exercises-pollinators-datasets-exploration

April 10, 2022

1 Exercises - Pollinators datasets exploration

Exercises with some pollinators datasets.

1.1 Packages import

[420]:
```
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
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)

[6]:
```python
# 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]:
```python
# 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]:
```
imput_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

[15]:
```
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

[62]:
```
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
```

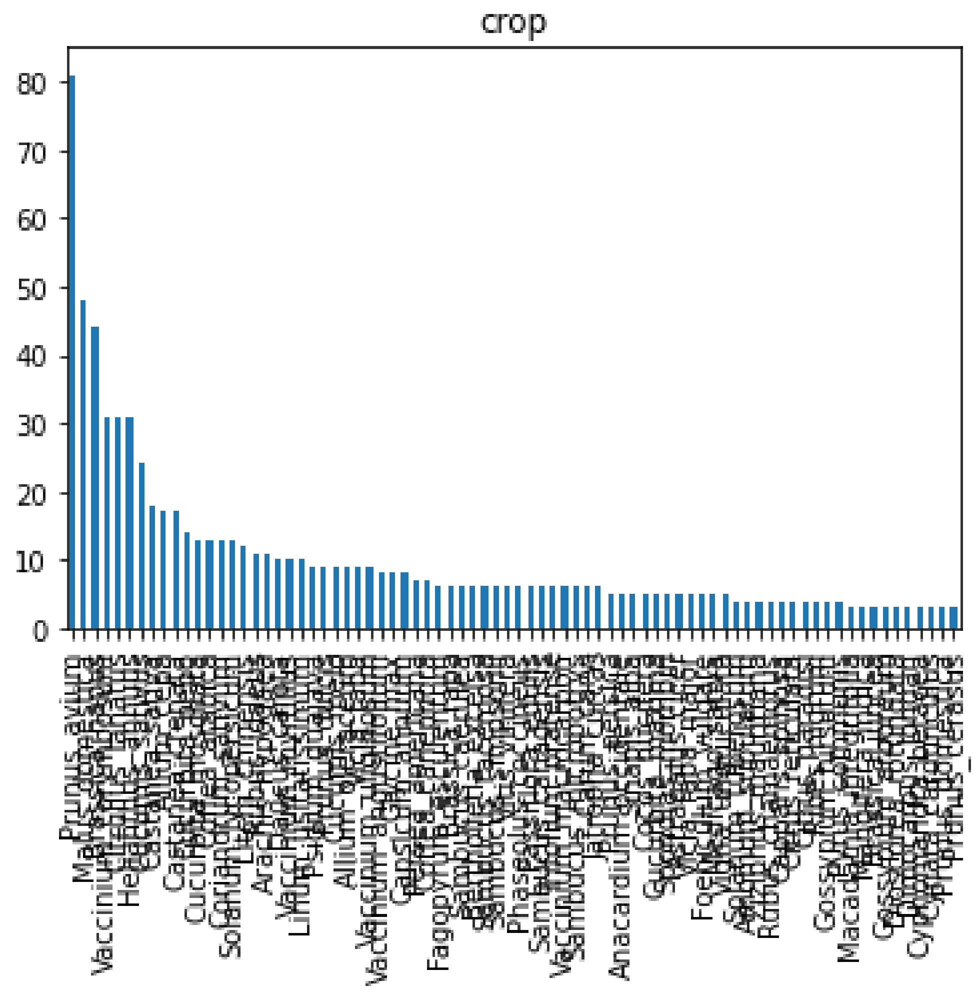
[67]:
```
crop                category
type                category
season              category
corolla             category
colour              category
nectar              category
b.system            category
s.pollination       category
inflorescence       category
composite           category
visitor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

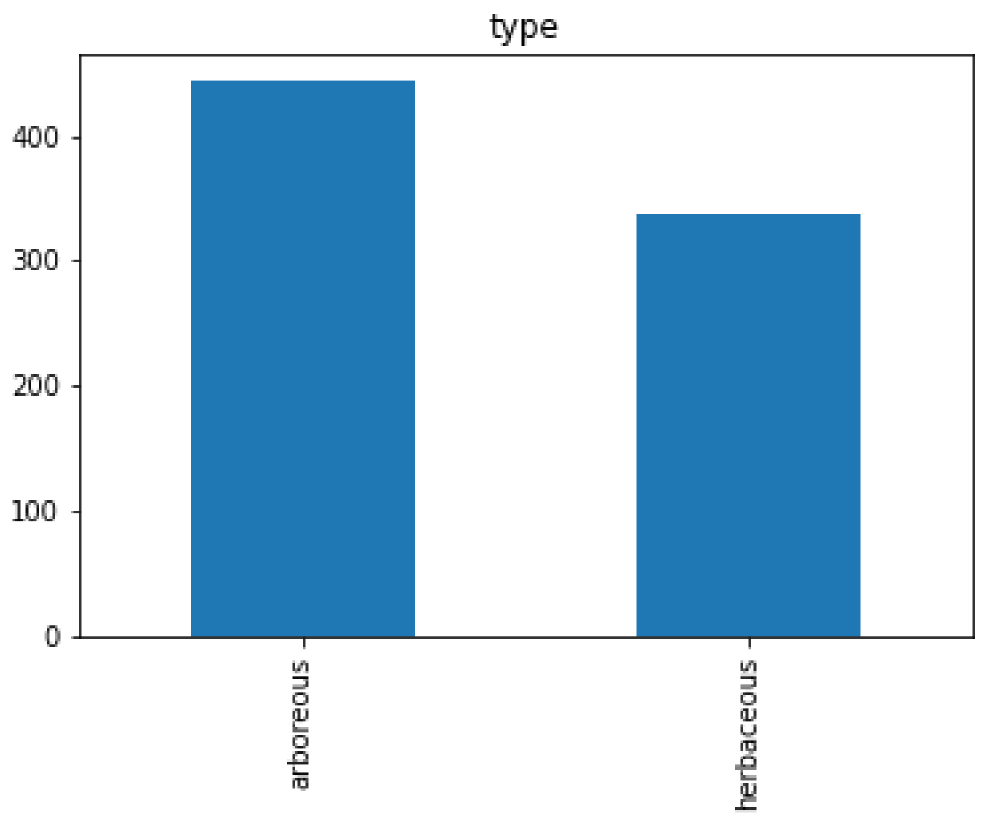
[66]:
```
GPD_dataset_subset2_0NaN.describe
```

