ML project

October 7, 2025

[1]:
```python
import pandas as pd
#read the dataset
data = pd.read_csv('cats_dataset.csv')
```

[2]:
```python
#Show 5 first samples
data.head()
```

[2]:
```
               Breed  Age (Years)  Weight (kg)          Color  Gender
0       Russian Blue           19            7  Tortoiseshell  Female
1  Norwegian Forest           19            9  Tortoiseshell  Female
2          Chartreux            3            3          Brown  Female
3            Persian           13            6          Sable  Female
4            Ragdoll           10            8          Tabby    Male
```

[3]:
```python
#The distributions of features age and weight
data[["Age (Years)", "Weight (kg)"]].describe()
```

[3]:
```
       Age (Years)  Weight (kg)
count  1000.000000   1000.00000
mean     10.210000      5.55000
std       5.535751      2.22676
min       1.000000      2.00000
25%       5.000000      4.00000
50%      10.000000      6.00000
75%      15.000000      7.00000
max      19.000000      9.00000
```

[4]:
```python
#Value counts of the labels
data["Breed"].value_counts()
```

[4]:
```
Breed
Ragdoll              51
American Shorthair   40
Egyptian Mau         39
Persian              37
Oriental             37
British Shorthair    36
Burmese              36
```

```
Balinese             35
Bengal               35
Siberian             34
Birman               33
Manx                 33
Maine Coon           33
Abyssinian           33
Ocicat               33
Chartreux            33
Singapura            32
Munchkin             32
Sphynx               32
Siamese              32
Exotic Shorthair     31
Turkish Angora       31
Savannah             31
Scottish Fold        31
Tonkinese            30
Himalayan            30
Cornish Rex          29
Devon Rex            28
Russian Blue         28
Norwegian Forest     25
Name: count, dtype: int64
```

[5]:
```
#Value counts of the feature Color
data["Color"].value_counts()
```

[5]:
```
Color
Tricolor         73
Gray             73
Pointed          70
Bicolor          69
Sable            68
Cream            68
Black            67
Red              67
Tortoiseshell    66
Brown            64
Tabby            64
Calico           64
Orange           64
Blue             63
White            60
Name: count, dtype: int64
```

[6]:
```
#The value counts of the feature Gender
data["Gender"].value_counts()
```

[6]:
```
Gender
Male      505
Female    495
Name: count, dtype: int64
```

[7]:
```
#Remove the feature Gender
data_new = data.drop('Gender', axis=1)
data_new.head()
```

[7]:

	Breed	Age (Years)	Weight (kg)	Color
0	Russian Blue	19	7	Tortoiseshell
1	Norwegian Forest	19	9	Tortoiseshell
2	Chartreux	3	3	Brown
3	Persian	13	6	Sable
4	Ragdoll	10	8	Tabby

[12]:
```
#Dropping the duplicate rows
data_new = data_new.drop_duplicates()
#Value counts of the labels
data_new["Breed"].value_counts()
```

[12]:
```
Breed
Ragdoll               51
American Shorthair    39
Egyptian Mau          38
Oriental              37
British Shorthair     36
Burmese               36
Persian               36
Balinese              35
Siberian              34
Manx                  33
Maine Coon            33
Bengal                33
Abyssinian            33
Chartreux             33
Siamese               32
Singapura             32
Munchkin              32
Sphynx                32
Ocicat                32
Birman                32
Exotic Shorthair      31
Turkish Angora        31
```

```
Savannah             31
Scottish Fold        31
Tonkinese            30
Himalayan            30
Cornish Rex          29
Devon Rex            28
Russian Blue         28
Norwegian Forest     25
Name: count, dtype: int64
```

[10]:
```
#Value counts of the feature Color
data_new["Color"].value_counts()
```

[10]:
```
Color
Gray             72
Tricolor         71
Pointed          69
Bicolor          69
Sable            67
Black            67
Red              67
Cream            67
Tortoiseshell    66
Tabby            64
Calico           64
Orange           64
Brown            63
Blue             63
White            60
Name: count, dtype: int64
```

[11]:
```
#The distributions of features age and weight
data_new[["Age (Years)", "Weight (kg)"]].describe()
```

[11]:

	Age (Years)	Weight (kg)
count	993.000000	993.000000
mean	10.186304	5.544814
std	5.532213	2.229353
min	1.000000	2.000000
25%	5.000000	4.000000
50%	10.000000	6.000000
75%	15.000000	7.000000
max	19.000000	9.000000

[28]:
```
#Data augmentation
import random
```

```
breeds = data_new['Breed'].unique()
new_rows = []
for i in breeds:
    cats = data_new.loc[data_new["Breed"] == i]
    j = 51 - len(cats)
    while j > 0:
        sampled_color = random.choice(cats['Color'].unique())
        sampled_age = random.randrange(cats['Age (Years)'].min(), cats['Age␣
↪(Years)'].max())
        sampled_weight = random.randrange(cats['Weight (kg)'].min(),␣
↪cats['Weight (kg)'].max())
        row = [i,sampled_age,sampled_weight,sampled_color]
        if (cats != row).all(1).any() == False:
            new_rows.append([i,sampled_age,sampled_weight,sampled_color])
            j = j-1
```

[33]:
```
#Add the augmented samples to the dataframe
samples = pd.DataFrame(new_rows, columns = ['Breed', 'Age (Years)', 'Weight␣
↪(kg)', 'Color'])
data_all = pd.concat([data_new, samples], ignore_index = True)
```

[2]:
```
#The distributions of features age and weight
data_all[["Age (Years)", "Weight (kg)"]].describe()
```

[2]:

	Age (Years)	Weight (kg)
count	1530.000000	1530.000000
mean	9.898039	5.407190
std	5.346716	2.130369
min	1.000000	2.000000
25%	5.000000	4.000000
50%	10.000000	5.000000
75%	15.000000	7.000000
max	19.000000	9.000000

[3]:
```
#Value counts of the labels
data_all["Breed"].value_counts()
```

[3]:
```
Breed
Russian Blue         51
Norwegian Forest     51
Siamese              51
Munchkin             51
Savannah             51
Scottish Fold        51
Exotic Shorthair     51
Devon Rex            51
Balinese             51
```

```
Birman                 51
Siberian               51
Manx                   51
Sphynx                 51
Himalayan              51
Turkish Angora         51
Maine Coon             51
Singapura              51
Burmese                51
British Shorthair      51
Cornish Rex            51
Bengal                 51
American Shorthair     51
Egyptian Mau           51
Oriental               51
Abyssinian             51
Ocicat                 51
Ragdoll                51
Persian                51
Chartreux              51
Tonkinese              51
Name: count, dtype: int64
```

[4]:
```python
#Value counts of the feature color
data_all["Color"].value_counts()
```

[4]:
```
Color
Red              112
Black            109
Brown            108
Sable            106
Pointed          106
Tricolor         102
Cream            102
Gray             102
Blue             101
Calico           101
Tortoiseshell    100
Bicolor           99
Orange            98
Tabby             94
White             90
Name: count, dtype: int64
```

[5]:
```python
#Cross table of the labels and feature color
pd.crosstab(data_all["Breed"], data_all["Color"])
```

[5]:

Color Breed	Bicolor	Black	Blue	Brown	Calico	Cream	Gray	Orange	\
Abyssinian	2	4	2	1	4	2	3	1	
American Shorthair	7	7	3	5	0	3	3	2	
Balinese	4	4	5	5	2	2	3	7	
Bengal	0	2	3	3	2	2	0	4	
Birman	9	2	0	4	0	7	6	0	
British Shorthair	6	3	2	4	4	3	3	3	
Burmese	3	4	3	4	3	5	2	3	
Chartreux	2	4	3	2	4	4	4	1	
Cornish Rex	3	2	7	5	3	4	1	7	
Devon Rex	7	0	4	4	4	3	2	4	
Egyptian Mau	1	2	0	2	4	4	5	3	
Exotic Shorthair	5	10	2	4	6	1	4	2	
Himalayan	0	3	4	3	3	4	2	3	
Maine Coon	0	5	7	3	2	3	0	2	
Manx	0	6	7	1	6	1	4	2	
Munchkin	5	5	7	4	2	0	2	6	
Norwegian Forest	3	3	3	7	0	12	0	0	
Ocicat	2	3	7	3	3	3	5	4	
Oriental	3	2	5	3	3	4	6	3	
Persian	5	2	4	2	7	3	2	5	
Ragdoll	4	2	1	2	4	6	2	4	
Russian Blue	1	3	2	6	3	2	9	0	
Savannah	4	7	3	4	3	0	8	2	
Scottish Fold	0	3	2	3	0	4	7	3	
Siamese	2	2	2	7	4	0	5	6	
Siberian	7	4	0	1	6	4	6	3	
Singapura	5	5	4	3	5	2	1	6	
Sphynx	0	3	4	2	5	6	2	4	
Tonkinese	5	4	1	4	4	5	0	5	
Turkish Angora	4	3	4	7	5	3	5	3	

Color Breed	Pointed	Red	Sable	Tabby	Tortoiseshell	Tricolor	White
Abyssinian	4	7	3	5	5	2	6
American Shorthair	5	3	2	2	6	3	0
Balinese	3	3	0	3	5	2	3
Bengal	5	6	0	6	5	5	8
Birman	5	5	2	3	0	6	2
British Shorthair	2	7	1	3	5	3	2
Burmese	7	4	2	0	5	4	2
Chartreux	3	3	5	3	4	5	4
Cornish Rex	3	3	3	3	0	2	5
Devon Rex	4	7	0	3	3	2	4
Egyptian Mau	3	2	6	5	0	5	9
Exotic Shorthair	4	3	1	0	3	3	3

```
Himalayan                  4    6    4    2         4    4    5
Maine Coon                 5    0    7    5         4    5    3
Manx                       5    2    3    5         3    4    2
Munchkin                   1    5    5    0         5    4    0
Norwegian Forest           0    2    3    5         7    4    2
Ocicat                     2    6    6    0         4    2    1
Oriental                   0    2    5    4         3    6    2
Persian                    2    3    7    3         0    2    4
Ragdoll                    6    5    1    6         4    2    2
Russian Blue               4    4    5    4         5    1    2
Savannah                   2    2    5    3         4    0    4
Scottish Fold              0    5    9    1         3    8    3
Siamese                    6    2    0    6         2    2    5
Siberian                   7    4    2    4         0    1    2
Singapura                  3    1    5    4         0    5    2
Sphynx                     3    4    3    3         4    5    3
Tonkinese                  5    4    5    2         4    3    0
Turkish Angora             3    2    6    1         3    2    0
```

[25]:
```python
#Standardize features age and weight
from sklearn.preprocessing import StandardScaler
scaler = StandardScaler()
age = data_all['Age (Years)'].values
weight = data_all['Weight (kg)'].values
age = age.reshape(-1,1)
weight = weight.reshape(-1,1)
scaled_age = scaler.fit_transform(age)
scaled_weight = scaler.fit_transform(weight)
```

[40]:
```python
#Target encoding the feature color
from sklearn.preprocessing import TargetEncoder
encoder = TargetEncoder(target_type = 'multiclass')
X = data_all['Color'].values.reshape(-1,1)
y = data_all['Breed'].values.reshape(-1,1)
encoded_colors = encoder.fit_transform(X,y)
```

[46]:
```python
#Show the dataframe of encoded values
pd.DataFrame(encoded_colors)
```

[46]:
```
             0         1         2         3         4         5         6  \
0     0.066695  0.066695  0.053597  0.053624  0.000000  0.027090  0.066695
1     0.050294  0.050317  0.050317  0.037912  0.000000  0.050317  0.050317
2     0.011998  0.047368  0.047387  0.035687  0.047387  0.047387  0.035687
3     0.034084  0.022811  0.000000  0.000000  0.022811  0.011451  0.022806
4     0.045217  0.030336  0.045217  0.059902  0.000000  0.045217  0.000000
…          …         …         …         …         …         …         …
1525  0.068941  0.034857  0.023339  0.057664  0.034867  0.068941  0.034867
```

```
1526  0.034461  0.057019  0.034471  0.023072  0.023067  0.023072  0.034471
1527  0.023612  0.035272  0.023612  0.046823  0.046841  0.023612  0.046841
1528  0.049103  0.000000  0.012444  0.024771  0.000000  0.036990  0.024771
1529  0.035272  0.023612  0.000000  0.000000  0.023612  0.000000  0.011856

             7         8         9  …        20        21        22  \
0     0.040412  0.000000  0.040428  …  0.040428  0.000000  0.040428
1     0.025395  0.000000  0.037912  …  0.050317  0.062616  0.050294
2     0.011998  0.047387  0.011998  …  0.023886  0.070525  0.047387
3     0.034084  0.011451  0.000000  …  0.011451  0.056388  0.056388
4     0.045217  0.030346  0.045217  …  0.059864  0.030346  0.045217
…          …         …         …  …         …         …         …
1525  0.023339  0.034867  0.046308  …  0.023334  0.023339  0.011718
1526  0.034471  0.011581  0.000000  …  0.023072  0.034471  0.079208
1527  0.046841  0.011856  0.023612  …  0.023612  0.011855  0.000000
1528  0.036990  0.036990  0.049103  …  0.049082  0.036990  0.036990
1529  0.046823  0.035272  0.000000  …  0.011856  0.058324  0.046841

            23        24        25        26        27        28        29
0     0.040428  0.027097  0.000000  0.000000  0.040428  0.040428  0.027097
1     0.037912  0.000000  0.000000  0.000000  0.025395  0.050317  0.025388
2     0.011998  0.070525  0.000000  0.023886  0.023892  0.023886  0.058999
3     0.089291  0.000000  0.022811  0.056388  0.022806  0.045275  0.045275
4     0.015279  0.088771  0.045217  0.030336  0.030346  0.030336  0.000000
…          …         …         …         …         …         …         …
1525  0.057664  0.011718  0.046308  0.011717  0.034867  0.034857  0.023339
1526  0.034471  0.011583  0.034471  0.045786  0.034471  0.023072  0.034461
1527  0.069685  0.023612  0.000000  0.058324  0.046841  0.023612  0.011856
1528  0.000000  0.036990  0.061118  0.061086  0.036990  0.024766  0.061118
1529  0.046841  0.000000  0.023612  0.035272  0.035272  0.046841  0.046841

[1530 rows x 30 columns]
```

[58]:
```python
#Choose the encoded color value for each sample
colors_encoded = []
breeds = sorted(data_all['Breed'].unique())
for i in range(1530):
    breed = data_all['Breed'][i]
    breed_index = breeds.index(breed)
    color_encoded = pd.DataFrame(encoded_colors).iloc[i,breed_index]
    colors_encoded.append(color_encoded)
```

[65]:
```python
#Add the standardized and encoded values to the dataframe
data_all.insert(4,'scaled_age',scaled_age)
data_all.insert(5,'scaled_weight',scaled_weight)
data_all.insert(6,'encoded_colors',colors_encoded)
```

[66]:
```
#Show the final dataset
data_all
```

[66]:
```
                  Breed  Age (Years)  Weight (kg)         Color  scaled_age  \
0          Russian Blue           19            7  Tortoiseshell    1.702903
1      Norwegian Forest           19            9  Tortoiseshell    1.702903
2             Chartreux            3            3          Brown   -1.290567
3               Persian           13            6          Sable    0.580352
4               Ragdoll           10            8          Tabby    0.019076
…                   …            …            …            …          …
1525          Tonkinese           12            4            Red    0.393260
1526          Tonkinese            8            6          Black   -0.355108
1527          Tonkinese            5            8       Tricolor   -0.916383
1528          Tonkinese            2            5         Calico   -1.477659
1529          Tonkinese           13            6          Sable    0.580352

      scaled_weight  encoded_colors
0          0.747913        0.000000
1          1.687025        0.062581
2         -1.130310        0.011998
3          0.278358        0.034074
4          1.217469        0.059864
…               …             …
1525      -0.660754        0.034857
1526       0.278358        0.023072
1527       1.217469        0.023612
1528      -0.191198        0.024766
1529       0.278358        0.046841

[1530 rows x 7 columns]
```

[67]:
```
#Split the data into training set and testing set with 70 - 30 % ratio.
from sklearn.model_selection import train_test_split

X = data_all[["Age (Years)", "Weight (kg)", "Color", "scaled_age",␣
↪"scaled_weight", "encoded_colors" ]]
y = data_all[["Breed"]]

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.30,␣
↪random_state=42,stratify = data_all['Breed'])
```

[71]:
```
#Split the testing set into validation set and testing set with 50 - 50 % ratio.
from sklearn.model_selection import train_test_split

X_valid, X_test, y_valid, y_test = train_test_split(X_test, y_test, test_size=0.
↪50, random_state=42,stratify = y_test['Breed'])
```

[74]:
```python
#Size of the training set
len(X_train)
```

[74]: 1071

[75]:
```python
#Size of the validation set
len(X_valid)
```

[75]: 229

[76]:
```python
#Size of the testing set
len(X_test)
```

[76]: 230

[77]:
```python
#samples in the training set per class
y_train.value_counts()
```

[77]:
```
Breed
Abyssinian            36
Maine Coon            36
Tonkinese             36
Sphynx                36
Siberian              36
Siamese               36
Scottish Fold         36
Savannah              36
Russian Blue          36
Ocicat                36
Norwegian Forest      36
American Shorthair    36
Munchkin              36
Himalayan             36
British Shorthair     36
Balinese              36
Bengal                36
Birman                36
Cornish Rex           36
Devon Rex             36
Exotic Shorthair      36
Persian               35
Ragdoll               35
Manx                  35
Chartreux             35
Burmese               35
Oriental              35
Singapura             35
Egyptian Mau          35
```

```
Turkish Angora        35
Name: count, dtype: int64
```

[78]:
```
#samples in the validation set per class
y_valid.value_counts()
```

[78]:
```
Breed
Abyssinian            8
Himalayan             8
Tonkinese             8
Singapura             8
Siamese               8
Russian Blue          8
Ragdoll               8
Persian               8
Oriental              8
Ocicat                8
Norwegian Forest      8
Manx                  8
Munchkin              8
Turkish Angora        8
Egyptian Mau          8
Cornish Rex           8
Chartreux             8
Burmese               8
Exotic Shorthair      8
Birman                7
Balinese              7
Sphynx                7
Bengal                7
Siberian              7
Maine Coon            7
Scottish Fold         7
Savannah              7
Devon Rex             7
American Shorthair    7
British Shorthair     7
Name: count, dtype: int64
```

