_spring_guild_crop_dataset_full.count(), \
               color = 'green', width = width, edgecolor = 'black', hatch='/',␣
  ↪label='Spring')
plt.pyplot.bar(x_range + width, arboreous_summer_guild_crop_dataset_full.
  ↪count(), \
               color = 'yellow', width = width, edgecolor = 'black', hatch=␣
  ↪'*', label='Summer')
plt.pyplot.bar(x_range + 2*width, arboreous_autumn_guild_crop_dataset_full.
  ↪count(), \
               color = 'orange', width = width, edgecolor = 'black', hatch='-',␣
  ↪label='Autumn')
plt.pyplot.bar(x_range +  3*width, arboreous_winter_guild_crop_dataset_full.
  ↪count(), \
               color = 'blue', width = width, edgecolor = 'black', hatch='x',␣
  ↪label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of different arboreous crops visited")
plt.pyplot.title("Number of different arboreous crops visited by pollinators",␣
  ↪fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset_sp['guild'].unique().
  ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.text(3, -7, 'Global pollinator database - Boreux & Klein - Figshare␣
  ↪Dataset',\
         fontsize=15)
plt.pyplot.text(5, -8.5, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
  ↪fontsize=10)

plt.pyplot.savefig('Images/Arboreous plants visited by pollinators.png',␣
  ↪dpi=150)
plt.pyplot.savefig('Images/Arboreous plants visited by pollinators.jpg',␣
  ↪dpi=150)


plt.pyplot.show()
```

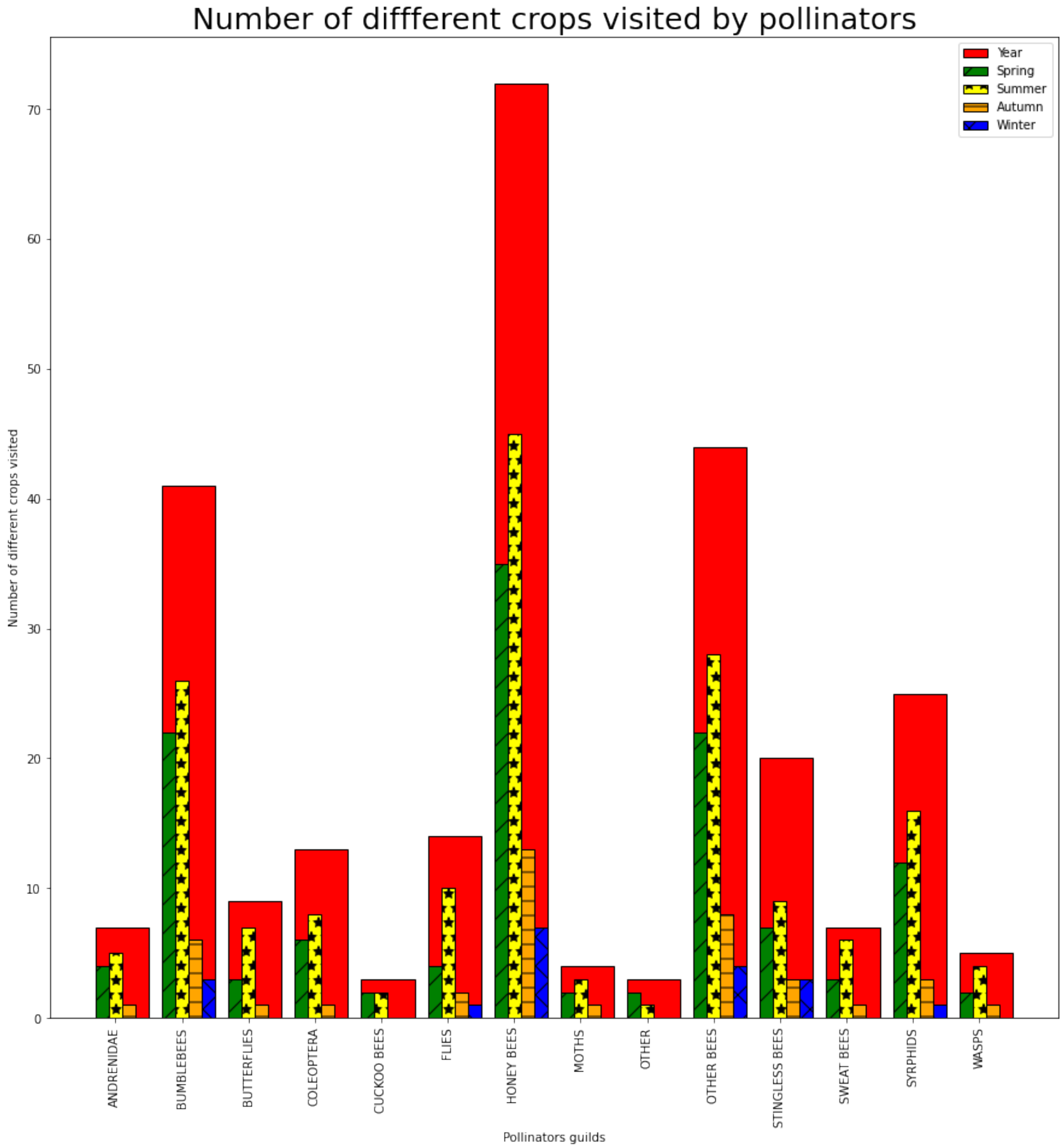


Global pollinator database - Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1

[756]:

```
plt.pyplot.figure(figsize=(15,15))

bar_number = len(GPD_seasons_dataset_sp['guild'].unique().to_list())
x_range = np.arange(bar_number)
width = 0.20

plt.pyplot.bar(x_range + 1.5*width, year_guild_crop_dataset.count(), color =␣
  ↪'red',
        width = 4*width, edgecolor = 'black', label='Year')
plt.pyplot.bar(x_range , spring_guild_crop_dataset.count(), color = 'green',
        width = width, edgecolor = 'black', hatch='/', label='Spring')
plt.pyplot.bar(x_range + width, summer_guild_crop_dataset.count(), color =␣
 ↪'yellow',
        width = width, edgecolor = 'black', hatch= '*', label='Summer')
plt.pyplot.bar(x_range + 2*width, autumn_guild_crop_dataset_full.count(), color␣
 ↪= 'orange',
        width = width, edgecolor = 'black', hatch='-', label='Autumn')
plt.pyplot.bar(x_range +  3*width, winter_guild_crop_dataset_full.count(),␣
 ↪color = 'blue',
        width = width, edgecolor = 'black', hatch='x', label='Winter')


plt.pyplot.xlabel("Pollinators guilds")
plt.pyplot.ylabel("Number of different crops visited")
plt.pyplot.title("Number of diffferent crops visited by pollinators",␣
 ↪fontsize=25)

plt.pyplot.xticks(x_range + width, GPD_seasons_dataset_sp['guild'].unique().
 ↪to_list(), \
                 rotation = 'vertical')
plt.pyplot.legend()

#fig.tight_layout()

plt.pyplot.text(3, -12, 'Global pollinator database - Boreux & Klein - Figshare␣
 ↪Dataset',\
         fontsize=15)
plt.pyplot.text(5, -13.5, 'https://doi.org/10.6084/m9.figshare.9980471.v1',␣
 ↪fontsize=10)


plt.pyplot.savefig('Images/Plants visited by pollinators.png', dpi=150)
plt.pyplot.savefig('Images/Plants visited by pollinators.jpg', dpi=150)


plt.pyplot.show()
```



Global pollinator database - Boreux & Klein - Figshare Dataset

https://doi.org/10.6084/m9.figshare.9980471.v1