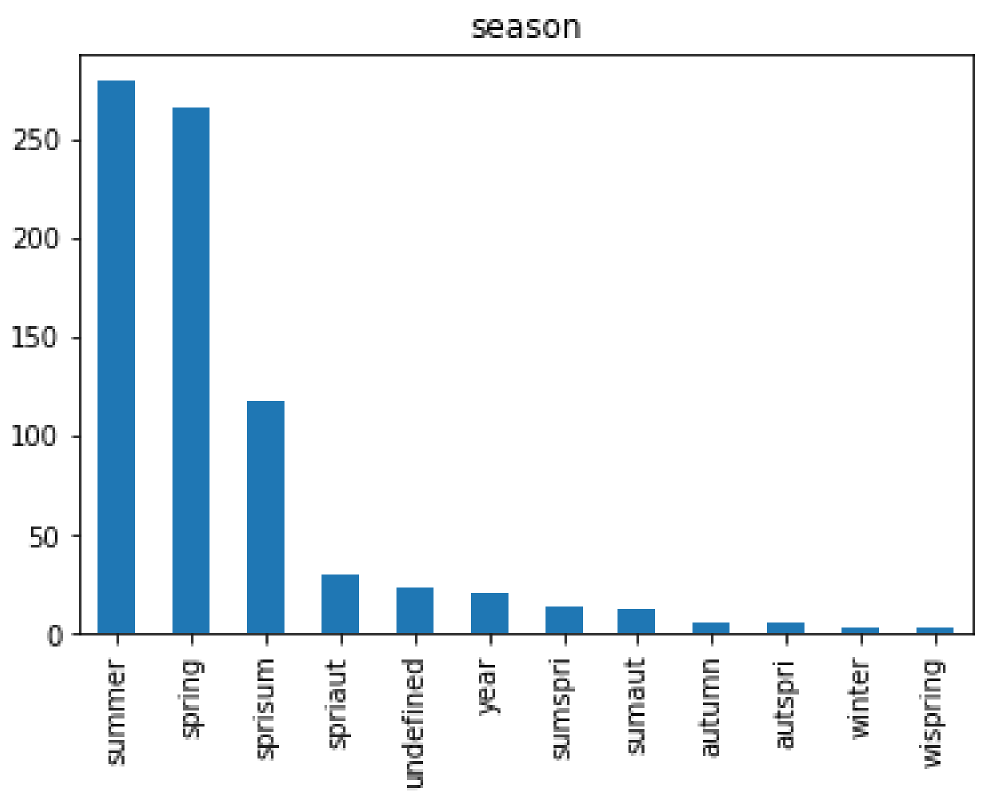
[66]:
```
<bound method NDFrame.describe of                       crop        type   season
corolla  colour nectar  \
0    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
1    Vaccinium_corymbosum   arboreous  sprisum  CAMPANULATE   white    yes
2           Brassica_napus  herbaceous   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
..            …            …            …        …
```

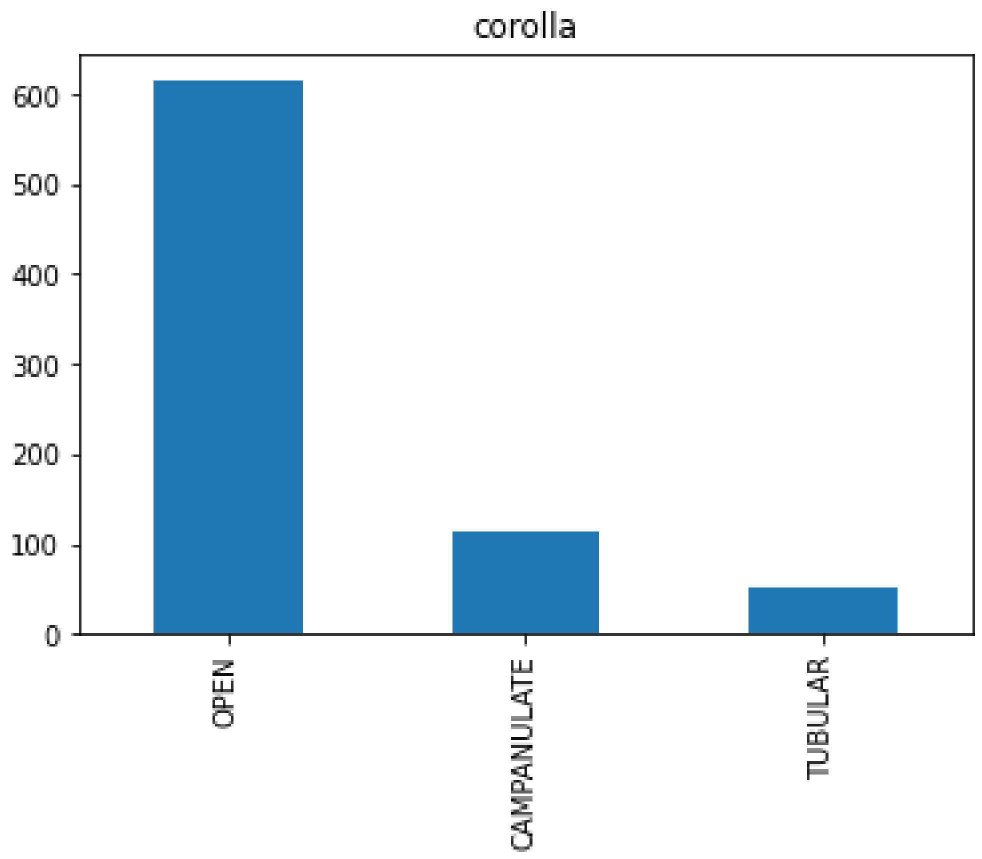
```
774       insects           no          yes        no
775       insects           no          yes        no
776       insects           no          yes        no
777       insects           no          yes        no
778       insects           no     solitary        no

                      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]>
```

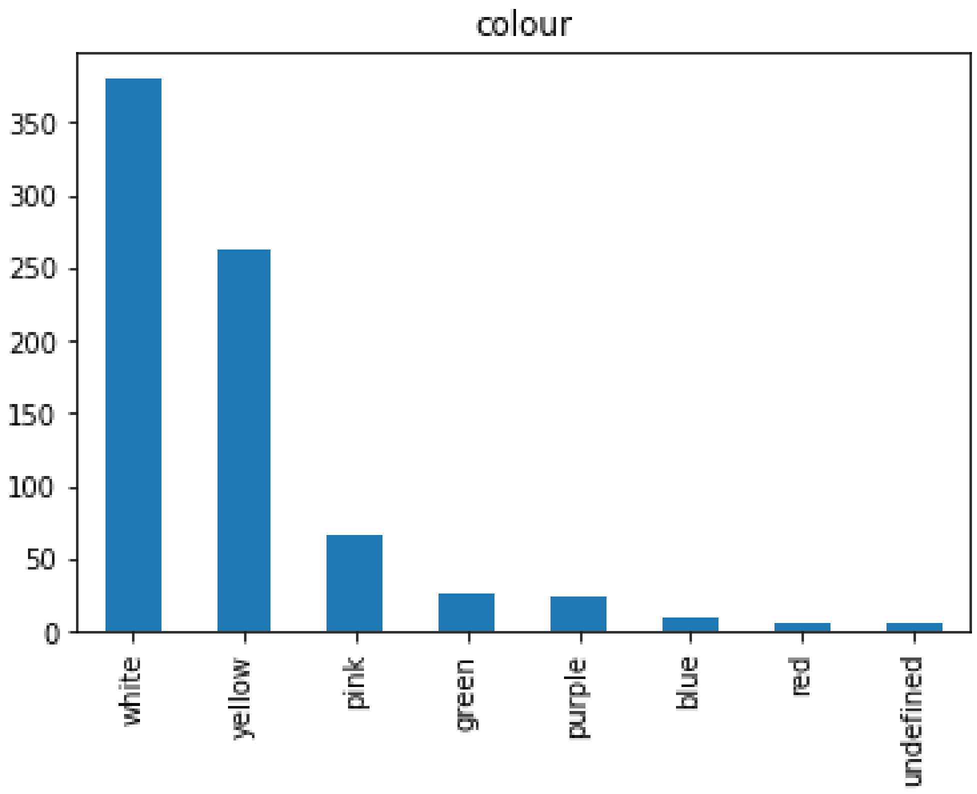
[68]:
```
for column in GPD_dataset_subset2_0NaN.columns.tolist():
    plt.pyplot.figure()
    plt.pyplot.title(column)
    GPD_dataset_subset2_0NaN[column].value_counts().plot(kind = 'bar')
```