[79]:
```
#samples in the testing set per class
y_test.value_counts()
```

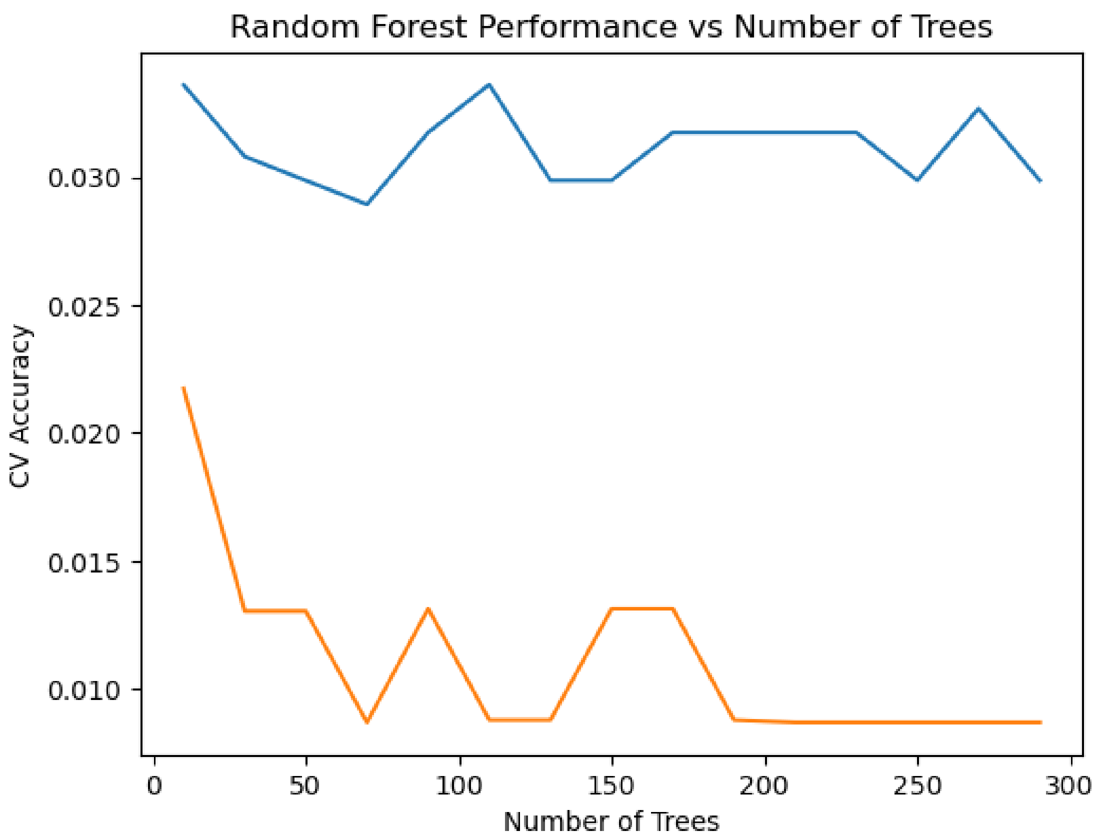
[79]:
```
Breed
Turkish Angora        8
Savannah              8
Ragdoll               8
Persian               8
```

```
Oriental              8
Siberian              8
American Shorthair    8
Manx                  8
Maine Coon            8
Singapura             8
Sphynx                8
Egyptian Mau          8
Devon Rex             8
Chartreux             8
Burmese               8
British Shorthair     8
Birman                8
Bengal                8
Balinese              8
Scottish Fold         8
Tonkinese             7
Siamese               7
Abyssinian            7
Russian Blue          7
Ocicat                7
Norwegian Forest      7
Himalayan             7
Exotic Shorthair      7
Cornish Rex           7
Munchkin              7
Name: count, dtype: int64
```

[255]:

```
#Cross validation to choose the number of trees
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import cross_val_score
import matplotlib.pyplot as plt

scores_train = []
scores_valid = []
tree_range = range(10, 310, 20)

for n in tree_range:
    rf = RandomForestClassifier(n_estimators=n, random_state=42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
↪scoring='accuracy').mean()
    scores_train.append(score_train)
    scores_valid.append(score_valid)
```

```
plt.plot(tree_range, scores_train)
plt.plot(tree_range, scores_valid)
plt.xlabel('Number of Trees')
plt.ylabel('CV Accuracy')
plt.title('Random Forest Performance vs Number of Trees')
plt.show()

#10 is the best choice
```



[271]:
```
#Fiting the RF model

from sklearn.ensemble import RandomForestClassifier

rf = RandomForestClassifier(n_estimators = 10, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
    ↪to_numpy().flatten())
```

[271]: RandomForestClassifier(n_estimators=10, random_state=42)

```
[272]: #Predicting the labels
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

```
[273]: #Computing the accuracy, precision, recall, and F1 score values.
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay,␣
↪precision_score, recall_score, f1_score

rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
[274]: #Training accuracy
rf_accuracy_train
```

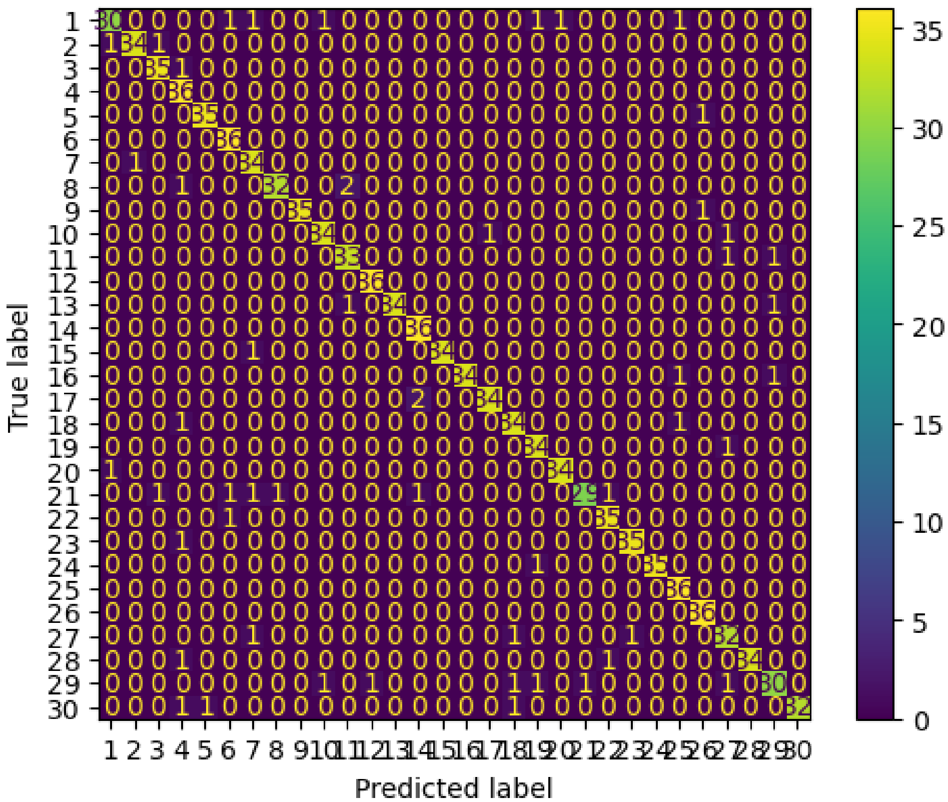
```
[274]: 0.9505135387488328
```

```
[275]: #Validation accuracy
rf_accuracy_valid
```

```
[275]: 0.05240174672489083
```

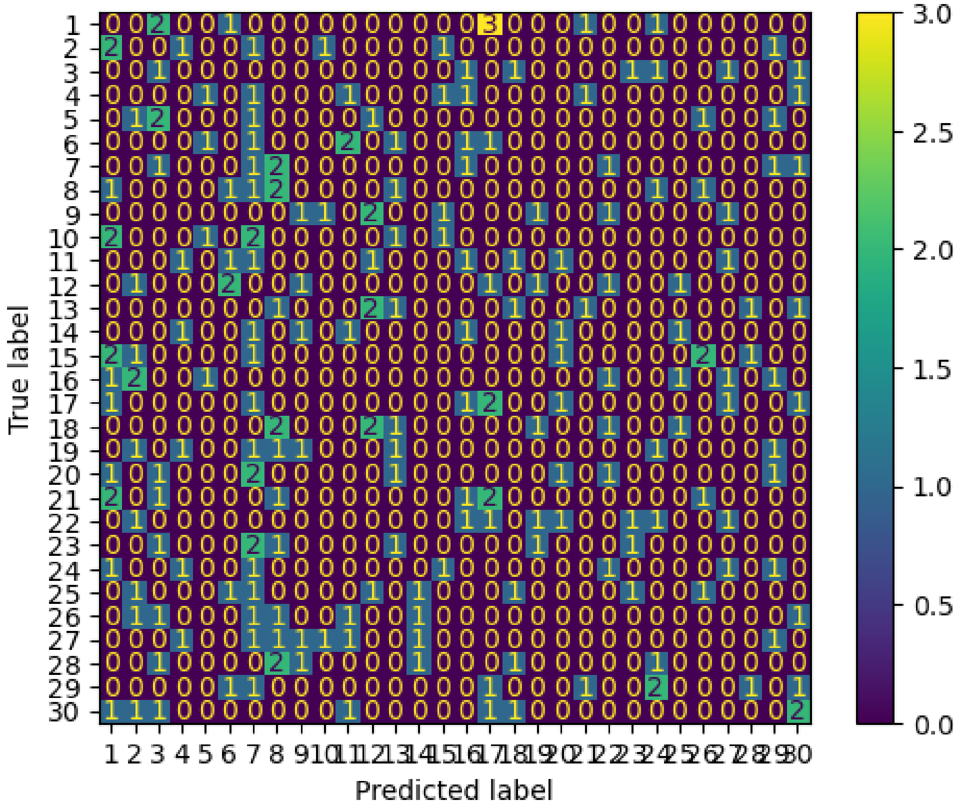
```
[276]: #Confusion matrix (training data)
import matplotlib.pyplot as plt

disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
```

```
plt.show()
```



[277]:

```
#Confusion matrix (validation data)
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



```
[278]: #Training precision
rf_precision_train
```

```
[278]: array([0.9375    , 0.97142857, 0.94594595, 0.85714286, 0.97222222,
       0.92307692, 0.89473684, 0.96969697, 1.        , 0.94444444,
       0.91666667, 0.97297297, 1.        , 0.92307692, 1.        ,
       1.        , 0.97142857, 0.91891892, 0.91891892, 0.97142857,
       0.96666667, 0.94594595, 0.97222222, 1.        , 0.92307692,
       0.94736842, 0.88888889, 1.        , 0.90909091, 1.        ])
```

```
[279]: #Validation precision
rf_precision_valid
```

```
[279]: array([0.        , 0.        , 0.08333333, 0.        , 0.        ,
       0.        , 0.04545455, 0.14285714, 0.16666667, 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.16666667, 0.        , 0.        , 0.16666667,
       0.        , 0.        , 0.25      , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.22222222])
```

[280]:
```
#Training recall
rf_recall_train
```

[280]:
```
array([0.83333333, 0.94444444, 0.97222222, 1.        , 0.97222222,
       1.        , 0.97142857, 0.91428571, 0.97222222, 0.94444444,
       0.94285714, 1.        , 0.94444444, 1.        , 0.97142857,
       0.94444444, 0.94444444, 0.94444444, 0.97142857, 0.97142857,
       0.82857143, 0.97222222, 0.97222222, 0.97222222, 1.        ,
       1.        , 0.91428571, 0.94444444, 0.83333333, 0.91428571])
```

[281]:
```
#Validation recall
rf_recall_valid
```

[281]:
```
array([0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.125     , 0.25      , 0.125     , 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.25      , 0.        , 0.        , 0.125     ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.25      ])
```

[282]:
```
#Training F1 score
rf_f1_train
```

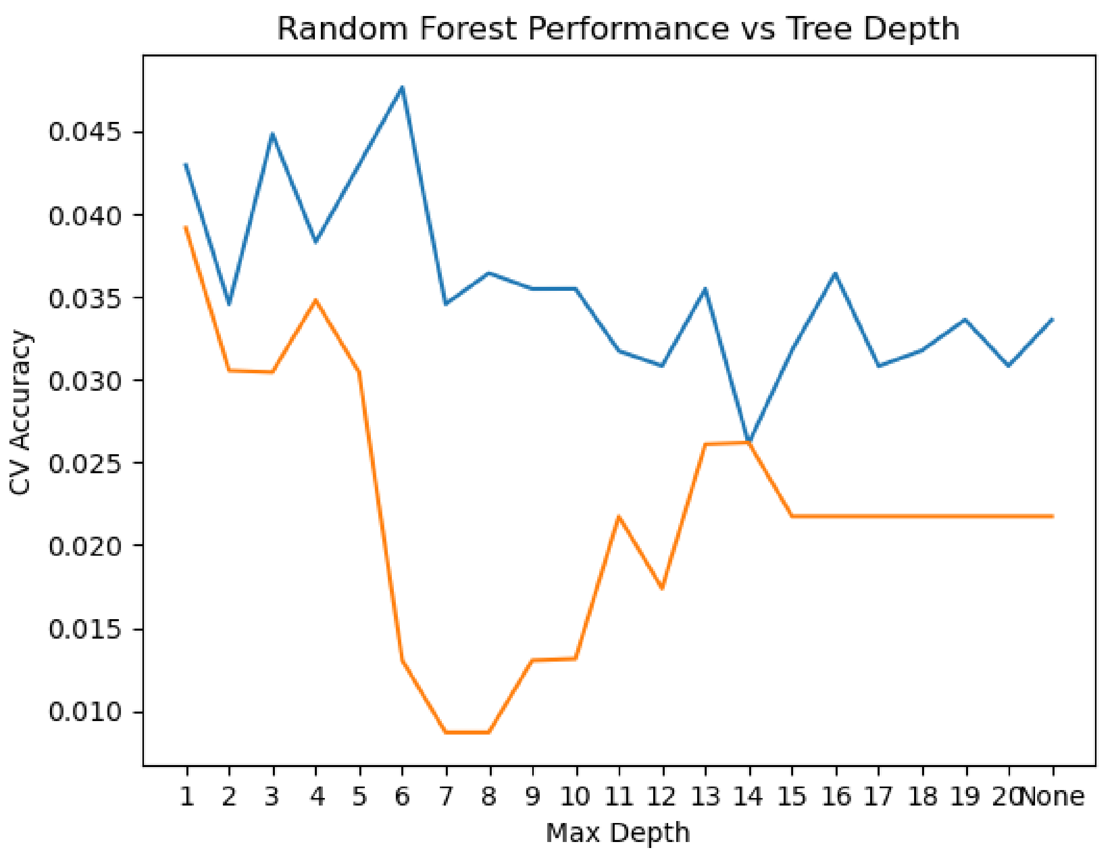
[282]:
```
array([0.88235294, 0.95774648, 0.95890411, 0.92307692, 0.97222222,
       0.96      , 0.93150685, 0.94117647, 0.98591549, 0.94444444,
       0.92957746, 0.98630137, 0.97142857, 0.96      , 0.98550725,
       0.97142857, 0.95774648, 0.93150685, 0.94444444, 0.97142857,
       0.89230769, 0.95890411, 0.97222222, 0.98591549, 0.96      ,
       0.97297297, 0.90140845, 0.97142857, 0.86956522, 0.95522388])
```

[283]:
```
#Validation F1 score
rf_f1_valid
```

[283]:
```
array([0.        , 0.        , 0.10526316, 0.        , 0.        ,
       0.        , 0.06666667, 0.18181818, 0.14285714, 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.2       , 0.        , 0.        , 0.14285714,
       0.        , 0.        , 0.18181818, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.23529412])
```

[330]:
```
depths = [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,None]  # Try␣
 ↪depths from 1 to 20
scores_train = []
scores_valid = []

for d in depths:
    rf = RandomForestClassifier(n_estimators = 10, max_depth=d, random_state=42)
```

```
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
↪scoring='accuracy').mean()
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot([str(depth) for depth in depths], scores_train)
plt.plot([str(depth) for depth in depths], scores_valid)
plt.xlabel('Max Depth')
plt.ylabel('CV Accuracy')
plt.title('Random Forest Performance vs Tree Depth')
plt.show()

#4 is the best
```



[315]:
```
rf = RandomForestClassifier(n_estimators = 10, max_depth = 4, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[315]: RandomForestClassifier(max_depth=4, n_estimators=10, random_state=42)

[316]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[317]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
```

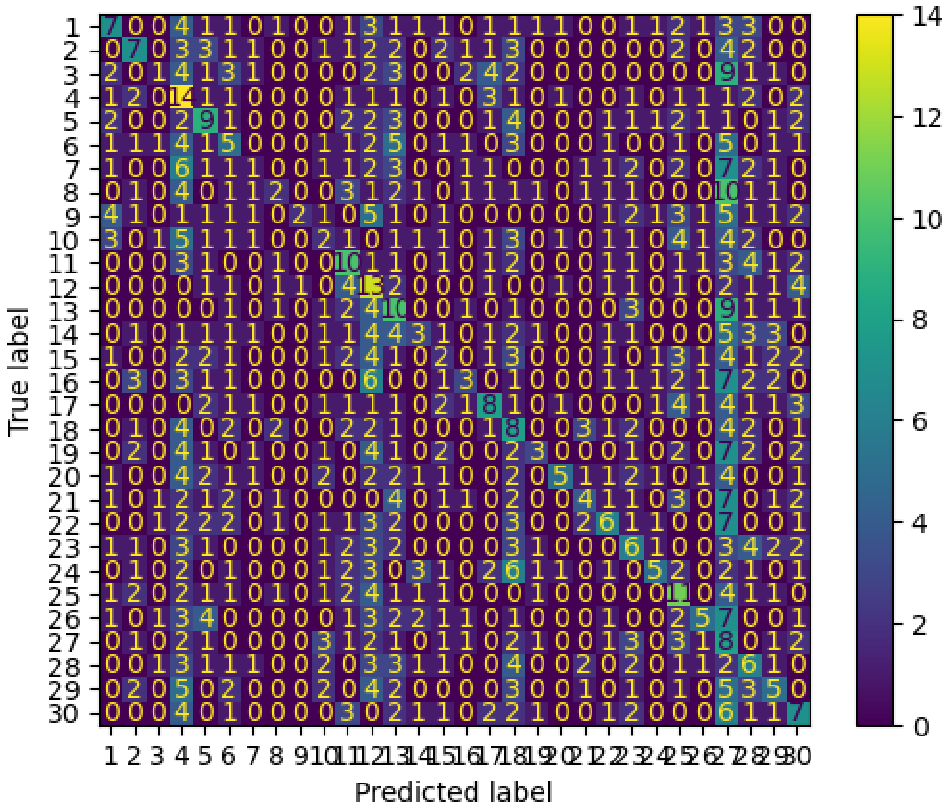
[318]:
```
rf_accuracy_train
```

[318]: 0.16619981325863678

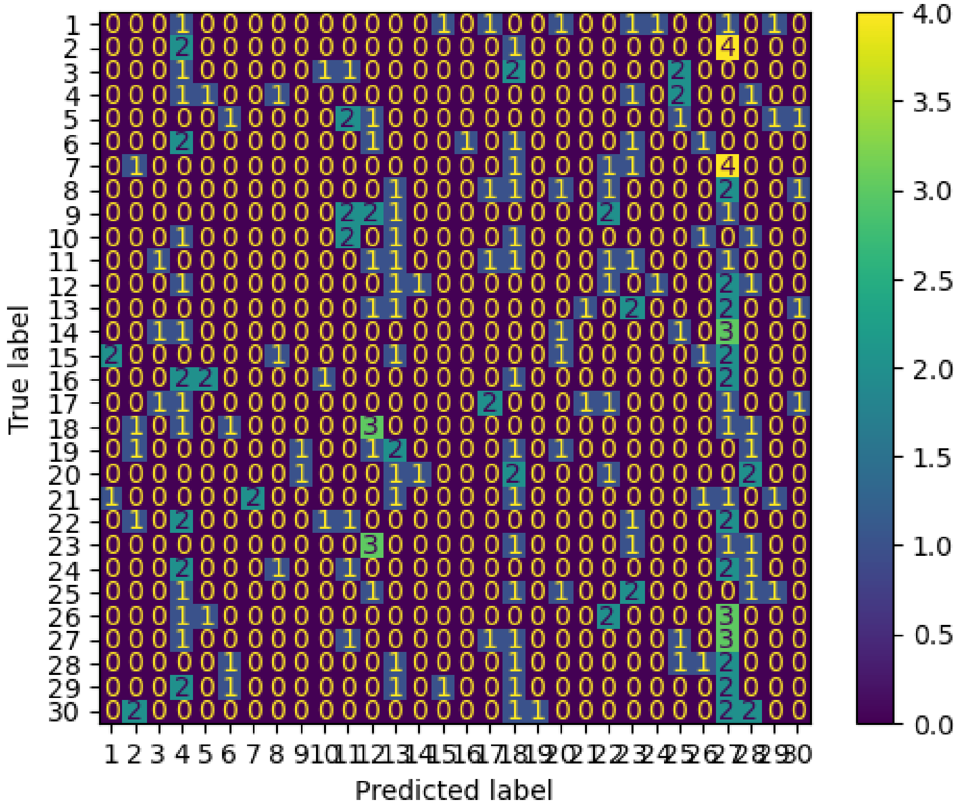
[319]:
```
rf_accuracy_valid
```

[319]: 0.034934497816593885

[320]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
 ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[321]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[322]:
```
rf_precision_train
```

[322]:
```
array([0.25925926, 0.26923077, 0.14285714, 0.14583333, 0.2195122 ,
       0.14285714, 0.09090909, 0.18181818, 0.66666667, 0.08333333,
       0.22222222, 0.15116279, 0.15625   , 0.2       , 0.08333333,
       0.21428571, 0.26666667, 0.12121212, 0.27272727, 0.45454545,
       0.26666667, 0.25      , 0.16216216, 0.35714286, 0.20754717,
       0.29411765, 0.05369128, 0.12765957, 0.17241379, 0.17948718])
```

[323]:
```
rf_precision_valid
```

[323]:
```
array([0.        , 0.        , 0.        , 0.04347826, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.07692308, 0.        , 0.        ,
       0.        , 0.33333333, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.09090909, 0.        , 0.        ,
       0.        , 0.06818182, 0.        , 0.        , 0.        ])
```

[324]:
```
rf_recall_train
```

[324]: array([0.19444444, 0.19444444, 0.02777778, 0.38888889, 0.25   ,
        0.13888889, 0.02857143, 0.05714286, 0.05555556, 0.05555556,
        0.28571429, 0.36111111, 0.27777778, 0.08333333, 0.05714286,
        0.08333333, 0.22222222, 0.22222222, 0.08571429, 0.14285714,
        0.11428571, 0.16666667, 0.16666667, 0.13888889, 0.30555556,
        0.13888889, 0.22857143, 0.16666667, 0.13888889, 0.2   ])

[325]:
```
rf_recall_valid
```

[325]: array([0.   , 0.   , 0.   , 0.14285714, 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.125   , 0.   , 0.   ,
        0.   , 0.25   , 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.14285714, 0.   , 0.   ,
        0.   , 0.375   , 0.   , 0.   , 0.   ])

[326]:
```
rf_f1_train
```

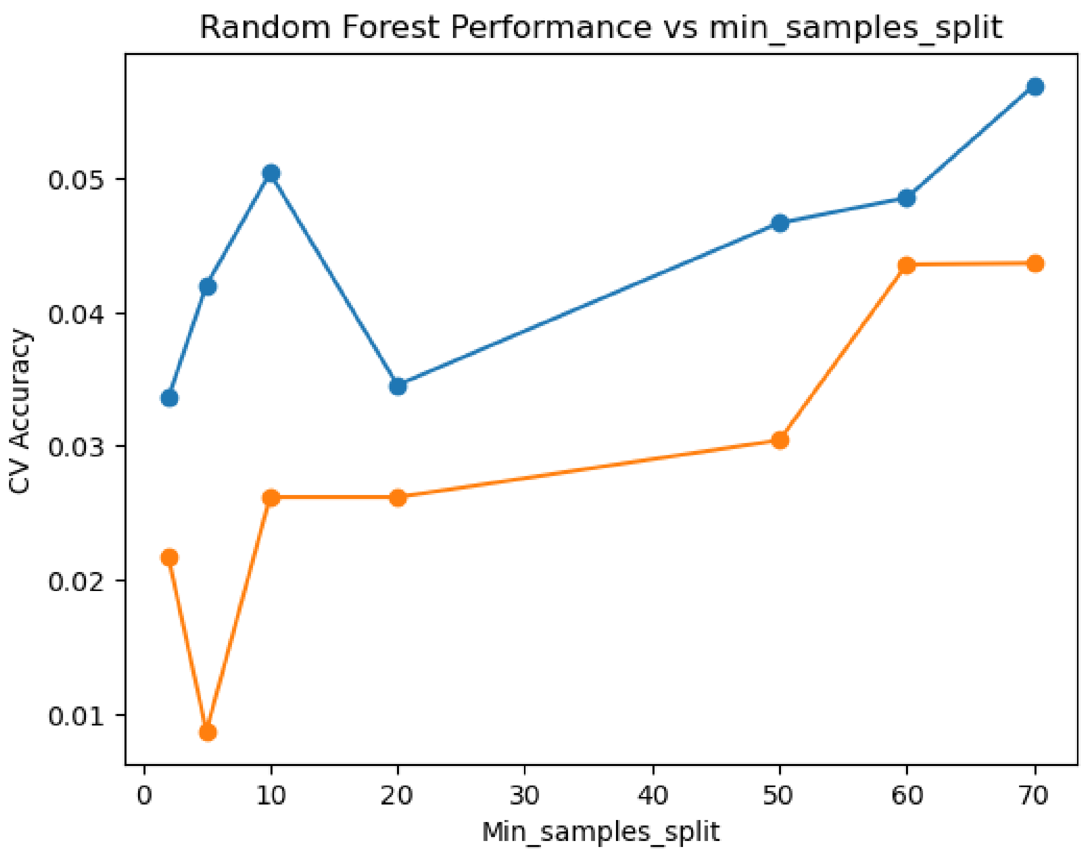
[326]: array([0.22222222, 0.22580645, 0.04651163, 0.21212121, 0.23376623,
        0.14084507, 0.04347826, 0.08695652, 0.1025641 , 0.06666667,
        0.25   , 0.21311475, 0.2   , 0.11764706, 0.06779661,
        0.12   , 0.24242424, 0.15686275, 0.13043478, 0.2173913 ,
        0.16   , 0.2   , 0.16438356, 0.2   , 0.24719101,
        0.18867925, 0.08695652, 0.14457831, 0.15384615, 0.18918919])

[327]:
```
rf_f1_valid
```

[327]: array([0.   , 0.   , 0.   , 0.06666667, 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.0952381 , 0.   , 0.   ,
        0.   , 0.28571429, 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.11111111, 0.   , 0.   ,
        0.   , 0.11538462, 0.   , 0.   , 0.   ])

[340]:
```
split_values = [2, 5, 10, 20, 50, 60, 70]
scores_train = []
scores_valid = []

for value in split_values:
    rf = RandomForestClassifier(n_estimators = 10, min_samples_split = value,␣
 ↪random_state=42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot(split_values, scores_train, marker = 'o')
plt.plot(split_values, scores_valid, marker = 'o')
plt.xlabel('Min_samples_split')
plt.ylabel('CV Accuracy')
plt.title('Random Forest Performance vs min_samples_split')
plt.show()

#60 is the best
```



[353]:
```
rf = RandomForestClassifier(n_estimators = 10, min_samples_split = 60,␣
 ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[353]: RandomForestClassifier(min_samples_split=60, n_estimators=10, random_state=42)

[354]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
```

[355]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
    ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
    ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
    ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
    ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
    ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
    ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
    ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
    ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

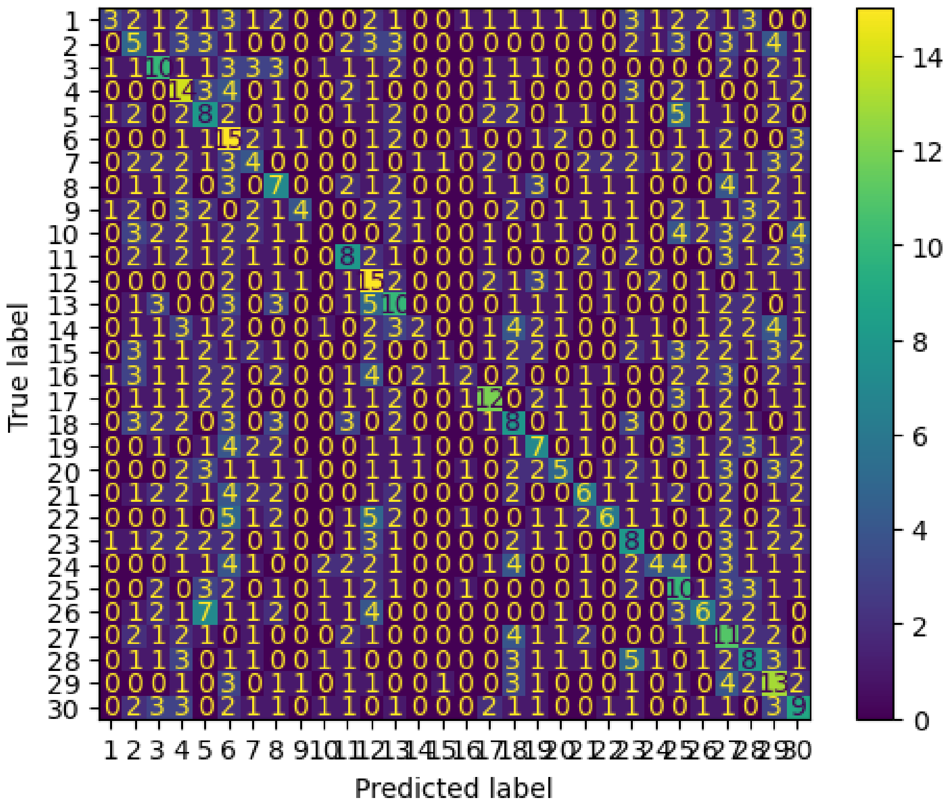
[356]:
```
rf_accuracy_train
```

[356]: 0.20634920634920634

[357]:
```
rf_accuracy_valid
```

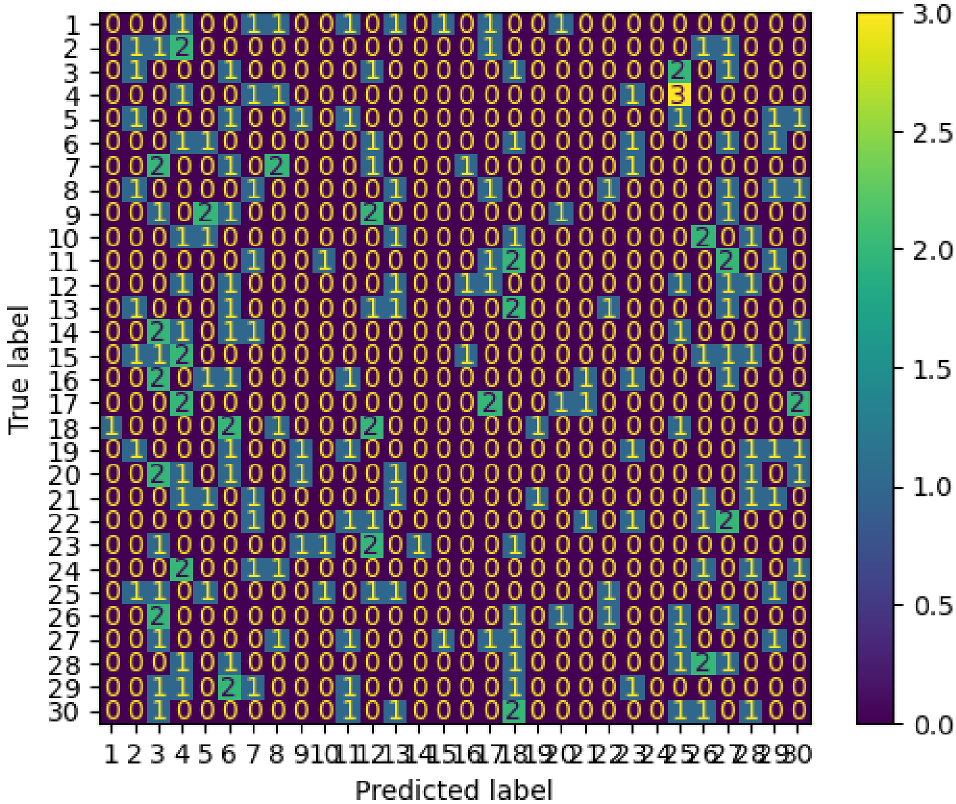
[357]: 0.021834061135371178

[358]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
    ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[359]:

```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[360]:
```
rf_precision_train
```

[360]:
```
array([0.375     , 0.125     , 0.24390244, 0.23333333, 0.16666667,
       0.18292683, 0.14285714, 0.17073171, 0.44444444, 0.        ,
       0.23529412, 0.23076923, 0.2173913 , 0.22222222, 0.25      ,
       0.25      , 0.4       , 0.16666667, 0.21875   , 0.23809524,
       0.24      , 0.375     , 0.17021277, 0.26666667, 0.18867925,
       0.20689655, 0.15277778, 0.19512195, 0.20967742, 0.18367347])
```

[361]:
```
rf_precision_valid
```

[361]:
```
array([0.        , 0.125     , 0.        , 0.05555556, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.11111111, 0.        , 0.        ,
       0.        , 0.25      , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[362]:
```
rf_recall_train
```

[362]: array([0.08333333, 0.13888889, 0.27777778, 0.38888889, 0.22222222,
       0.41666667, 0.11428571, 0.2   , 0.11111111, 0.   ,
       0.22857143, 0.41666667, 0.27777778, 0.05555556, 0.02857143,
       0.05555556, 0.33333333, 0.22222222, 0.2   , 0.14285714,
       0.17142857, 0.16666667, 0.22222222, 0.11111111, 0.27777778,
       0.16666667, 0.31428571, 0.22222222, 0.36111111, 0.25714286])

[363]:
```
rf_recall_valid
```

[363]: array([0.   , 0.14285714, 0.   , 0.14285714, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.125   , 0.   , 0.   ,
       0.   , 0.25   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ])

[364]:
```
rf_f1_train
```

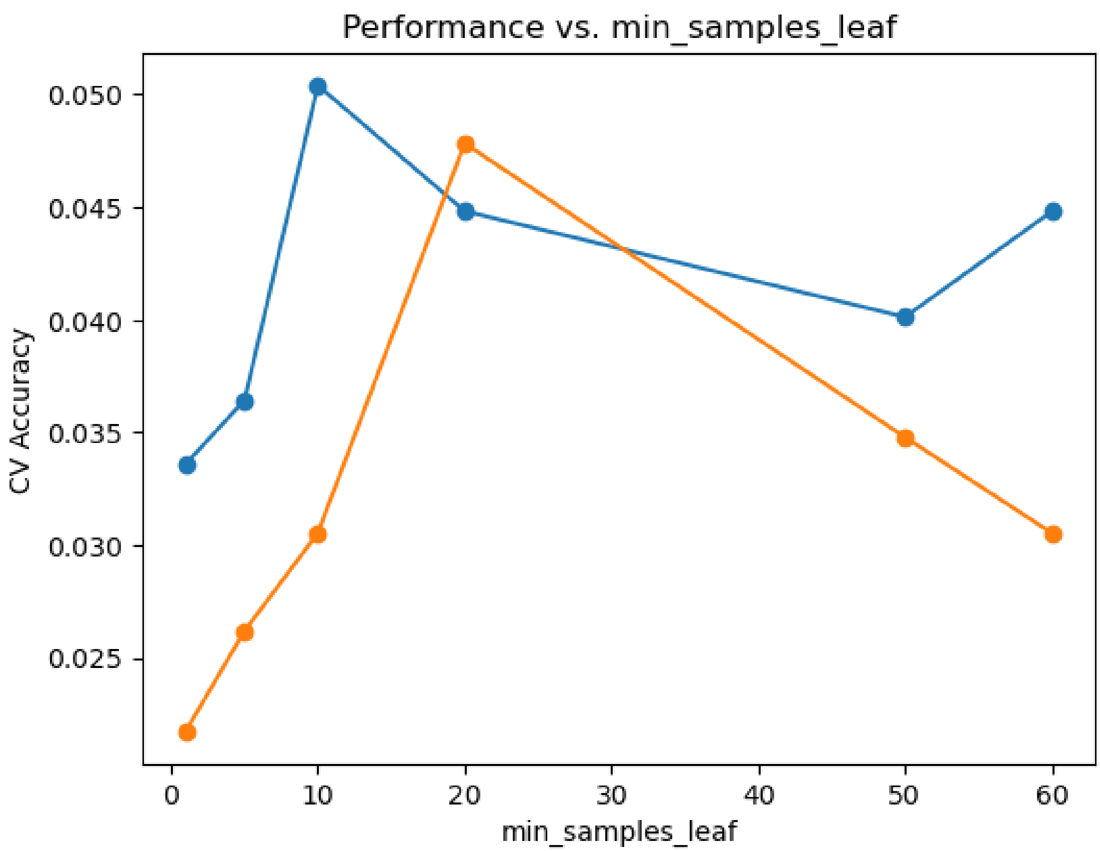
[364]: array([0.13636364, 0.13157895, 0.25974026, 0.29166667, 0.19047619,
       0.25423729, 0.12698413, 0.18421053, 0.17777778, 0.   ,
       0.23188406, 0.2970297 , 0.24390244, 0.08888889, 0.05128205,
       0.09090909, 0.36363636, 0.19047619, 0.20895522, 0.17857143,
       0.2   , 0.23076923, 0.19277108, 0.15686275, 0.2247191 ,
       0.18461538, 0.20560748, 0.20779221, 0.26530612, 0.21428571])

[365]:
```
rf_f1_valid
```

[365]: array([0.   , 0.13333333, 0.   , 0.08   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.11764706, 0.   , 0.   ,
       0.   , 0.25   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ])

[368]:
```
leaf_values = [1, 5, 10, 20, 50, 60]
scores_train = []
scores_valid = []

for value in leaf_values:
    rf = RandomForestClassifier(n_estimators = 10, min_samples_leaf = value,␣
 ↪random_state = 42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot(leaf_values, scores_train, marker = 'o')
plt.plot(leaf_values, scores_valid, marker = 'o')
plt.xlabel('min_samples_leaf')
plt.ylabel('CV Accuracy')
plt.title('Performance vs. min_samples_leaf')
plt.show()

#20 is the best
```



[385]:
```
rf = RandomForestClassifier(n_estimators = 10, min_samples_leaf = 20,␣
↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
↪to_numpy().flatten())
```