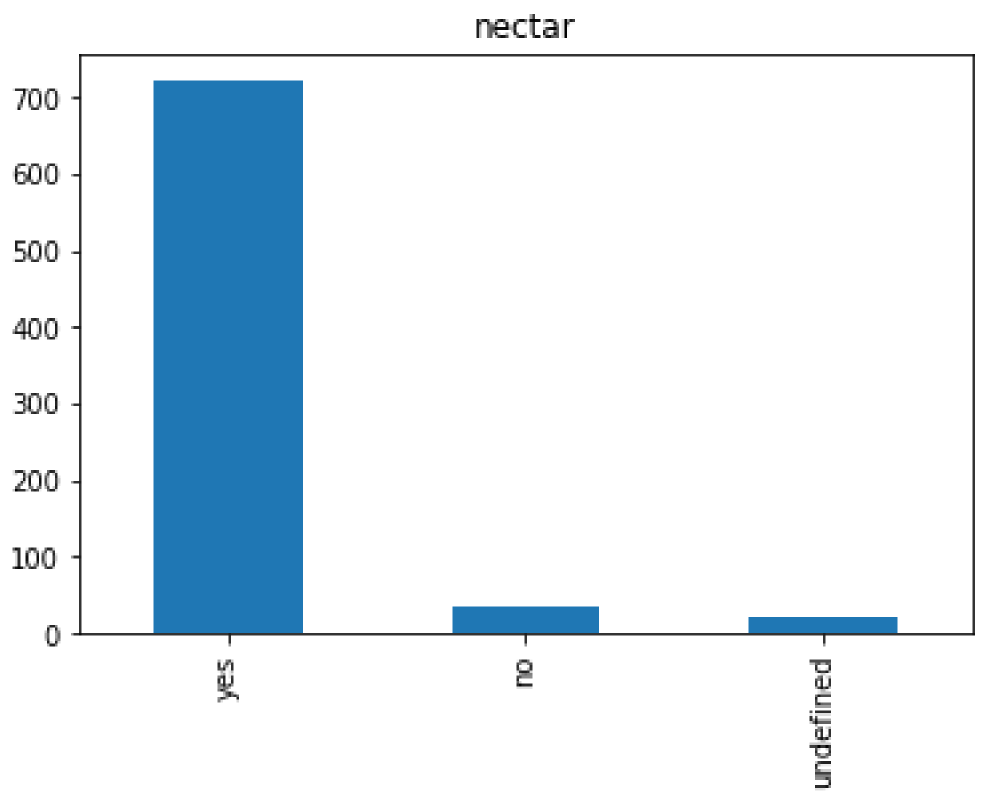

crop
80
70
60
50
40
30
20
10
0
Prunus_avium
Malus
Vaccinium
Helianthus
Cucurbita
Solanum
Arachis
Linum
Allium
Vaccinium
Capsicum
Fagopyrum
Phaseolus
Sambucus
Anacardium
Gossypium
Macadamia
Cynara
Prunus_cerasus