[385]:
```
RandomForestClassifier(min_samples_leaf=20, n_estimators=10, random_state=42)
```

[386]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[387]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

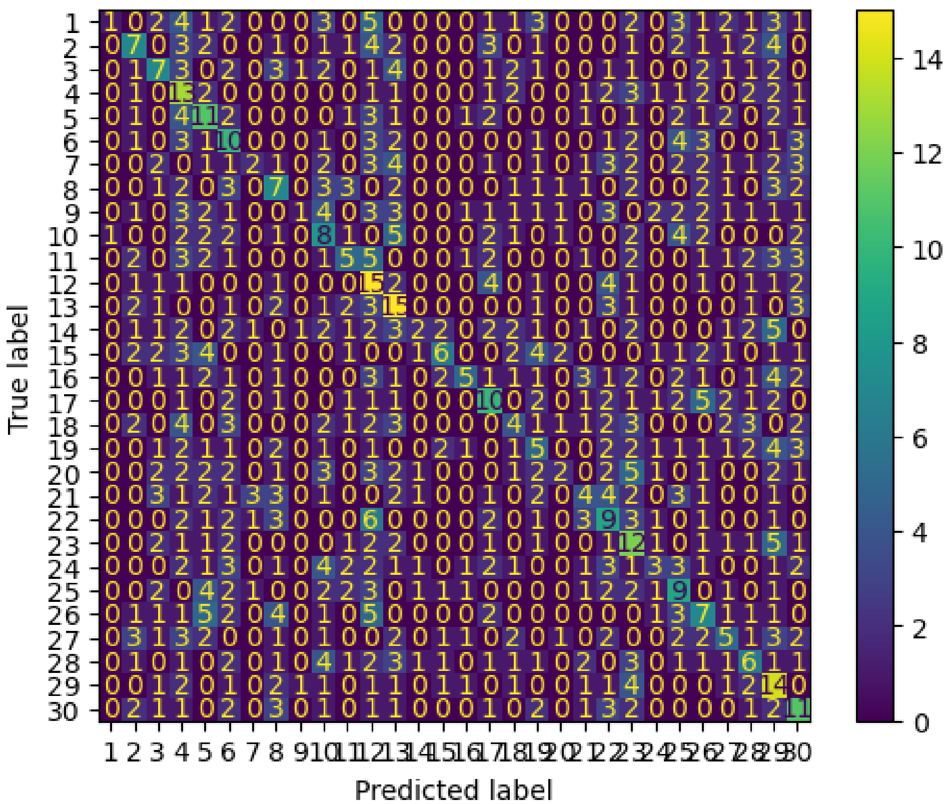
[388]:
```
rf_accuracy_train
```

[388]: 0.20168067226890757

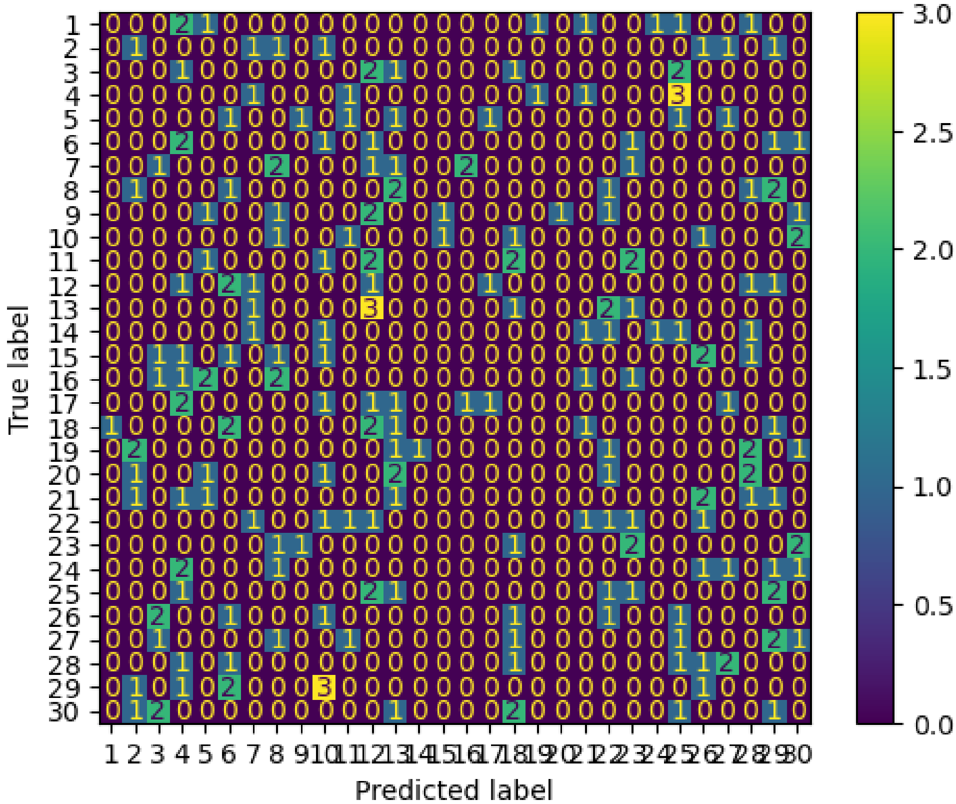
[389]:
```
rf_accuracy_valid
```

[389]: 0.026200873362445413

[390]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[391]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
  ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[392]:
```
rf_precision_train
```

[392]:
```
array([0.5       , 0.24137931, 0.21875   , 0.18571429, 0.2244898 ,
       0.18867925, 0.25      , 0.175     , 0.25      , 0.16326531,
       0.2173913 , 0.1875    , 0.23809524, 0.25      , 0.375     ,
       0.38461538, 0.24390244, 0.16666667, 0.14705882, 0.22222222,
       0.16666667, 0.17647059, 0.1875    , 0.21428571, 0.19148936,
       0.15909091, 0.18518519, 0.18181818, 0.19444444, 0.22916667])
```

[393]:
```
rf_precision_valid
```

[393]:
```
array([0.        , 0.125     , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05555556, 0.        , 0.        , 0.        ,
       0.        , 0.33333333, 0.        , 0.        , 0.        ,
       0.        , 0.1       , 0.2       , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[394]:
```
rf_recall_train
```

[394]: array([0.02777778, 0.19444444, 0.19444444, 0.36111111, 0.30555556,
        0.27777778, 0.05714286, 0.2   , 0.02777778, 0.22222222,
        0.14285714, 0.41666667, 0.41666667, 0.05555556, 0.17142857,
        0.13888889, 0.27777778, 0.11111111, 0.14285714, 0.05714286,
        0.11428571, 0.25   , 0.33333333, 0.08333333, 0.25   ,
        0.19444444, 0.14285714, 0.16666667, 0.38888889, 0.31428571])

[395]:
```
rf_recall_valid
```

[395]: array([0.   , 0.14285714, 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.28571429, 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ])

[396]:
```
rf_f1_train
```

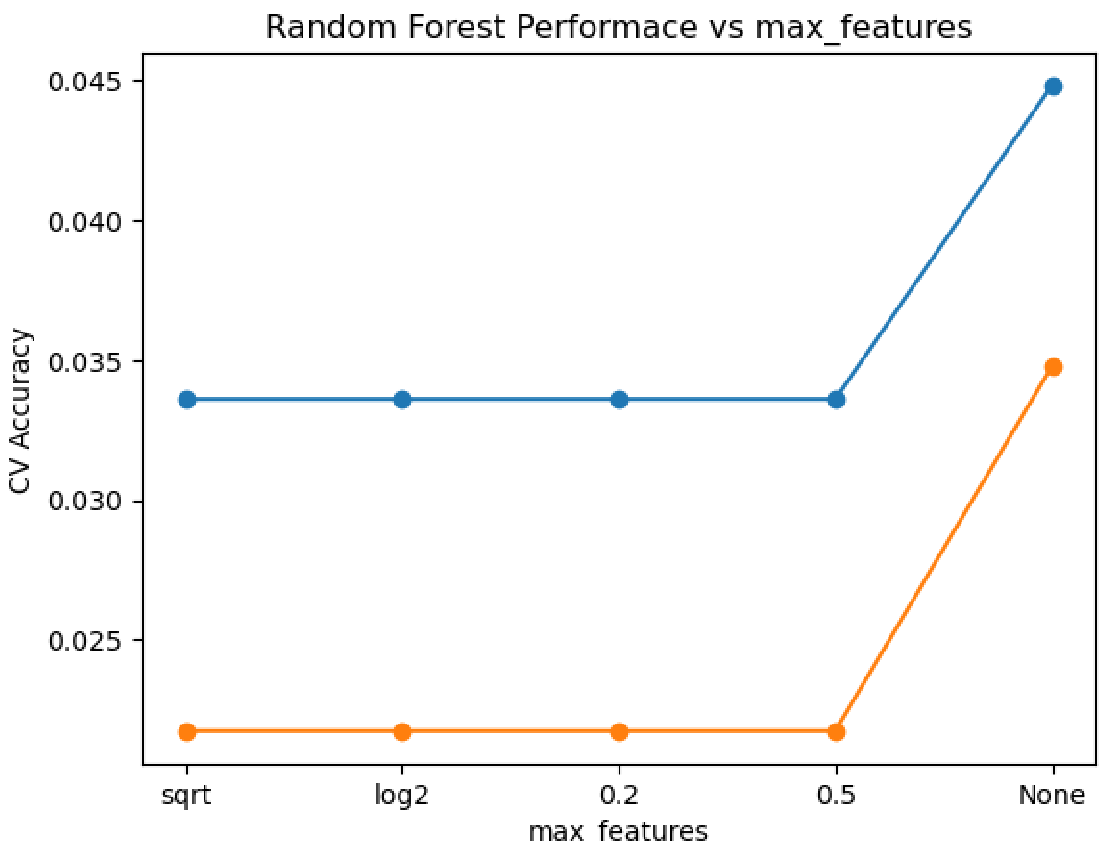
[396]: array([0.05263158, 0.21538462, 0.20588235, 0.24528302, 0.25882353,
        0.2247191 , 0.09302326, 0.18666667, 0.05   , 0.18823529,
        0.17241379, 0.25862069, 0.3030303 , 0.09090909, 0.23529412,
        0.20408163, 0.25974026, 0.13333333, 0.14492754, 0.09090909,
        0.13559322, 0.20689655, 0.24   , 0.12   , 0.21686747,
        0.175   , 0.16129032, 0.17391304, 0.25925926, 0.26506024])

[397]:
```
rf_f1_valid
```

[397]: array([0.   , 0.13333333, 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.07692308, 0.   , 0.   , 0.   ,
        0.   , 0.18181818, 0.   , 0.   , 0.   ,
        0.   , 0.11111111, 0.23529412, 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ])

[413]:
```
feature_options = ['sqrt', 'log2', 0.2, 0.5, None]
scores_train = []
scores_valid = []

for option in feature_options:
    rf = RandomForestClassifier(n_estimators = 10, max_features = option,␣
 ↪random_state = 42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```python
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot(['sqrt', 'log2', '0.2', '0.5', 'None'], scores_train, marker = 'o')
plt.plot(['sqrt', 'log2', '0.2', '0.5', 'None'], scores_valid, marker = 'o')
plt.xlabel('max_features')
plt.ylabel('CV Accuracy')
plt.title('Random Forest Performace vs max_features')
plt.show()

#None is the best
```



[399]:
```python
rf = RandomForestClassifier(n_estimators = 10, max_features = None,␣
 ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[399]:
```
RandomForestClassifier(max_features=None, n_estimators=10, random_state=42)
```

[400]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[401]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

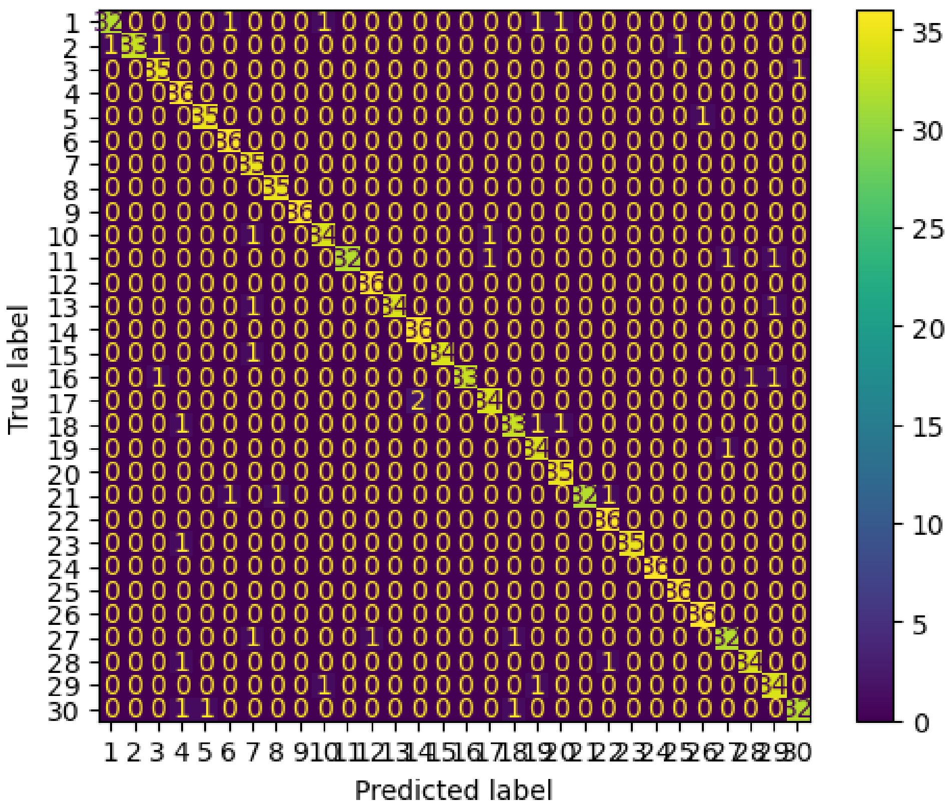
[402]:
```
rf_accuracy_train
```

[402]: 0.9626517273576097

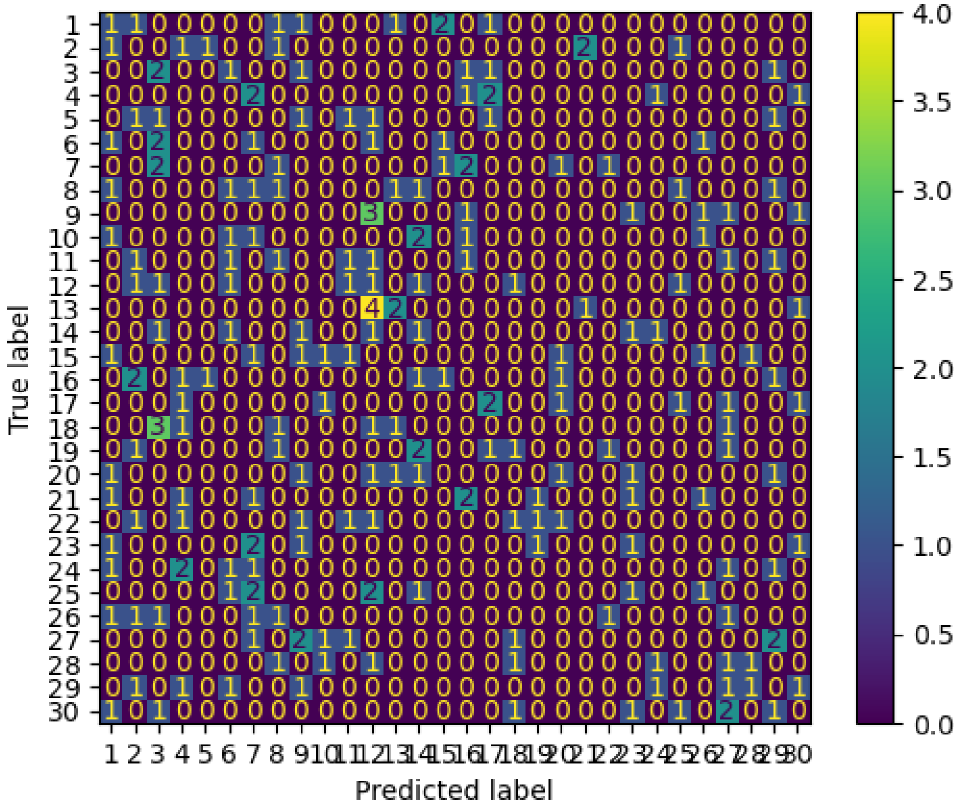
[403]:
```
rf_accuracy_valid
```

[403]: 0.0611353711790393

[404]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[405]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[406]:
```
rf_precision_train
```

[406]:
```
array([0.96969697, 1.        , 0.94594595, 0.9       , 0.97222222,
       0.94736842, 0.8974359 , 0.97222222, 1.        , 0.94444444,
       1.        , 0.97297297, 1.        , 0.94736842, 1.        ,
       1.        , 0.94444444, 0.94285714, 0.91891892, 0.94594595,
       1.        , 0.94736842, 1.        , 1.        , 0.97297297,
       0.97297297, 0.94117647, 0.97142857, 0.91891892, 0.96969697])
```

[407]:
```
rf_precision_valid
```

[407]:
```
array([0.08333333, 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.11111111, 0.        , 0.        ,
       0.16666667, 0.05555556, 0.33333333, 0.1       , 0.        ,
       0.        , 0.25      , 0.        , 0.        , 0.16666667,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.33333333, 0.        , 0.        ])
```

[408]:
```
rf_recall_train
```

```
[408]: array([0.88888889, 0.91666667, 0.97222222, 1.        , 0.97222222,
        1.        , 1.        , 1.        , 1.        , 0.94444444,
        0.91428571, 1.        , 0.94444444, 1.        , 0.97142857,
        0.91666667, 0.94444444, 0.91666667, 0.97142857, 1.        ,
        0.91428571, 1.        , 0.97222222, 1.        , 1.        ,
        1.        , 0.91428571, 0.94444444, 0.94444444, 0.91428571])
```

```
[409]: rf_recall_valid
```

```
[409]: array([0.125     , 0.        , 0.28571429, 0.        , 0.        ,
        0.        , 0.        , 0.125     , 0.        , 0.        ,
        0.125     , 0.125     , 0.25      , 0.14285714, 0.        ,
        0.        , 0.25      , 0.        , 0.        , 0.125     ,
        0.        , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.14285714, 0.        , 0.        ])
```

```
[410]: rf_f1_train
```

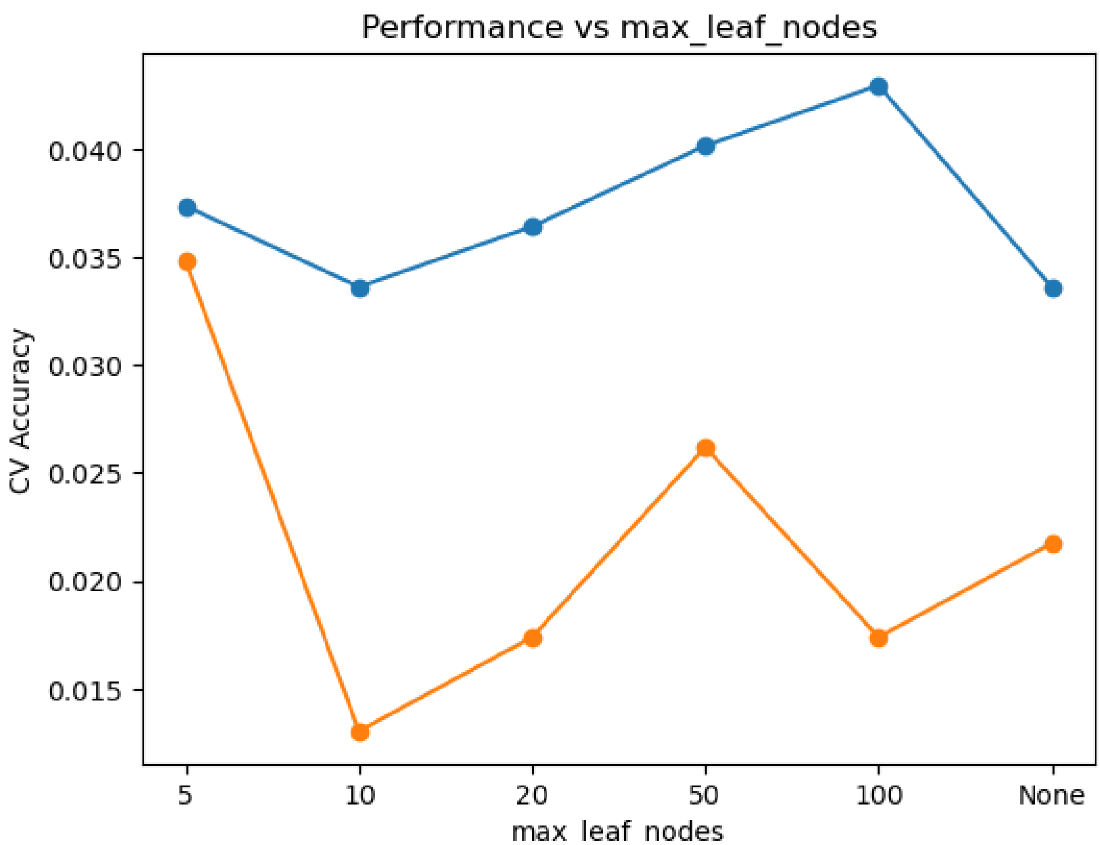
```
[410]: array([0.92753623, 0.95652174, 0.95890411, 0.94736842, 0.97222222,
        0.97297297, 0.94594595, 0.98591549, 1.        , 0.94444444,
        0.95522388, 0.98630137, 0.97142857, 0.97297297, 0.98550725,
        0.95652174, 0.94444444, 0.92957746, 0.94444444, 0.97222222,
        0.95522388, 0.97297297, 0.98591549, 1.        , 0.98630137,
        0.98630137, 0.92753623, 0.95774648, 0.93150685, 0.94117647])
```

```
[411]: rf_f1_valid
```

```
[411]: array([0.1       , 0.        , 0.19047619, 0.        , 0.        ,
        0.        , 0.        , 0.11764706, 0.        , 0.        ,
        0.14285714, 0.07692308, 0.28571429, 0.11764706, 0.        ,
        0.        , 0.25      , 0.        , 0.        , 0.14285714,
        0.        , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.2       , 0.        , 0.        ])
```

```
[414]: leaf_node_options = [5, 10, 20, 50, 100, None]
scores_train = []
scores_valid = []

for option in leaf_node_options:
    rf = RandomForestClassifier(n_estimators = 10, max_leaf_nodes = option,␣
 ↪random_state = 42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot([str(o) for o in leaf_node_options], scores_train, marker = 'o')
plt.plot([str(o) for o in leaf_node_options], scores_valid, marker = 'o')
plt.xlabel('max_leaf_nodes')
plt.ylabel('CV Accuracy')
plt.title('Performance vs max_leaf_nodes')
plt.show()

#5 is the best
```



[417]:
```
rf = RandomForestClassifier(n_estimators = 10, max_leaf_nodes = 5, random_state␣
 ↪= 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[417]: RandomForestClassifier(max_leaf_nodes=5, n_estimators=10, random_state=42)

[418]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[419]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

[420]:
```
rf_accuracy_train
```

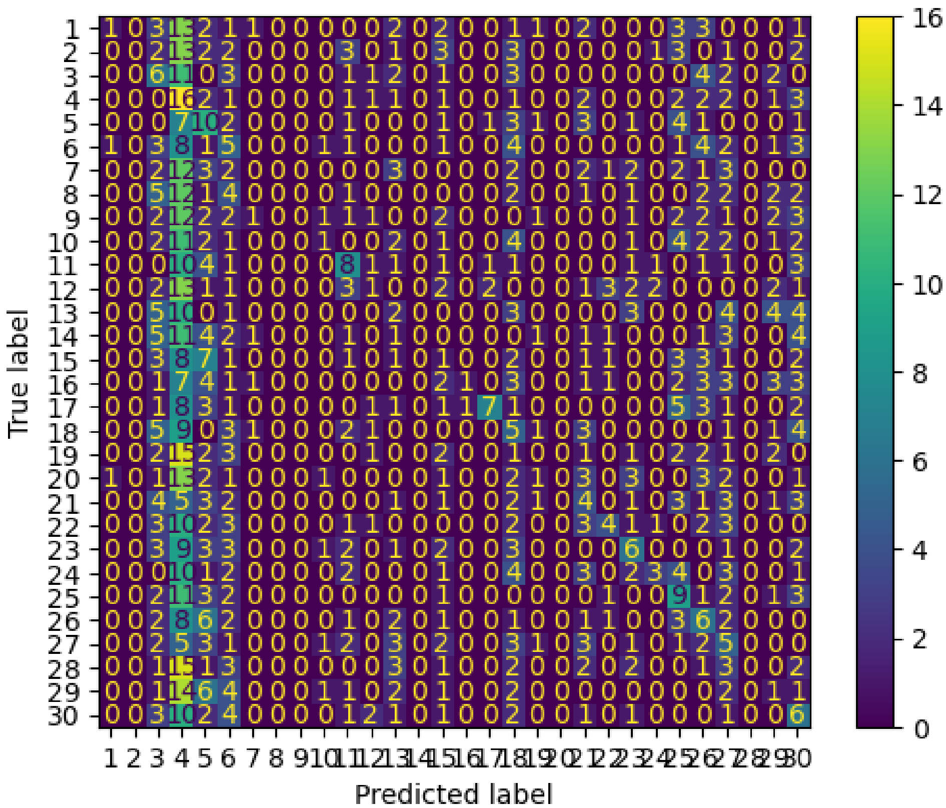
[420]:
```
0.10084033613445378
```

[421]:
```
rf_accuracy_valid
```

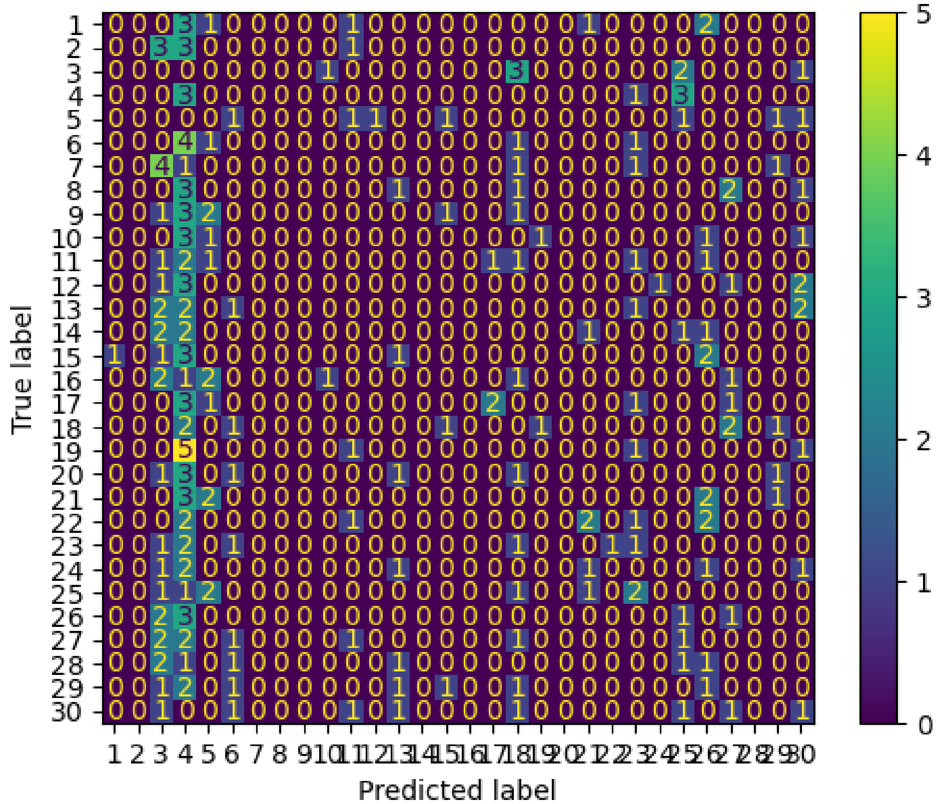
[421]:
```
0.03056768558951965
```

[422]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
 ↪display_labels=range(1,31))
```

```
disp_rf_train.plot()
plt.show()
```



[423]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[424]:
```
rf_precision_train
```

[424]:
```
array([0.33333333, 0.        , 0.08450704, 0.05063291, 0.12195122,
       0.078125  , 0.        , 0.        , 0.        , 0.14285714,
       0.23529412, 0.09090909, 0.06666667, 0.        , 0.03030303,
       0.5       , 0.63636364, 0.08064516, 0.        , 0.        ,
       0.10526316, 0.30769231, 0.2       , 0.375     , 0.16981132,
       0.12      , 0.0877193 , 0.        , 0.04166667, 0.10169492])
```

[425]:
```
rf_precision_valid
```

[425]:
```
array([0.        , 0.        , 0.        , 0.04477612, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.66666667, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.09090909, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.09090909])
```

[426]:
```
rf_recall_train
```

[426]: array([0.02777778, 0.   , 0.16666667, 0.44444444, 0.27777778,
        0.13888889, 0.   , 0.   , 0.   , 0.02777778,
        0.22857143, 0.02777778, 0.05555556, 0.   , 0.02857143,
        0.02777778, 0.19444444, 0.13888889, 0.   , 0.   ,
        0.11428571, 0.11111111, 0.16666667, 0.08333333, 0.25   ,
        0.16666667, 0.14285714, 0.   , 0.02777778, 0.17142857])

[427]:
```
rf_recall_valid
```

[427]:
```
array([0.        , 0.        , 0.        , 0.42857143, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.25      , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.125     ])
```

[428]:
```
rf_f1_train
```

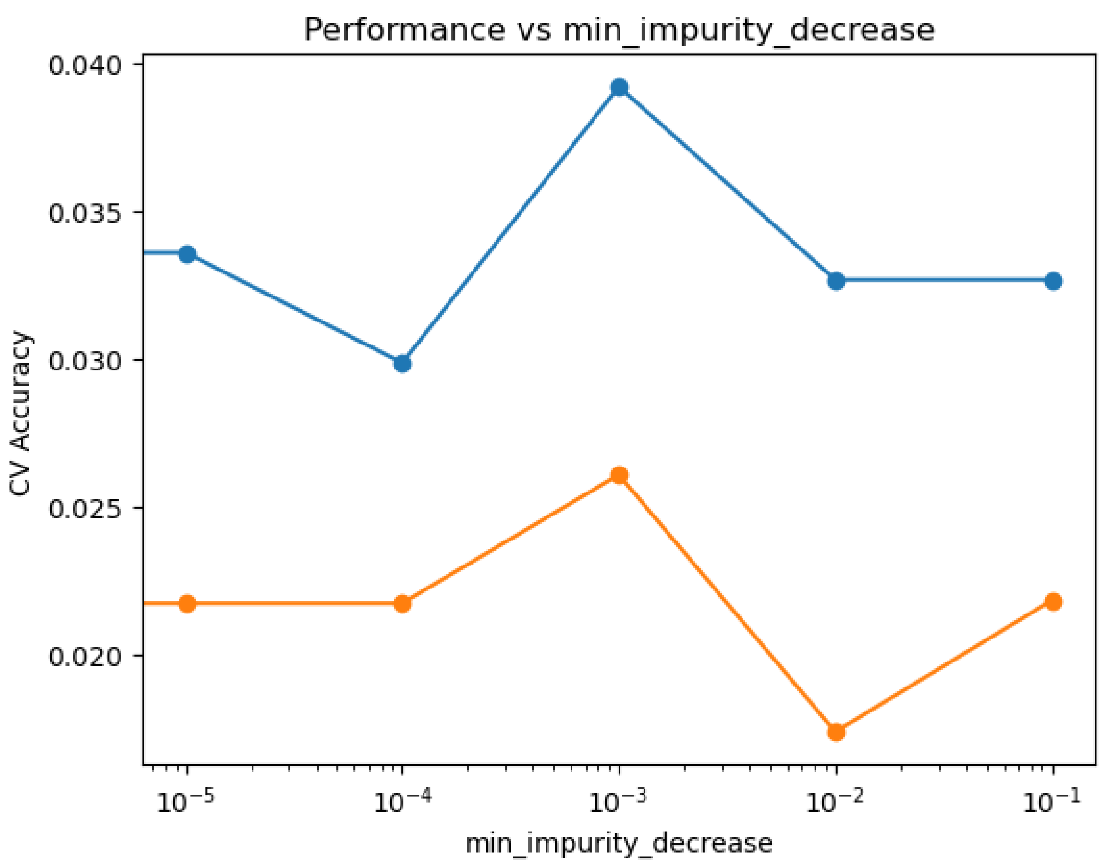
[428]:
```
array([0.05128205, 0.        , 0.11214953, 0.09090909, 0.16949153,
       0.1       , 0.        , 0.        , 0.        , 0.04651163,
       0.23188406, 0.04255319, 0.06060606, 0.        , 0.02941176,
       0.05263158, 0.29787234, 0.10204082, 0.        , 0.        ,
       0.10958904, 0.16326531, 0.18181818, 0.13636364, 0.20224719,
       0.13953488, 0.10869565, 0.        , 0.03333333, 0.12765957])
```

[429]:
```
rf_f1_valid
```

[429]:
```
array([0.        , 0.        , 0.        , 0.08108108, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.36363636, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.11111111, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.10526316])
```

[430]:
```
values = [0.0, 1e-5, 1e-4, 1e-3, 1e-2, 0.1]
scores_train = []
scores_valid = []

for value in values:
    rf = RandomForestClassifier(n_estimators = 10, min_impurity_decrease =␣
 ↪value, random_state = 42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot(values, scores_train, marker = 'o')
plt.plot(values, scores_valid, marker = 'o')
plt.xscale('log')
plt.xlabel('min_impurity_decrease')
plt.ylabel('CV Accuracy')
plt.title('Performance vs min_impurity_decrease')
plt.show()

#1e-3 is the best
```



[431]:
```
rf = RandomForestClassifier(n_estimators = 10, min_impurity_decrease = 1e-3,␣
  ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
  ↪to_numpy().flatten())
```

[431]:
```
RandomForestClassifier(min_impurity_decrease=0.001, n_estimators=10,
                       random_state=42)
```

[432]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[433]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
```

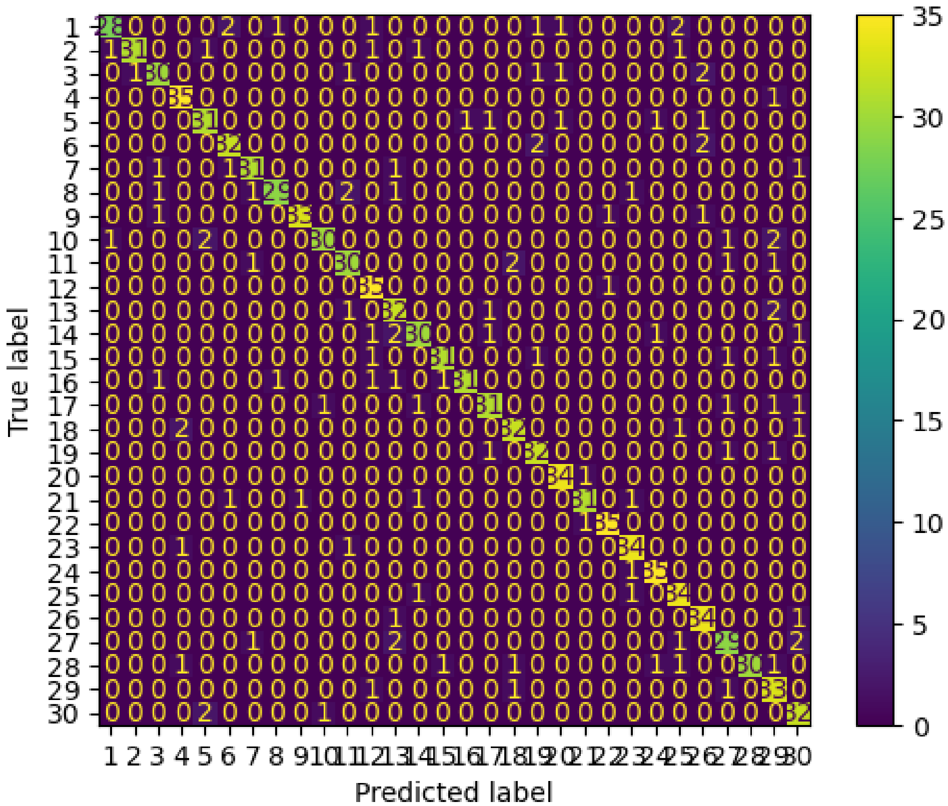
[434]:
```
rf_accuracy_train
```

[434]:
```
0.8916900093370682
```

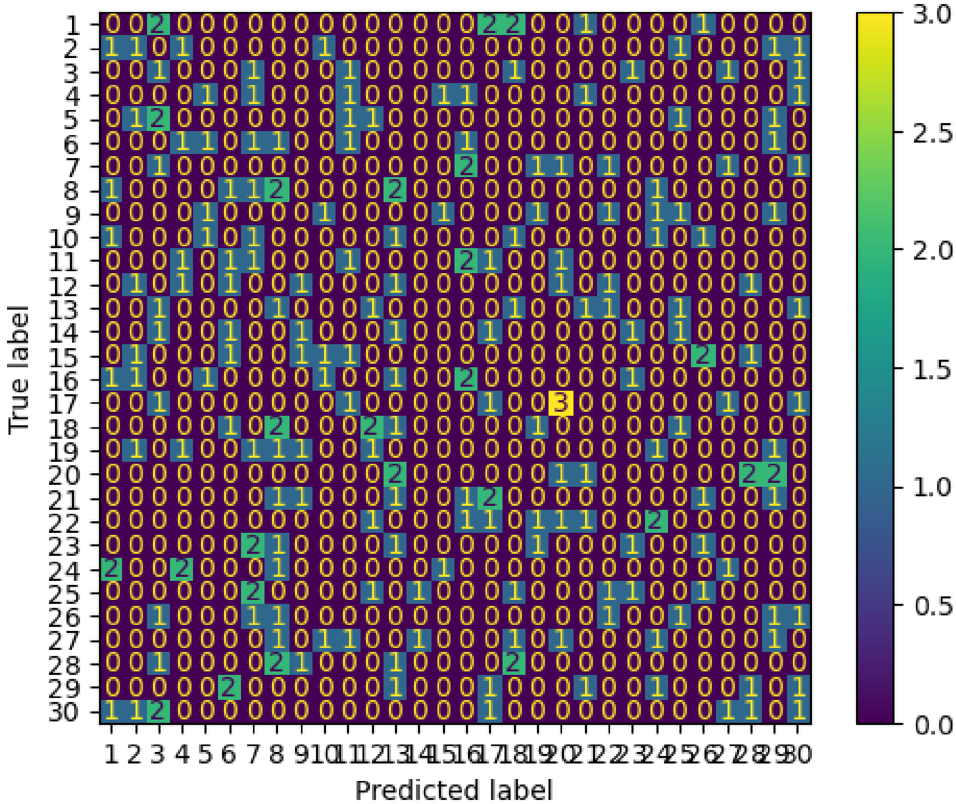
[435]:
```
rf_accuracy_valid
```

[435]:
```
0.048034934497816595
```

[436]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
 ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[437]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[438]:
```
rf_precision_train
```

[438]:
```
array([0.93333333, 0.96875   , 0.88235294, 0.8974359 , 0.86111111,
       0.88888889, 0.91176471, 0.93548387, 0.97058824, 0.9375    ,
       0.85714286, 0.85365854, 0.8       , 0.88235294, 0.93939394,
       0.96875   , 0.88571429, 0.88888889, 0.86486486, 0.91891892,
       0.93939394, 0.94594595, 0.89473684, 0.92105263, 0.85      ,
       0.85      , 0.82857143, 1.        , 0.76744186, 0.82051282])
```

[439]:
```
rf_precision_valid
```

[439]:
```
array([0.        , 0.14285714, 0.07692308, 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.125     , 0.        , 0.        , 0.        , 0.        ,
       0.2       , 0.1       , 0.        , 0.        , 0.11111111,
       0.        , 0.        , 0.2       , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.11111111])
```

[440]:
```
rf_recall_train
```

[440]: array([0.77777778, 0.86111111, 0.83333333, 0.97222222, 0.86111111,
        0.88888889, 0.88571429, 0.82857143, 0.91666667, 0.83333333,
        0.85714286, 0.97222222, 0.88888889, 0.83333333, 0.88571429,
        0.86111111, 0.86111111, 0.88888889, 0.91428571, 0.97142857,
        0.88571429, 0.97222222, 0.94444444, 0.97222222, 0.94444444,
        0.94444444, 0.82857143, 0.83333333, 0.91666667, 0.91428571])