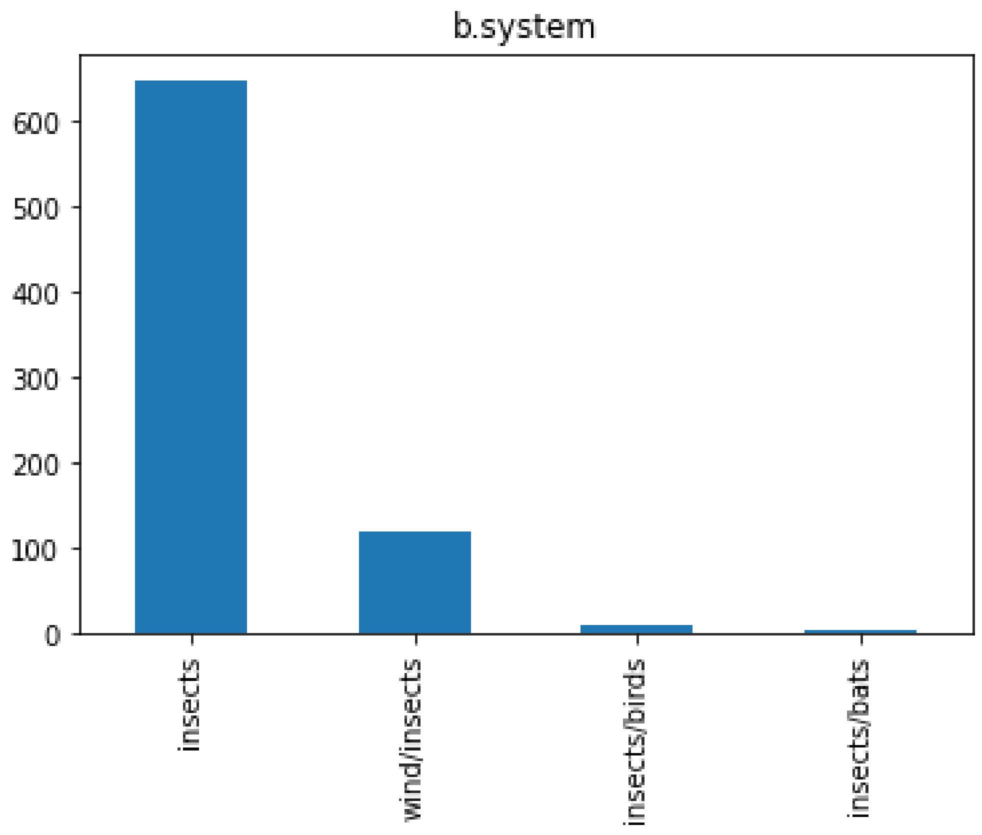

type
400
300
200
100
0
arboreous
herbaceous

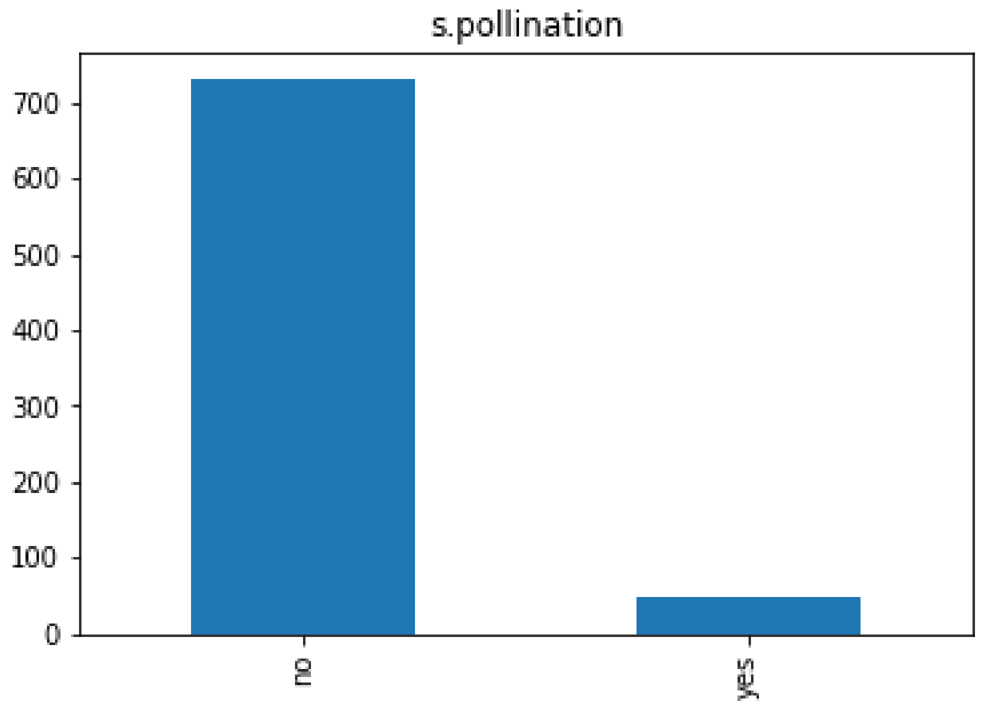

season
0
50
100
150
200
250
summer
spring
sprisum
spriaut
undefined
year
sumspri
sumaut
autumn
autspri
winter
wispring

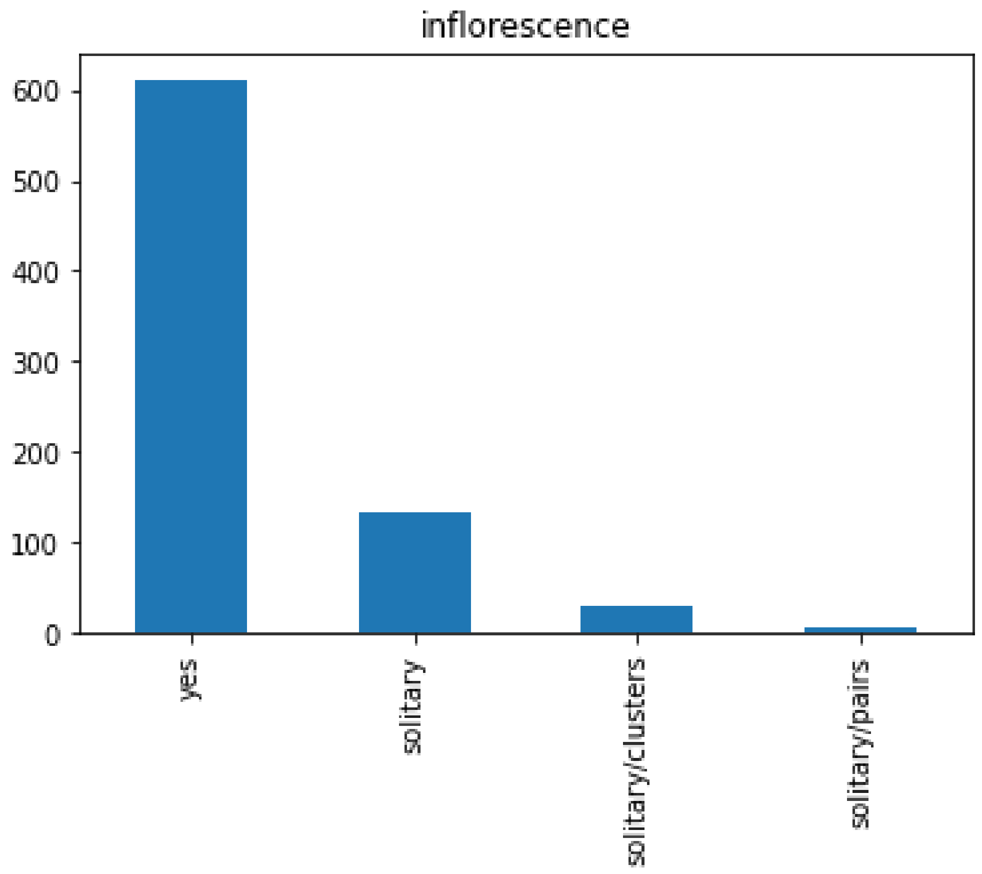

corolla
600
500
400
300
200
100
0
OPEN
CAMPANULATE
TUBULAR

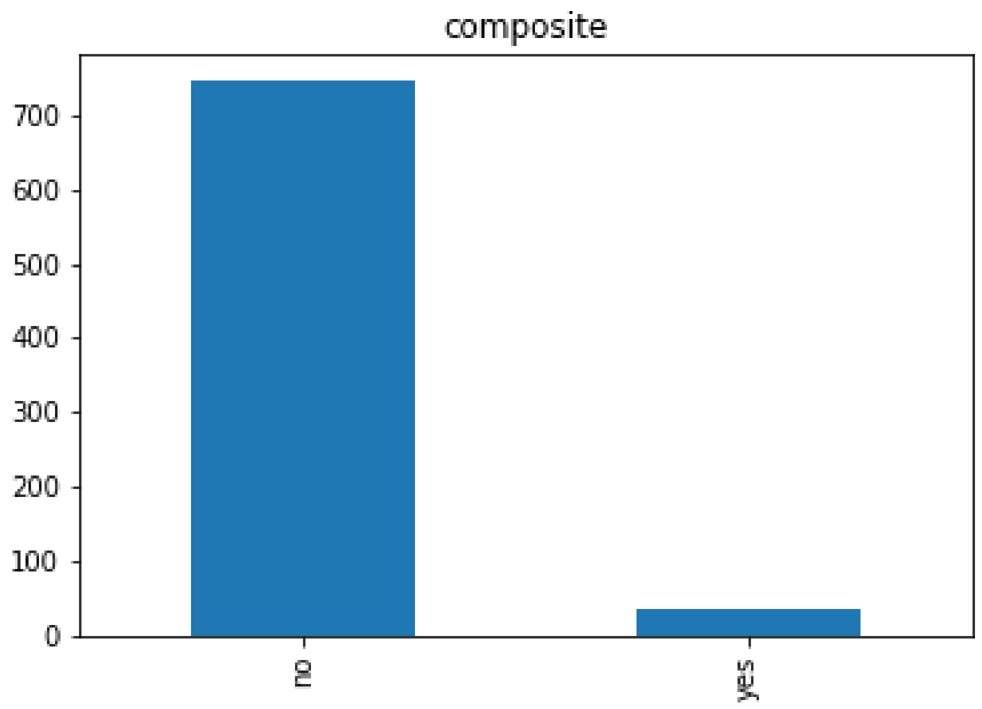

colour
0
50
100
150
200
250
300
350
white
yellow
pink
green
purple
blue
red
undefined

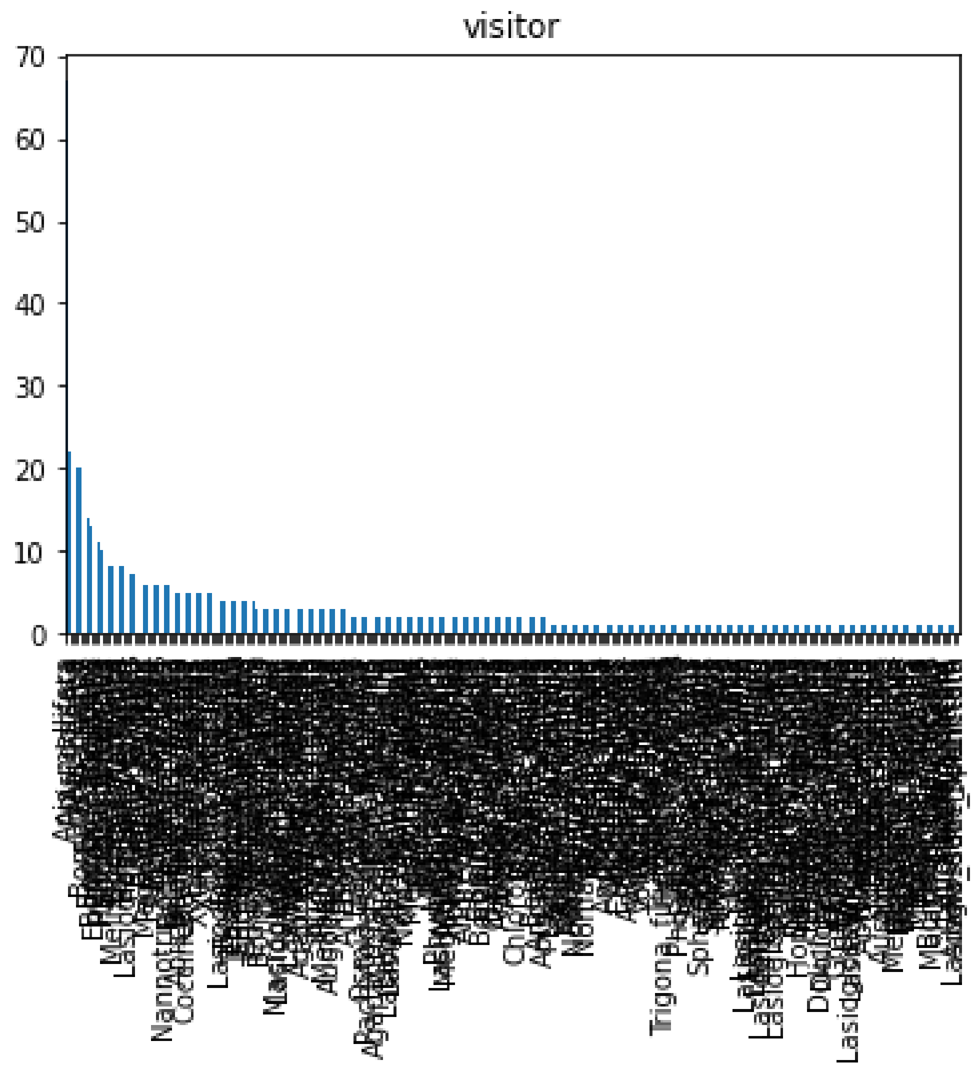

nectar
700
600
500
400
300
200
100
0
yes
no
undefined

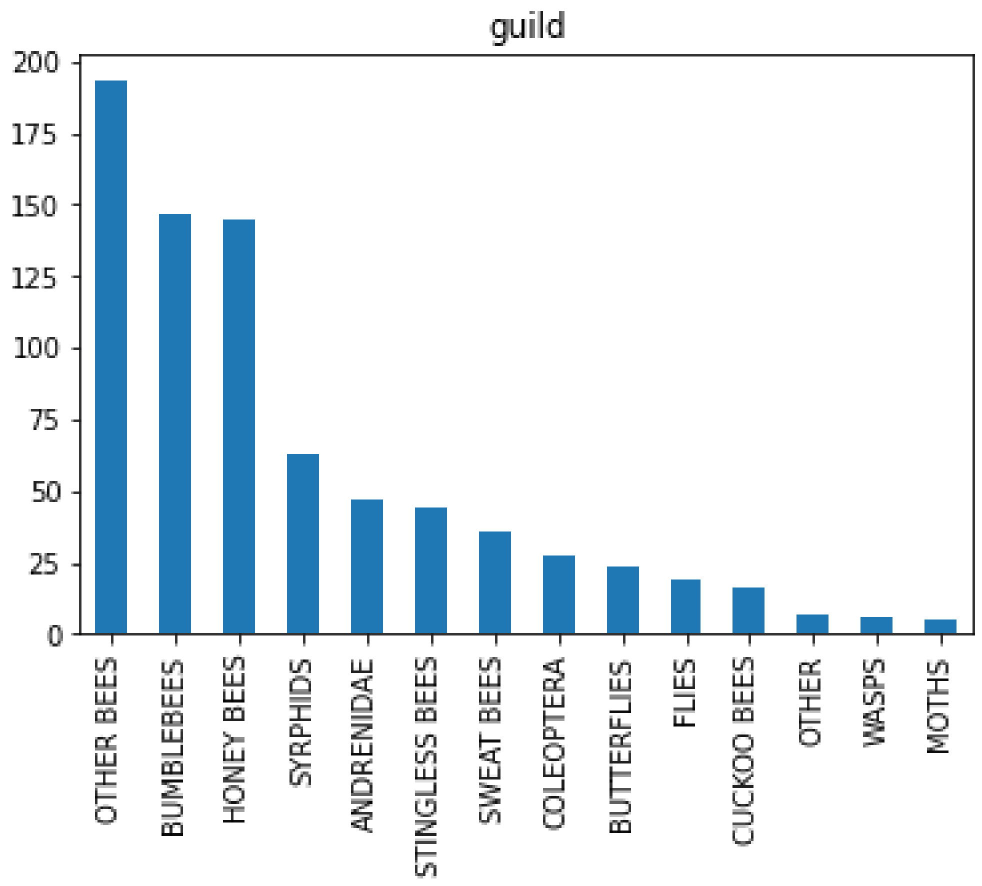

b.system
0
100
200
300
400
500
600
insects
wind/insects
insects/birds
insects/bats