```
[441]: rf_recall_valid
```

```
[441]: array([0.        , 0.14285714, 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.25      , 0.        , 0.        ,
        0.125     , 0.        , 0.        , 0.        , 0.        ,
        0.25      , 0.125     , 0.        , 0.        , 0.125     ,
        0.        , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.125     ])
```

```
[442]: rf_f1_train
```

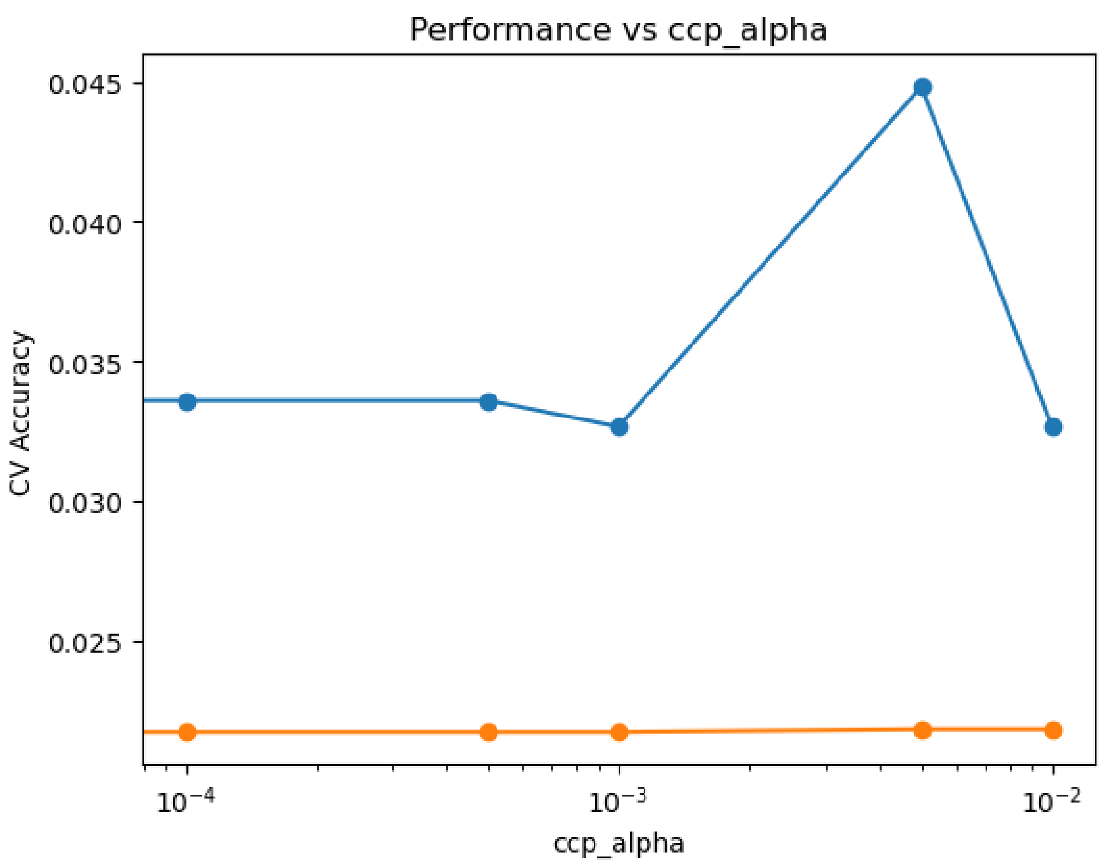
```
[442]: array([0.84848485, 0.91176471, 0.85714286, 0.93333333, 0.86111111,
        0.88888889, 0.89855072, 0.87878788, 0.94285714, 0.88235294,
        0.85714286, 0.90909091, 0.84210526, 0.85714286, 0.91176471,
        0.91176471, 0.87323944, 0.88888889, 0.88888889, 0.94444444,
        0.91176471, 0.95890411, 0.91891892, 0.94594595, 0.89473684,
        0.89473684, 0.82857143, 0.90909091, 0.83544304, 0.86486486])
```

```
[443]: rf_f1_valid
```

```
[443]: array([0.        , 0.14285714, 0.1       , 0.        , 0.        ,
        0.        , 0.        , 0.18181818, 0.        , 0.        ,
        0.125     , 0.        , 0.        , 0.        , 0.        ,
        0.22222222, 0.11111111, 0.        , 0.        , 0.11764706,
        0.        , 0.        , 0.16666667, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.11764706])
```

```
[444]: alphas = [0.0, 1e-4, 5e-4, 1e-3, 5e-3, 1e-2]
scores_train = []
scores_valid = []

for alpha in alphas:
    rf = RandomForestClassifier(n_estimators = 10, ccp_alpha = alpha,␣
 ↪random_state = 42)
    score_train = cross_val_score(rf, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(rf, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
```

```
    scores_train.append(score_train)
    scores_valid.append(score_valid)

plt.plot(alphas, scores_train, marker = 'o')
plt.plot(alphas, scores_valid, marker = 'o')
plt.xscale('log')
plt.xlabel('ccp_alpha')
plt.ylabel('CV Accuracy')
plt.title('Performance vs ccp_alpha')
plt.show()

#5e-3 is the best
```



[445]:
```
rf = RandomForestClassifier(n_estimators = 10, ccp_alpha = 5e-3, random_state =
 ↪42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[445]: RandomForestClassifier(ccp_alpha=0.005, n_estimators=10, random_state=42)

[446]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[447]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

[448]:
```
rf_accuracy_train
```

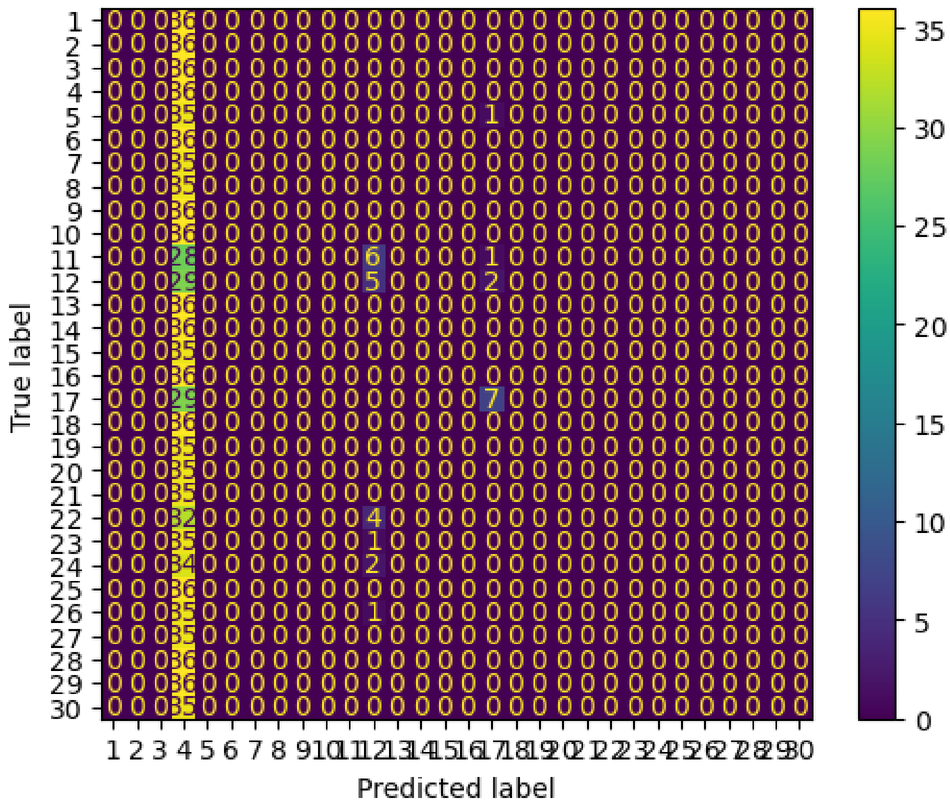
[448]: 0.04481792717086835

[449]:
```
rf_accuracy_valid
```

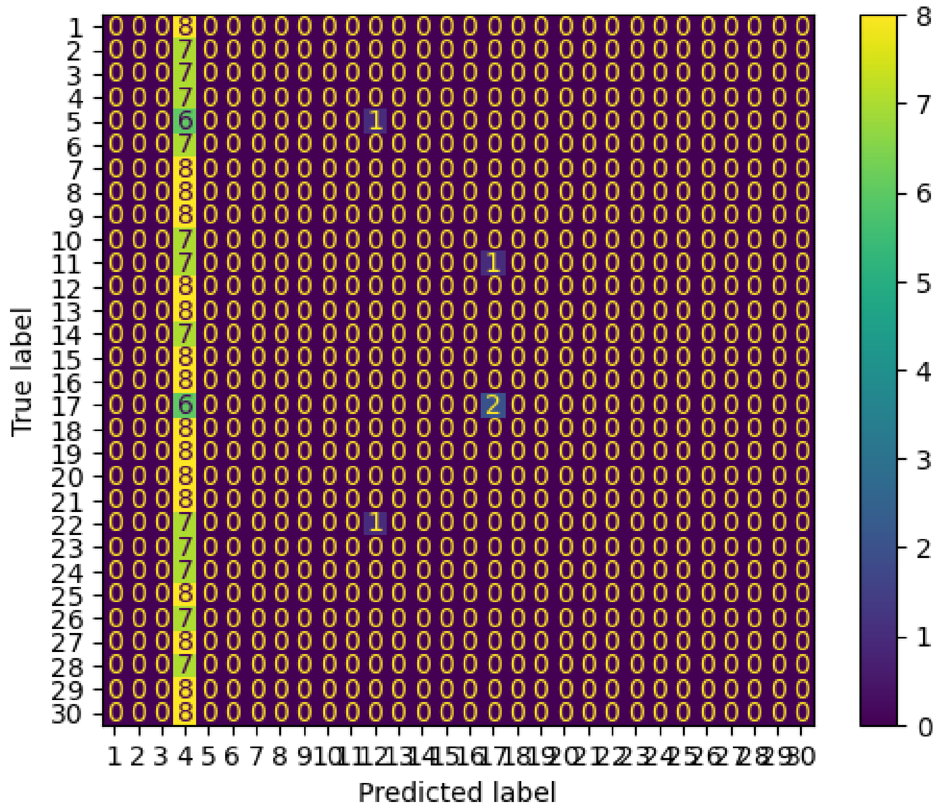
[449]: 0.039301310043668124

[450]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
```

```
disp_rf_train.plot()
plt.show()
```



[451]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
  ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[452]:
```
rf_precision_train
```

[452]:
```
array([0.        , 0.        , 0.        , 0.03458213, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.26315789, 0.        , 0.        , 0.        ,
       0.        , 0.63636364, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[453]:
```
rf_precision_valid
```

[453]:
```
array([0.        , 0.        , 0.        , 0.03125   , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.66666667, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[454]:
```
rf_recall_train
```

[454]:
```
array([0.        , 0.        , 0.        , 1.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.13888889, 0.        , 0.        , 0.        ,
       0.        , 0.19444444, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[455]:
```python
rf_recall_valid
```

[455]:
```
array([0.  , 0.  , 0.  , 1.  , 0.  , 0.  , 0.  , 0.  , 0.  , 0.  , 0.  ,
       0.  , 0.  , 0.  , 0.  , 0.  , 0.25, 0.  , 0.  , 0.  , 0.  , 0.  ,
       0.  , 0.  , 0.  , 0.  , 0.  , 0.  , 0.  , 0.  ])
```

[456]:
```python
rf_f1_train
```

[456]:
```
array([0.        , 0.        , 0.        , 0.06685237, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.18181818, 0.        , 0.        , 0.        ,
       0.        , 0.29787234, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[457]:
```python
rf_f1_valid
```

[457]:
```
array([0.        , 0.        , 0.        , 0.06060606, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.36363636, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[2]:
```python
import dill
dill.load_session('globalsave.pkl')
```

[7]:
```python
#Grid search to tune multiple parameter values
from sklearn.model_selection import GridSearchCV

param_grid = {
    'max_depth': [4, 5, 10, 15, 20, None],
    'n_estimators': [10, 50, 100, 150, 200],
    'max_features': ['sqrt', 'log2', None]
}

rf = RandomForestClassifier(random_state = 42)
grid_train = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
```

```python
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())

print(grid_train.best_params_)
```

```
{'max_depth': 4, 'max_features': None, 'n_estimators': 50}
```

[8]:
```python
#Best validation parameters
print(grid_valid.best_params_)
```

```
{'max_depth': 5, 'max_features': None, 'n_estimators': 10}
```