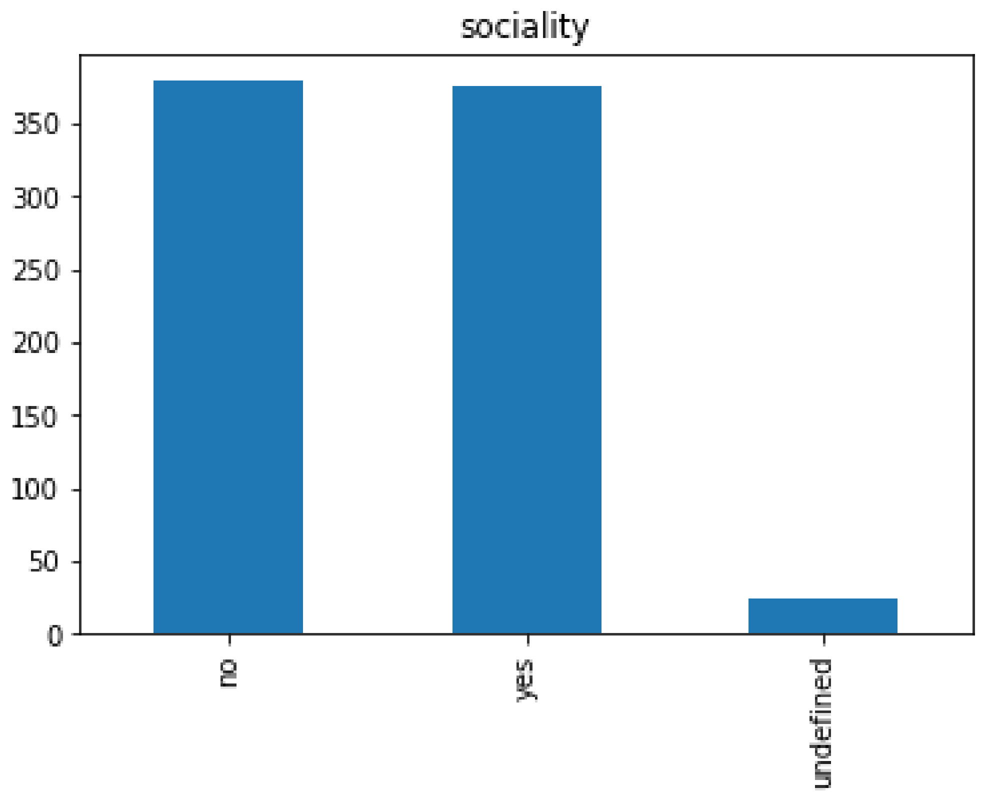

s.pollination
0
100
200
300
400
500
600
700
no
yes

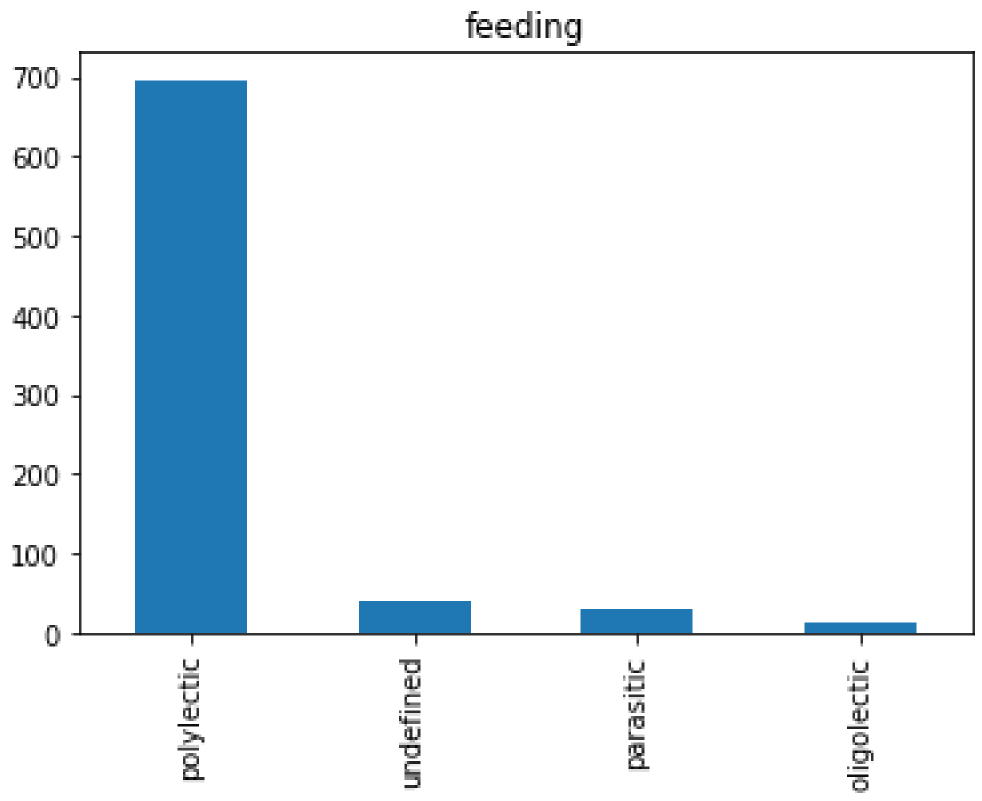

inflorescence
600
500
400
300
200
100
0
yes
solitary
solitary/clusters
solitary/pairs


composite
700
600
500
400
300
200
100
0
no
yes


visitor
70
60
50
40
30
20
10
0


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
350
300
250
200
150
100
50
0
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.').

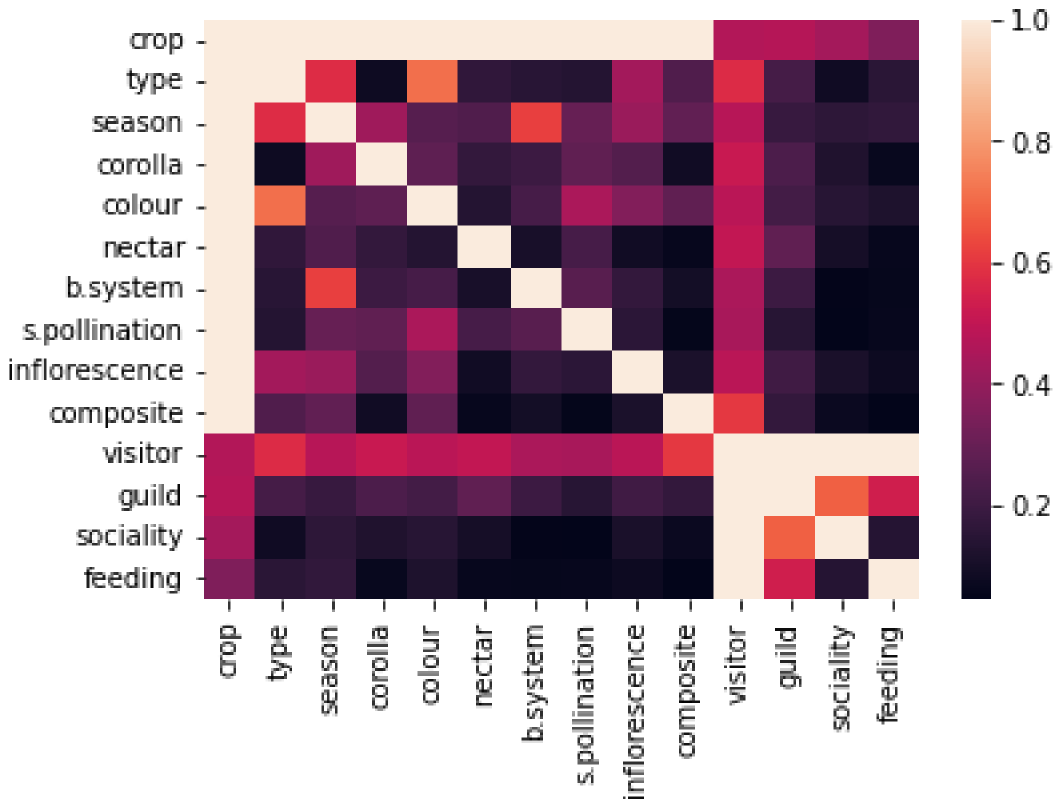
For the moment let's apply Cramer's V in a future we will improve the implementation with the bias correction.