[9]:
```python
rf = RandomForestClassifier(n_estimators = 10, max_depth = 5, max_features =␣
 ↪None, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[9]:
```
RandomForestClassifier(max_depth=5, max_features=None, n_estimators=10,
                       random_state=42)
```

[10]:
```python
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[11]:
```python
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
```

```
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

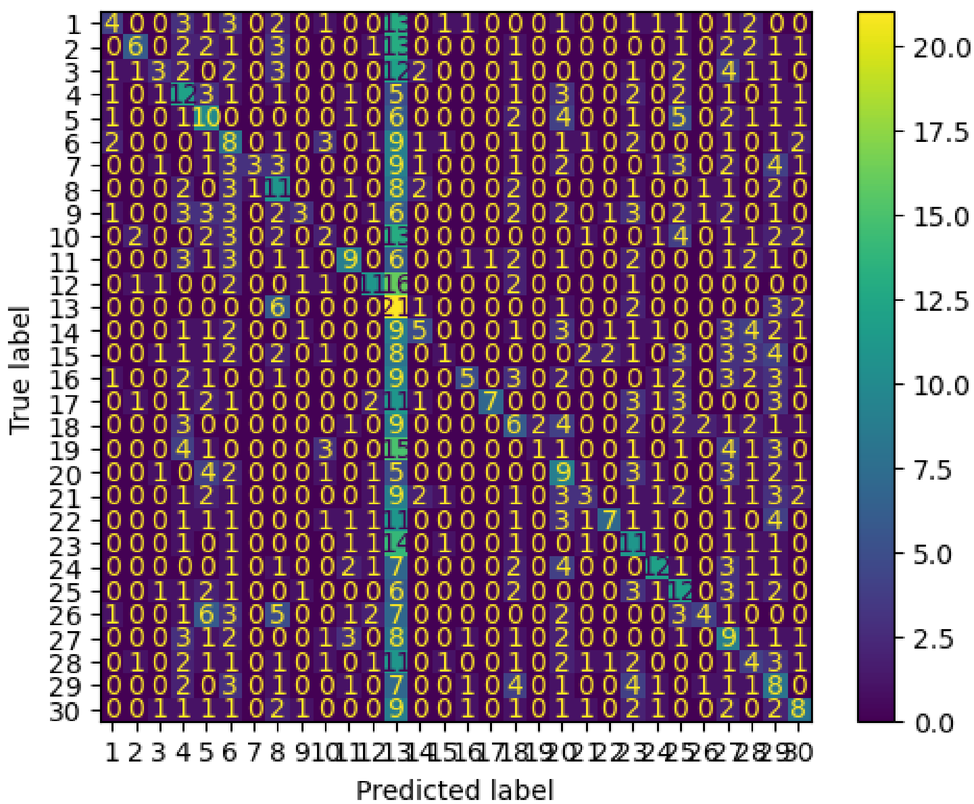
[12]:
```
rf_accuracy_train
```

[12]: 0.20074696545284781

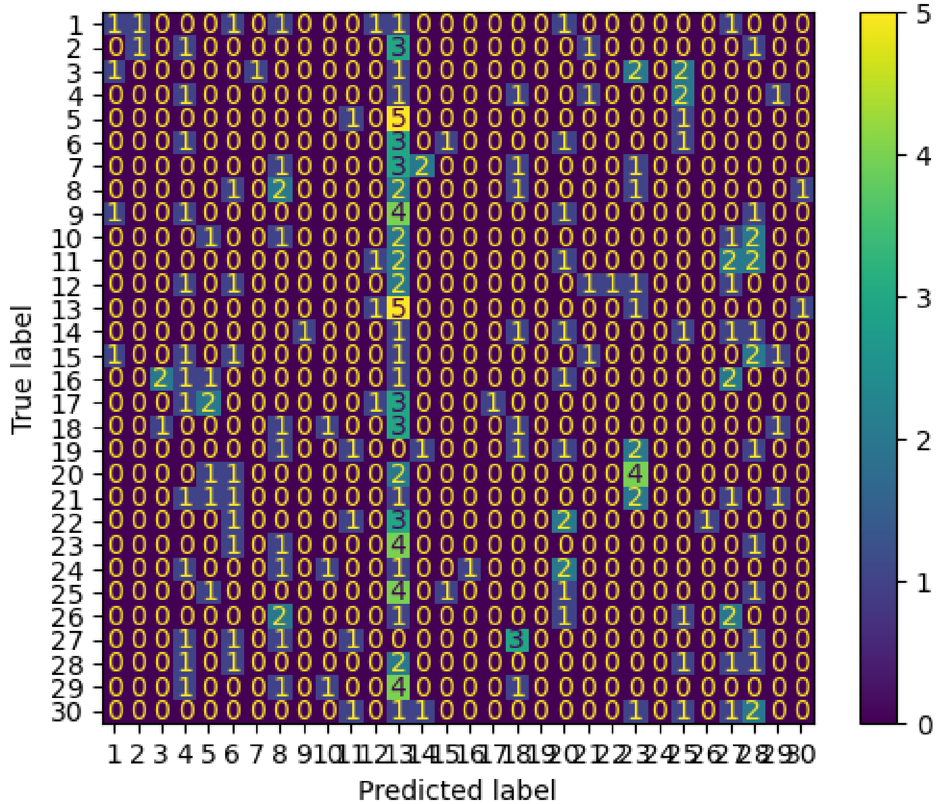
[13]:
```
rf_accuracy_valid
```

[13]: 0.056768558951965066

[14]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
    ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[15]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
    ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[16]:
```
rf_precision_train
```

[16]:
```
array([0.33333333, 0.5       , 0.3       , 0.22641509, 0.20833333,
       0.14814815, 0.75      , 0.22916667, 0.375     , 0.13333333,
       0.40909091, 0.45833333, 0.07191781, 0.33333333, 0.16666667,
       0.5       , 0.875     , 0.15384615, 0.33333333, 0.17307692,
       0.25      , 0.58333333, 0.21568627, 0.48      , 0.24      ,
       0.44444444, 0.15517241, 0.125     , 0.13114754, 0.30769231])
```

[17]:
```
rf_precision_valid
```

[17]:
```
array([0.25      , 0.5       , 0.        , 0.07692308, 0.        ,
       0.        , 0.        , 0.15384615, 0.        , 0.        ,
       0.        , 0.        , 0.07575758, 0.        , 0.        ,
       0.        , 1.        , 0.1       , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.0625    , 0.        , 0.        ])
```

[18]:
```
rf_recall_train
```

[18]:
```
array([0.11111111, 0.16666667, 0.08333333, 0.33333333, 0.27777778,
       0.22222222, 0.08571429, 0.31428571, 0.08333333, 0.05555556,
       0.25714286, 0.30555556, 0.58333333, 0.13888889, 0.02857143,
       0.13888889, 0.19444444, 0.16666667, 0.02857143, 0.25714286,
       0.08571429, 0.19444444, 0.30555556, 0.33333333, 0.33333333,
       0.11111111, 0.25714286, 0.11111111, 0.22222222, 0.22857143])
```

[19]:
```
rf_recall_valid
```

[19]:
```
array([0.125     , 0.14285714, 0.        , 0.14285714, 0.        ,
       0.        , 0.        , 0.25      , 0.        , 0.        ,
       0.        , 0.        , 0.625     , 0.        , 0.        ,
       0.        , 0.125     , 0.125     , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ])
```

[20]:
```
rf_f1_train
```

[20]:
```
array([0.16666667, 0.25      , 0.13043478, 0.26966292, 0.23809524,
       0.17777778, 0.15384615, 0.26506024, 0.13636364, 0.07843137,
       0.31578947, 0.36666667, 0.12804878, 0.19607843, 0.04878049,
       0.2173913 , 0.31818182, 0.16      , 0.05263158, 0.20689655,
       0.12765957, 0.29166667, 0.25287356, 0.39344262, 0.27906977,
       0.17777778, 0.19354839, 0.11764706, 0.16494845, 0.26229508])
```

[21]:
```
rf_f1_valid
```

[21]:
```
array([0.16666667, 0.22222222, 0.        , 0.1       , 0.        ,
       0.        , 0.        , 0.19047619, 0.        , 0.        ,
       0.        , 0.        , 0.13513514, 0.        , 0.        ,
       0.        , 0.22222222, 0.11111111, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.08695652, 0.        , 0.        ])
```

[22]:
```
rf = RandomForestClassifier(n_estimators = 50, max_depth = 4, max_features =␣
 ↪None, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[22]:
```
RandomForestClassifier(max_depth=4, max_features=None, n_estimators=50,
                       random_state=42)
```

[23]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[24]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

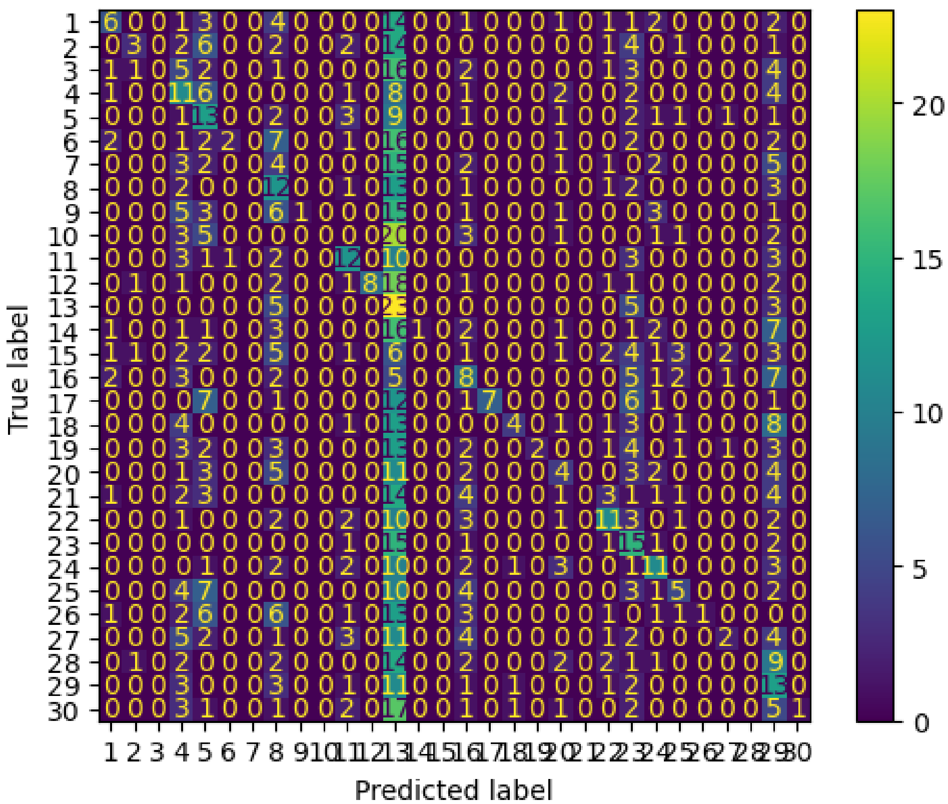
[25]:
```
rf_accuracy_train
```

[25]: 0.16433239962651727

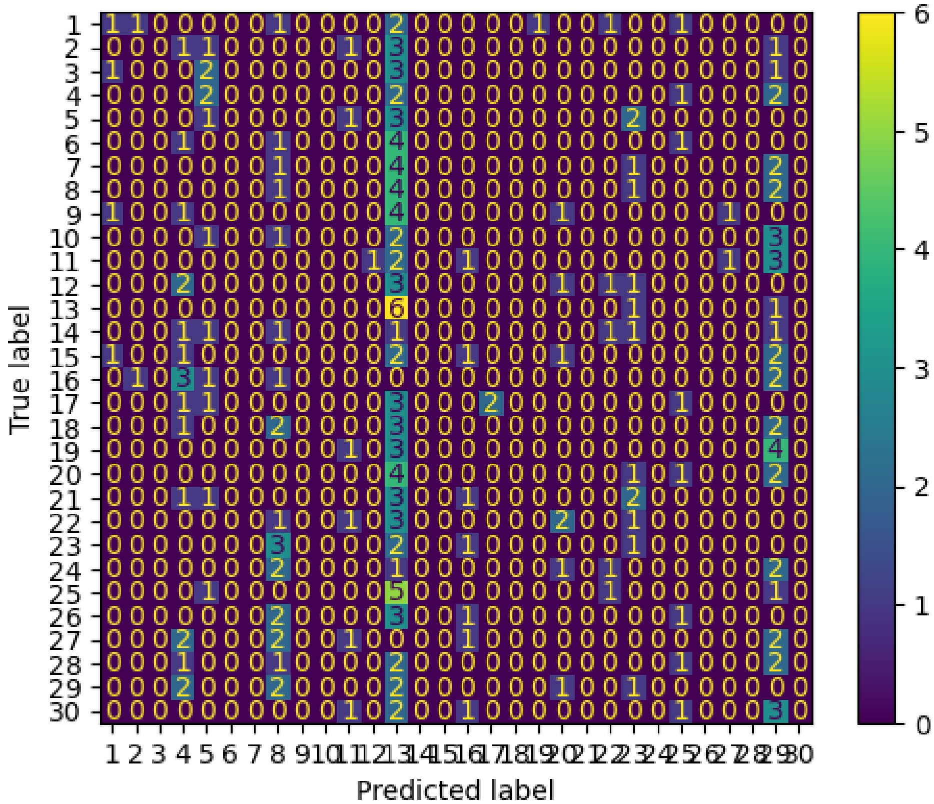
[26]:
```
rf_accuracy_valid
```

[26]: 0.05240174672489083

[27]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[28]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
    display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[29]:
```
rf_precision_train
```

[29]:
```
array([0.375     , 0.42857143, 0.        , 0.14864865, 0.16666667,
       0.66666667, 0.        , 0.14457831, 1.        , 0.        ,
       0.34285714, 1.        , 0.05867347, 1.        , 0.        ,
       0.14814815, 1.        , 0.57142857, 1.        , 0.17391304,
       0.        , 0.36666667, 0.18518519, 0.34375   , 0.27777778,
       1.        , 0.28571429, 0.        , 0.11818182, 1.        ])
```

[30]:
```
rf_precision_valid
```

[30]:
```
array([0.25      , 0.        , 0.        , 0.        , 0.08333333,
       0.        , 0.        , 0.04545455, 0.        , 0.        ,
       0.        , 0.        , 0.07407407, 0.        , 0.        ,
       0.        , 1.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.07692308, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[31]:
```
rf_recall_train
```

```
[31]: array([0.16666667, 0.08333333, 0.        , 0.30555556, 0.36111111,
        0.05555556, 0.        , 0.34285714, 0.02777778, 0.        ,
        0.34285714, 0.22222222, 0.63888889, 0.02777778, 0.        ,
        0.22222222, 0.19444444, 0.11111111, 0.05714286, 0.11428571,
        0.        , 0.30555556, 0.41666667, 0.30555556, 0.13888889,
        0.02777778, 0.05714286, 0.        , 0.36111111, 0.02857143])
```

```
[32]: rf_recall_valid
```

```
[32]: array([0.125     , 0.        , 0.        , 0.        , 0.14285714,
        0.        , 0.        , 0.125     , 0.        , 0.        ,
        0.        , 0.        , 0.75      , 0.        , 0.        ,
        0.        , 0.25      , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ])
```

```
[33]: rf_f1_train
```

```
[33]: array([0.23076923, 0.13953488, 0.        , 0.2       , 0.22807018,
        0.1025641 , 0.        , 0.20338983, 0.05405405, 0.        ,
        0.34285714, 0.36363636, 0.10747664, 0.05405405, 0.        ,
        0.17777778, 0.3255814 , 0.18604651, 0.10810811, 0.13793103,
        0.        , 0.33333333, 0.25641026, 0.32352941, 0.18518519,
        0.05405405, 0.0952381 , 0.        , 0.17808219, 0.05555556])
```

```
[34]: rf_f1_valid
```

```
[34]: array([0.16666667, 0.        , 0.        , 0.        , 0.10526316,
        0.        , 0.        , 0.06666667, 0.        , 0.        ,
        0.        , 0.        , 0.13483146, 0.        , 0.        ,
        0.        , 0.4       , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.1       , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ])
```

```
[35]: param_grid = {
    'max_depth': [4, 5, 10, 15, 20, None],
    'n_estimators': [10, 50, 100, 150, 200],
    'min_samples_split': [2, 5, 10, 20, 50, 60, 70]
}

rf = RandomForestClassifier(random_state = 42)
grid_train = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```
print(grid_train.best_params_)
```

```
{'max_depth': 15, 'min_samples_split': 70, 'n_estimators': 50}
```

[36]:
```
print(grid_valid.best_params_)
```

```
{'max_depth': 4, 'min_samples_split': 70, 'n_estimators': 10}
```

[37]:
```
rf = RandomForestClassifier(n_estimators = 50, max_depth = 15,␣
 ↪min_samples_split = 70, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[37]:
```
RandomForestClassifier(max_depth=15, min_samples_split=70, n_estimators=50,
                       random_state=42)
```

[38]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[39]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

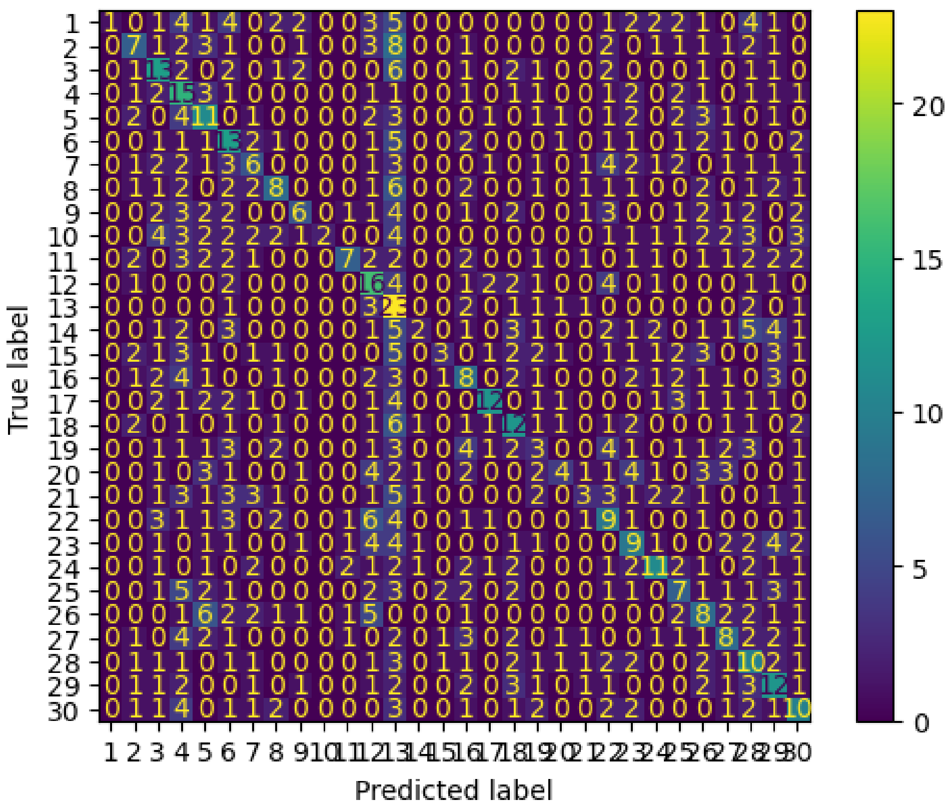
[40]:
```
rf_accuracy_train
```

[40]: 0.24183006535947713

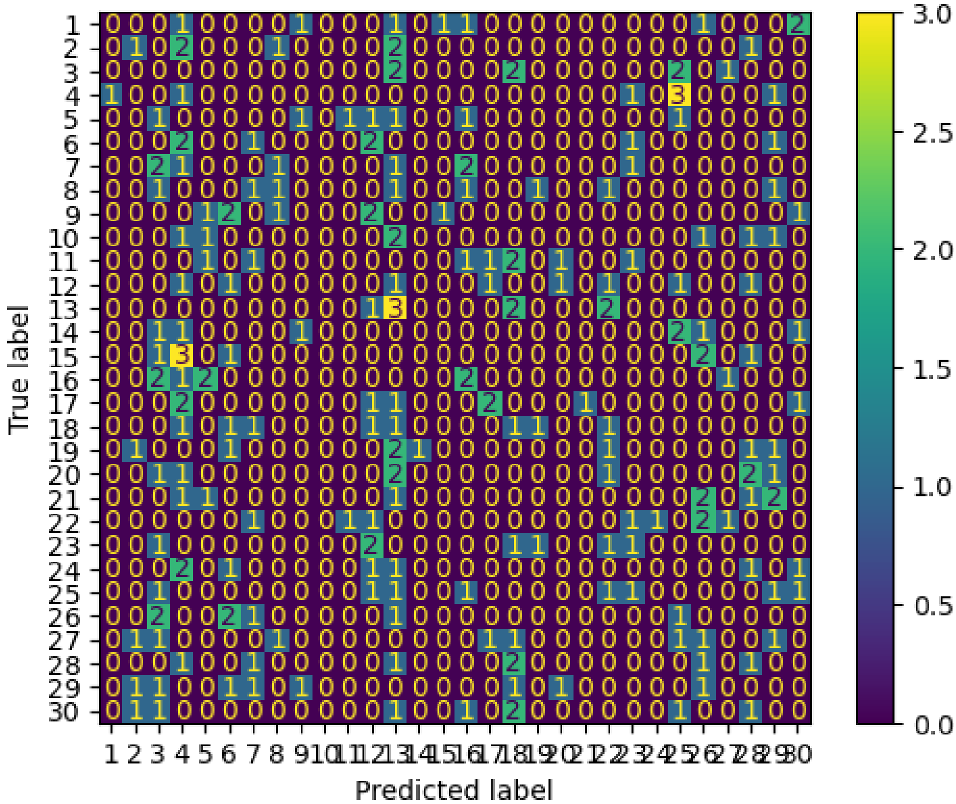
[41]:
```
rf_accuracy_valid
```

[41]: 0.056768558951965066

[42]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
  ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[43]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
  ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[44]:
```
rf_precision_train
```

[44]:
```
array([1.        , 0.28      , 0.28888889, 0.2027027 , 0.22916667,
       0.22413793, 0.23076923, 0.32      , 0.35294118, 1.        ,
       0.5       , 0.24615385, 0.17692308, 0.28571429, 0.375     ,
       0.19047619, 0.57142857, 0.28571429, 0.11538462, 0.33333333,
       0.23076923, 0.18367347, 0.2195122 , 0.39285714, 0.20588235,
       0.18604651, 0.24242424, 0.18518519, 0.24489796, 0.25641026])
```

[45]:
```
rf_precision_valid
```

[45]:
```
array([0.        , 0.2       , 0.        , 0.04545455, 0.        ,
       0.        , 0.        , 0.2       , 0.        , 0.        ,
       0.        , 0.        , 0.11538462, 0.        , 0.        ,
       0.2       , 0.4       , 0.07142857, 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.09090909, 0.        , 0.        ])
```