[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:>
```

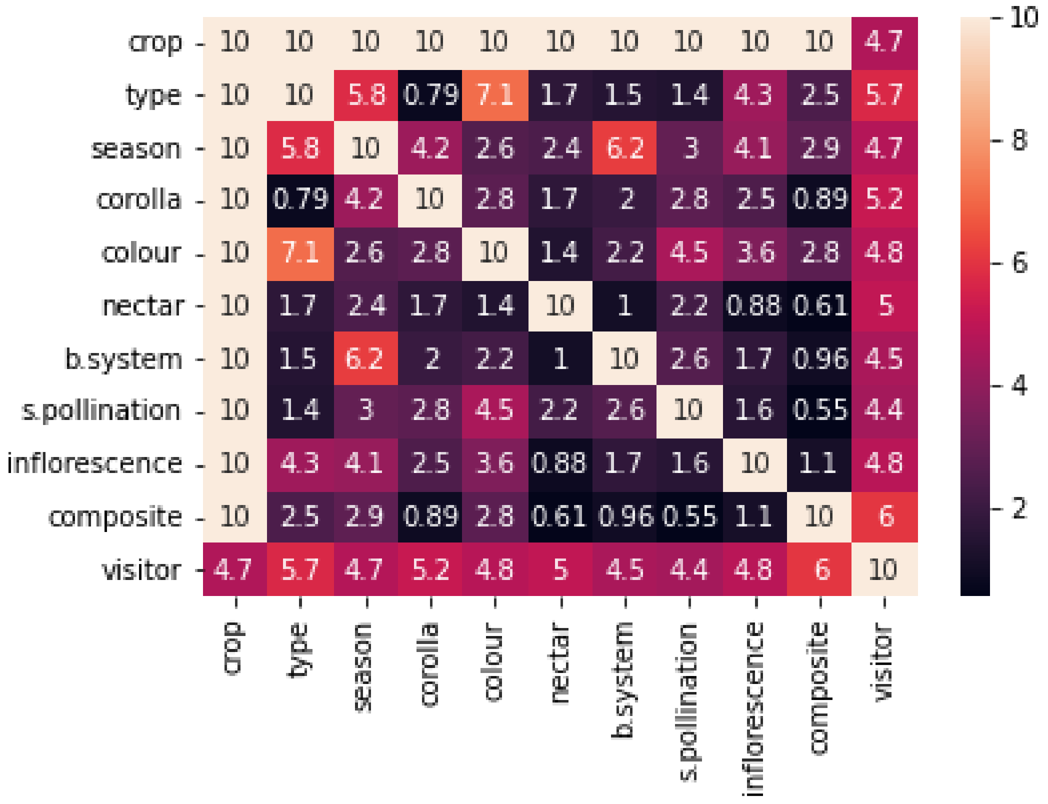


As we could expect whe have an evident separation of correlation between plants and bees where the crop is higly coreelated with the information about the plants charateristics; the guild is higly related with the pollintators charateristics and the "visitor" variable is the link between the two groups.

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:>
```

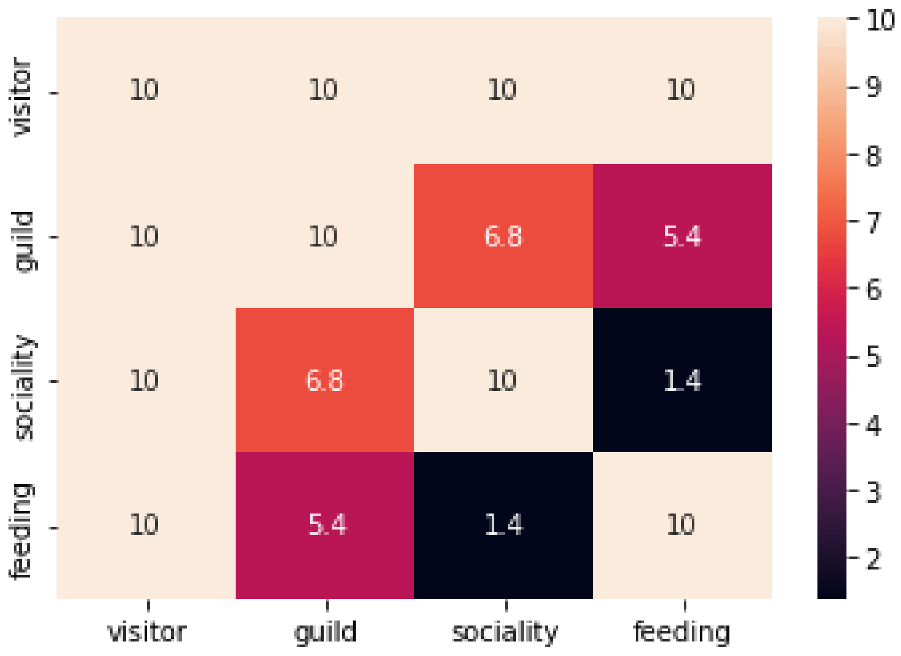


We can see that type (arboreous or heraceous) seems higly related to the flower colour and also quite related with the season.

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
```

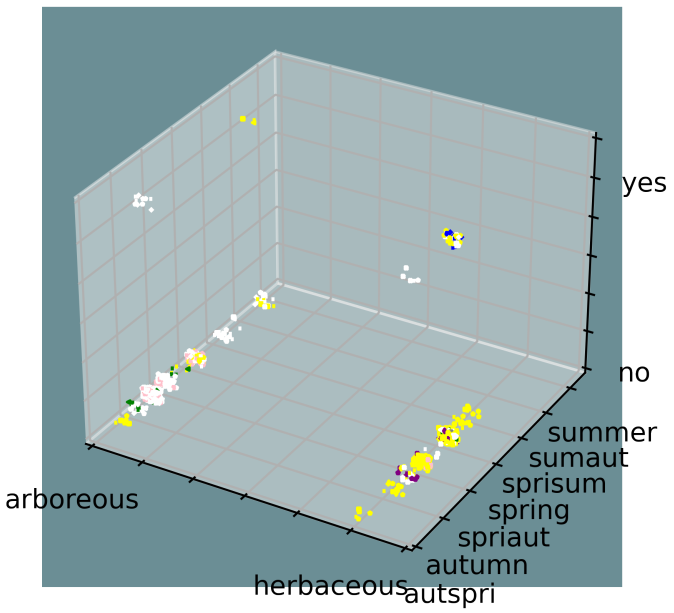
```
[669]: GPD_dataset_subset2_0NaN_T.describe
```

```
[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
```

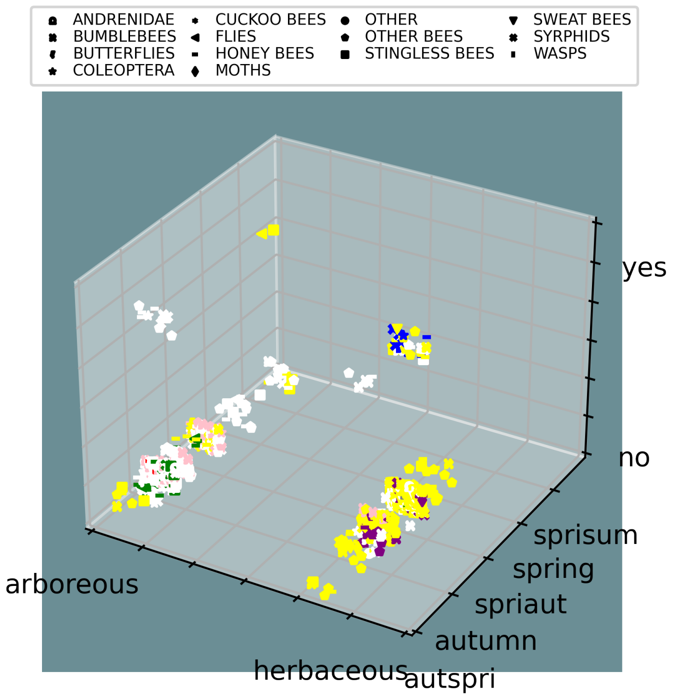


we need more space between season and bigger symbols

[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
```

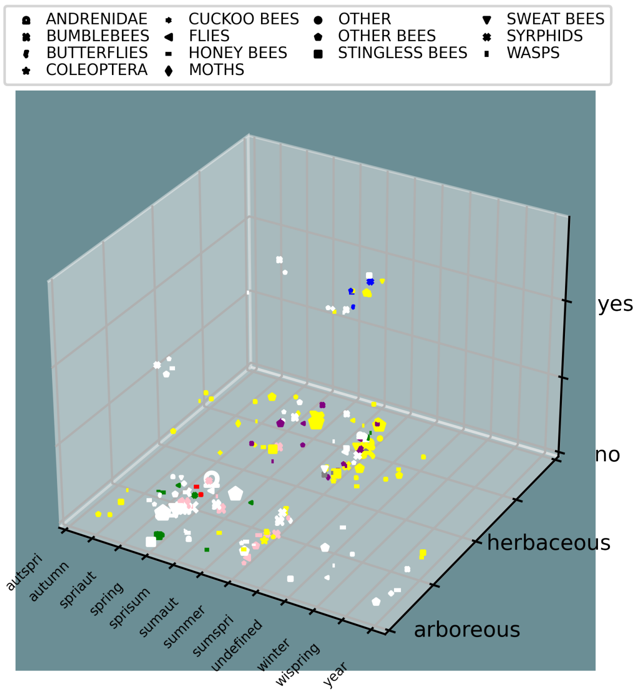
```
[734]: GPD_dataset_subset2_0NaN_T_colour.value_counts()
```

```
[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()
```



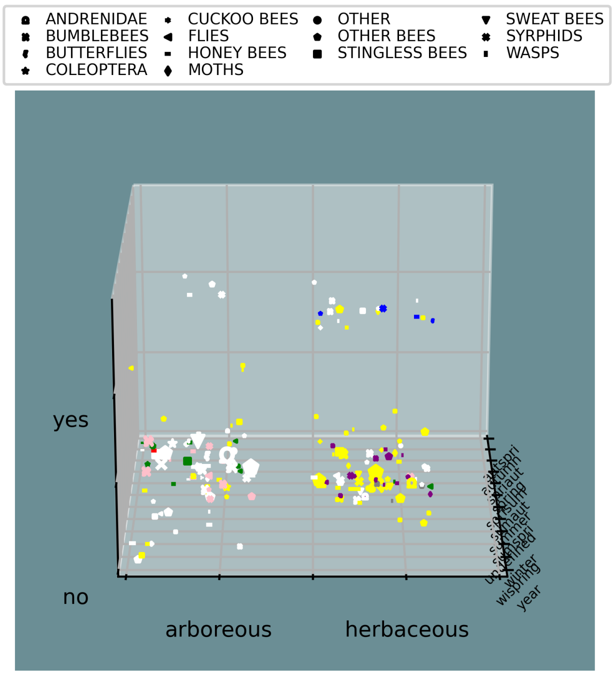
```
[764]: for i in type_encoder.inverse_transform([0,1]):
           print(i)
           print(type_encoder.transform([i])+3)
           print(guild_mark_encoder.inverse_transform(type_encoder.transform([i])+3))
```

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

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

[673]:
```
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
anim.save('Images/GPD_subset_exploration.gif', dpi=180, writer='imagemagick',␣
 ↪fps=8)
```



[ ]:
```

```

[675]:
```
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")
```

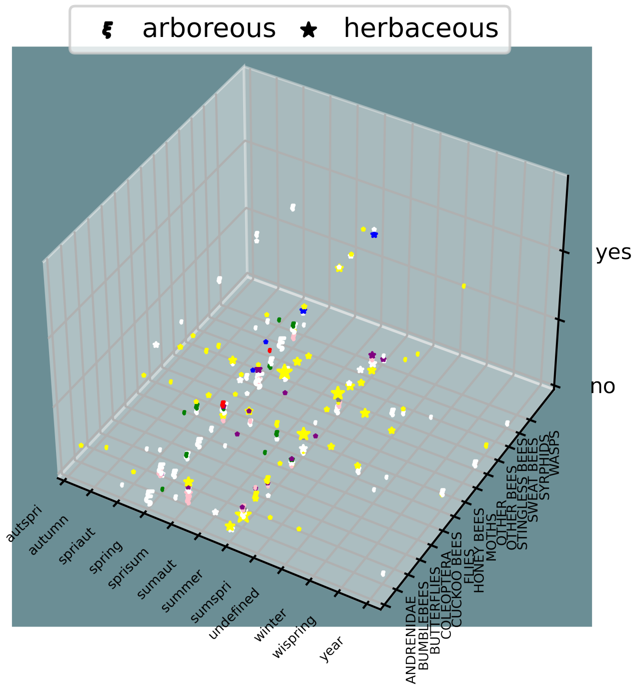
Slower version

[ ]:
```
#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
     anim.save('Images/GPD_subset_exploration_2_slow.gif', dpi=150,␣
      ↪writer='imagemagick', fps=6)
```

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