[46]:
```
rf_recall_train
```

```
[46]: array([0.02777778, 0.19444444, 0.36111111, 0.41666667, 0.30555556,
       0.36111111, 0.17142857, 0.22857143, 0.16666667, 0.05555556,
       0.2       , 0.44444444, 0.63888889, 0.05555556, 0.08571429,
       0.22222222, 0.33333333, 0.33333333, 0.08571429, 0.11428571,
       0.08571429, 0.25      , 0.25      , 0.30555556, 0.19444444,
       0.22222222, 0.22857143, 0.27777778, 0.33333333, 0.28571429])
```

```
[47]: rf_recall_valid
```

```
[47]: array([0.        , 0.14285714, 0.        , 0.14285714, 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.        , 0.375     , 0.        , 0.        ,
       0.25      , 0.25      , 0.125     , 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ])
```

```
[48]: rf_f1_train
```

```
[48]: array([0.05405405, 0.2295082 , 0.32098765, 0.27272727, 0.26190476,
       0.27659574, 0.19672131, 0.26666667, 0.22641509, 0.10526316,
       0.28571429, 0.31683168, 0.27710843, 0.09302326, 0.13953488,
       0.20512821, 0.42105263, 0.30769231, 0.09836066, 0.17021277,
       0.125     , 0.21176471, 0.23376623, 0.34375   , 0.2       ,
       0.20253165, 0.23529412, 0.22222222, 0.28235294, 0.27027027])
```

```
[49]: rf_f1_valid
```

```
[49]: array([0.        , 0.16666667, 0.        , 0.06896552, 0.        ,
       0.        , 0.        , 0.15384615, 0.        , 0.        ,
       0.        , 0.        , 0.17647059, 0.        , 0.        ,
       0.22222222, 0.30769231, 0.09090909, 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.11111111, 0.        , 0.        ])
```

```
[50]: rf = RandomForestClassifier(n_estimators = 10, max_depth = 4, min_samples_split␣
      ↪= 70, random_state = 42)
      rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
      ↪to_numpy().flatten())
```

```
[50]: RandomForestClassifier(max_depth=4, min_samples_split=70, n_estimators=10,
                             random_state=42)
```

```
[51]: rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
      ↪'Color'], axis=1))
      rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
      ↪'Color'], axis=1))
```

[52]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

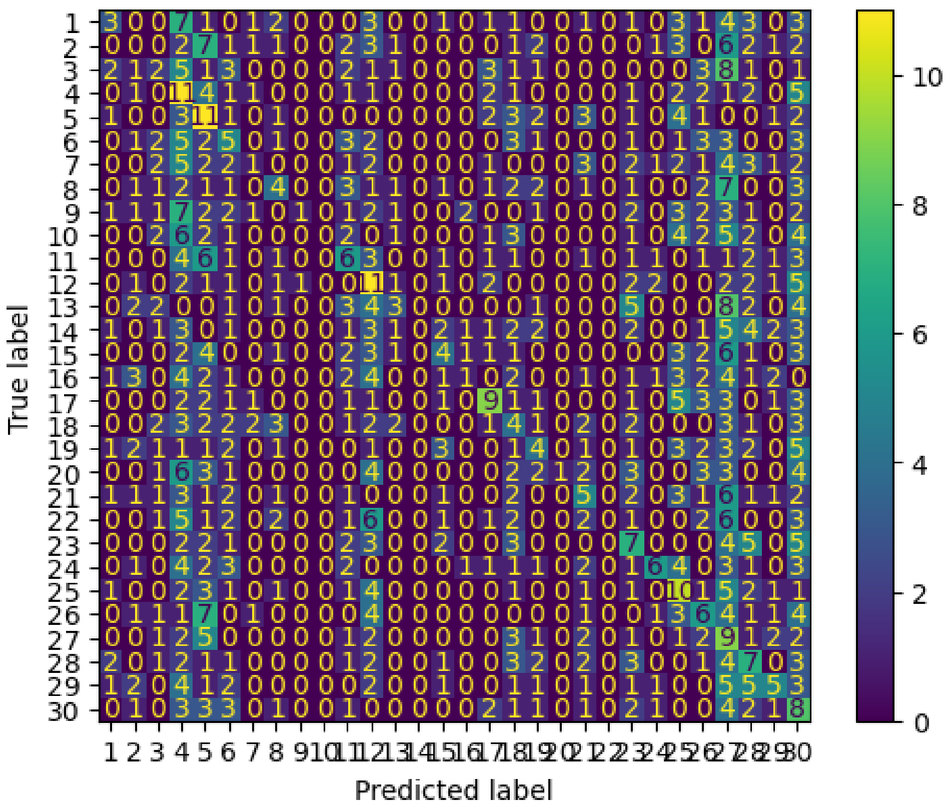
[53]:
```
rf_accuracy_train
```

[53]: 0.13445378151260504

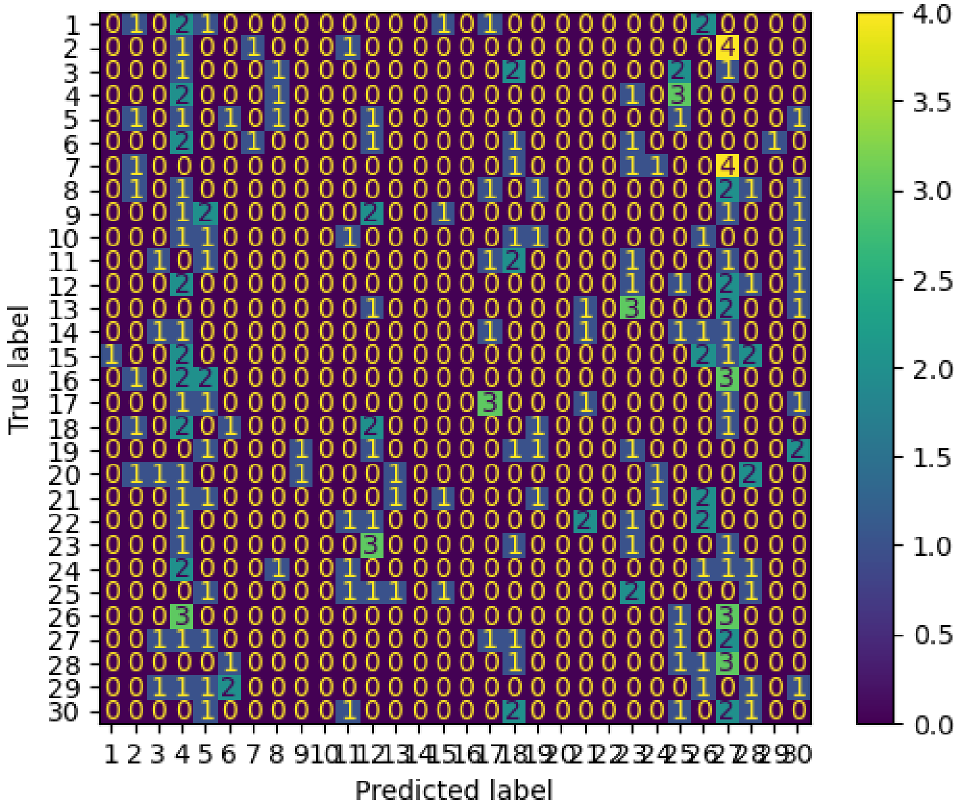
[54]:
```
rf_accuracy_valid
```

[54]: 0.039301310043668124

[55]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[56]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
    display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[57]:
```
rf_precision_train
```

[57]:
```
array([0.2       , 0.        , 0.09090909, 0.10185185, 0.1375    ,
       0.11627907, 0.11111111, 0.18181818, 0.5       , 0.        ,
       0.14634146, 0.14864865, 0.23076923, 0.        , 0.19047619,
       0.16666667, 0.3       , 0.08695652, 0.15384615, 1.        ,
       0.15625   , 0.        , 0.14893617, 0.4       , 0.1754386 ,
       0.13636364, 0.06976744, 0.12962963, 0.23809524, 0.08510638])
```

[58]:
```
rf_precision_valid
```

[58]:
```
array([0.        , 0.        , 0.        , 0.06060606, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.375     , 0.        , 0.2       , 0.        ,
       0.        , 0.        , 0.07692308, 0.        , 0.        ,
       0.        , 0.05555556, 0.        , 0.        , 0.        ])
```

[59]:
```
rf_recall_train
```

[59]: array([0.08333333, 0.   , 0.05555556, 0.30555556, 0.30555556,
       0.13888889, 0.02857143, 0.11428571, 0.02777778, 0.   ,
       0.17142857, 0.30555556, 0.08333333, 0.   , 0.11428571,
       0.02777778, 0.25   , 0.11111111, 0.11428571, 0.02857143,
       0.14285714, 0.   , 0.19444444, 0.16666667, 0.27777778,
       0.16666667, 0.25714286, 0.19444444, 0.13888889, 0.22857143])

[60]:
```
rf_recall_valid
```

[60]: array([0.   , 0.   , 0.   , 0.28571429, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.375   , 0.   , 0.125   , 0.   ,
       0.   , 0.   , 0.14285714, 0.   , 0.   ,
       0.   , 0.25   , 0.   , 0.   , 0.   ])

[61]:
```
rf_f1_train
```

[61]: array([0.11764706, 0.   , 0.06896552, 0.15277778, 0.18965517,
       0.12658228, 0.04545455, 0.14035088, 0.05263158, 0.   ,
       0.15789474, 0.2   , 0.12244898, 0.   , 0.14285714,
       0.04761905, 0.27272727, 0.09756098, 0.13114754, 0.05555556,
       0.14925373, 0.   , 0.1686747 , 0.23529412, 0.21505376,
       0.15   , 0.1097561 , 0.15555556, 0.1754386 , 0.12403101])

[62]:
```
rf_f1_valid
```

[62]: array([0.   , 0.   , 0.   , 0.1   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.375   , 0.   , 0.15384615, 0.   ,
       0.   , 0.   , 0.1   , 0.   , 0.   ,
       0.   , 0.09090909, 0.   , 0.   , 0.   ])

[63]:
```
param_grid = {
    'max_depth': [4, 5, 10, 15, 20, None],
    'n_estimators': [10, 50, 100, 150, 200],
    'min_samples_leaf': [2, 5, 10, 20, 50, 60, 70]
}

rf = RandomForestClassifier(random_state = 42)
grid_train = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
↪y_valid.to_numpy().flatten())
```

```
print(grid_train.best_params_)
```

{'max_depth': 5, 'min_samples_leaf': 50, 'n_estimators': 100}

[64]:
```
print(grid_valid.best_params_)
```

{'max_depth': 4, 'min_samples_leaf': 20, 'n_estimators': 200}

[78]:
```
rf = RandomForestClassifier(n_estimators = 100, max_depth = 5, min_samples_leaf␣
↪= 50, random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
↪to_numpy().flatten())
```

[78]: RandomForestClassifier(max_depth=5, min_samples_leaf=50, random_state=42)

[79]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[80]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
```

```
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

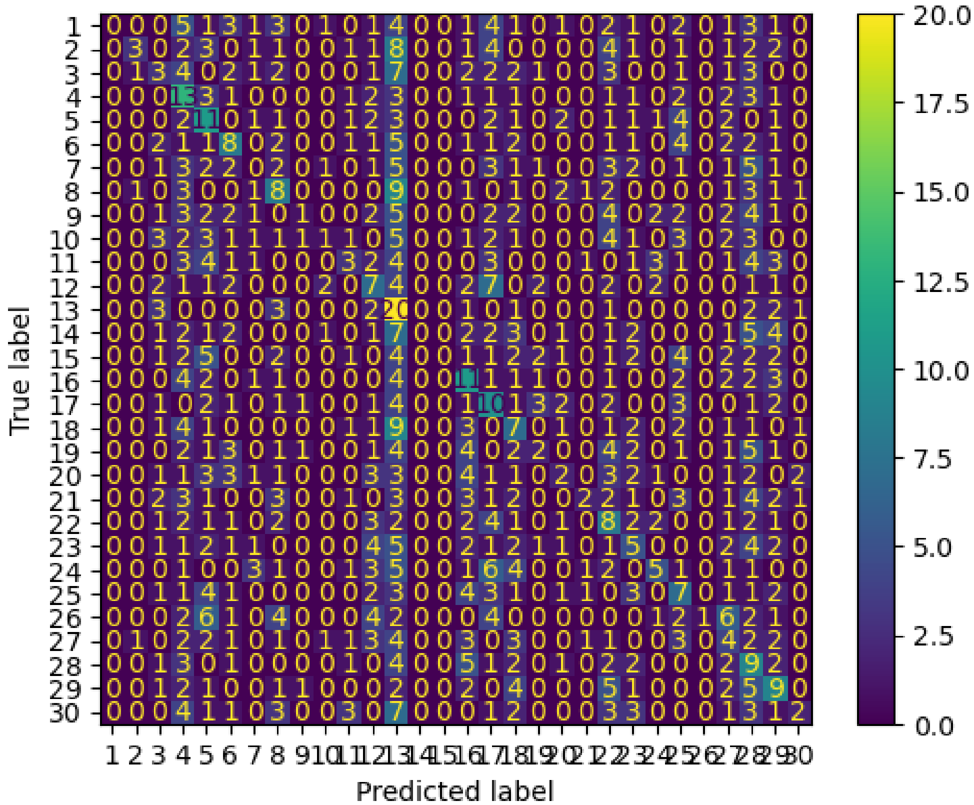
[81]:
```python
rf_accuracy_train
```

[81]: 0.15126050420168066

[82]:
```python
rf_accuracy_valid
```

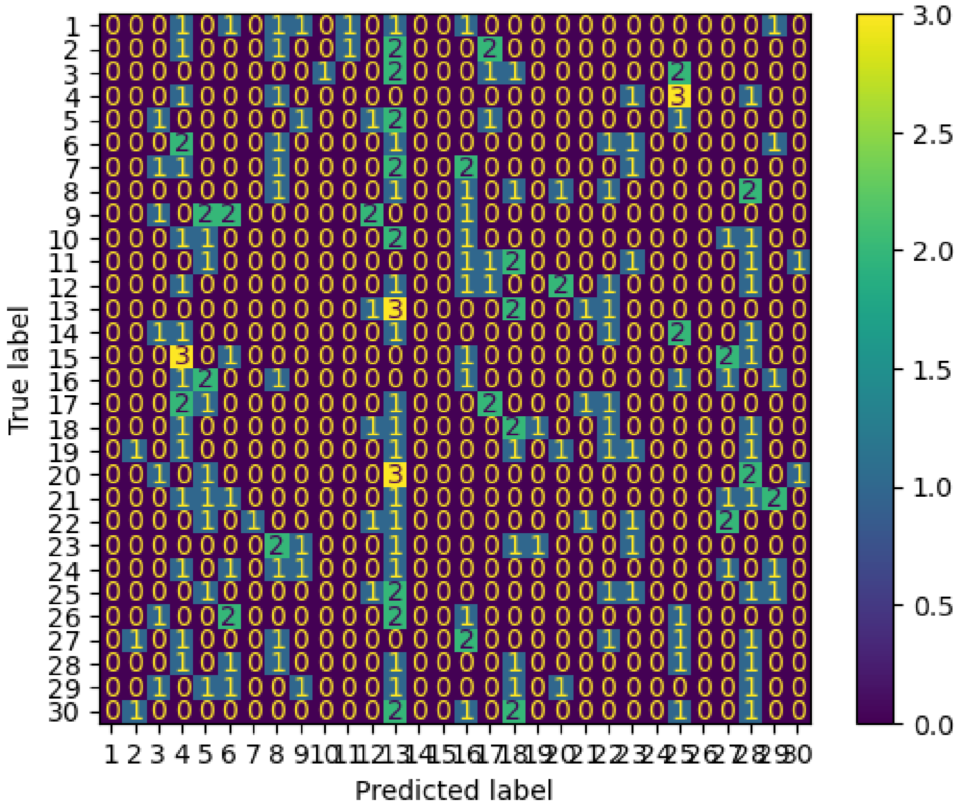
[82]: 0.05240174672489083

[83]:
```python
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
 ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[84]:
```python
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_rf_valid.plot()
```

```
plt.show()
```



[85]:
```
rf_precision_train
```

[85]:
```
array([0.        , 0.5       , 0.11111111, 0.16666667, 0.171875  ,
       0.21052632, 0.        , 0.18181818, 0.2       , 0.14285714,
       0.17647059, 0.14583333, 0.12987013, 0.        , 0.        ,
       0.18644068, 0.14925373, 0.1372549 , 0.15384615, 0.125     ,
       0.28571429, 0.12307692, 0.13888889, 0.29411765, 0.14285714,
       1.        , 0.08888889, 0.10465116, 0.18367347, 0.25      ])
```

[86]:
```
rf_precision_valid
```

[86]:
```
array([0.        , 0.        , 0.        , 0.04761905, 0.        ,
       0.        , 0.        , 0.08333333, 0.        , 0.        ,
       0.        , 0.        , 0.08333333, 0.        , 0.        ,
       0.07142857, 0.25      , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.        , 0.05555556, 0.        , 0.        ])
```

[87]:
```
rf_recall_train
```

```
[87]: array([0.        , 0.08333333, 0.08333333, 0.36111111, 0.30555556,
       0.22222222, 0.        , 0.22857143, 0.02777778, 0.02777778,
       0.08571429, 0.19444444, 0.55555556, 0.        , 0.        ,
       0.30555556, 0.27777778, 0.19444444, 0.05714286, 0.05714286,
       0.05714286, 0.22222222, 0.13888889, 0.13888889, 0.19444444,
       0.02777778, 0.11428571, 0.25      , 0.25      , 0.05714286])
```

```
[88]: rf_recall_valid
```

```
[88]: array([0.        , 0.        , 0.        , 0.14285714, 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.        , 0.        , 0.375     , 0.        , 0.        ,
       0.125     , 0.25      , 0.25      , 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ])
```

```
[89]: rf_f1_train
```

```
[89]: array([0.        , 0.14285714, 0.0952381 , 0.22807018, 0.22      ,
       0.21621622, 0.        , 0.20253165, 0.04878049, 0.04651163,
       0.11538462, 0.16666667, 0.21052632, 0.        , 0.        ,
       0.23157895, 0.19417476, 0.16091954, 0.08333333, 0.07843137,
       0.0952381 , 0.15841584, 0.13888889, 0.18867925, 0.16470588,
       0.05405405, 0.1       , 0.14754098, 0.21176471, 0.09302326])
```

```
[90]: rf_f1_valid
```

```
[90]: array([0.        , 0.        , 0.        , 0.07142857, 0.        ,
       0.        , 0.        , 0.1       , 0.        , 0.        ,
       0.        , 0.        , 0.13636364, 0.        , 0.        ,
       0.09090909, 0.25      , 0.18181818, 0.        , 0.        ,
       0.        , 0.        , 0.13333333, 0.        , 0.        ,
       0.        , 0.        , 0.08      , 0.        , 0.        ])
```

```
[91]: rf = RandomForestClassifier(n_estimators = 200, max_depth = 4, min_samples_leaf␣
       ↪= 20, random_state = 42)
      rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
       ↪to_numpy().flatten())
```

```
[91]: RandomForestClassifier(max_depth=4, min_samples_leaf=20, n_estimators=200,
                             random_state=42)
```

```
[92]: rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
       ↪'Color'], axis=1))
      rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
       ↪'Color'], axis=1))
```

[93]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

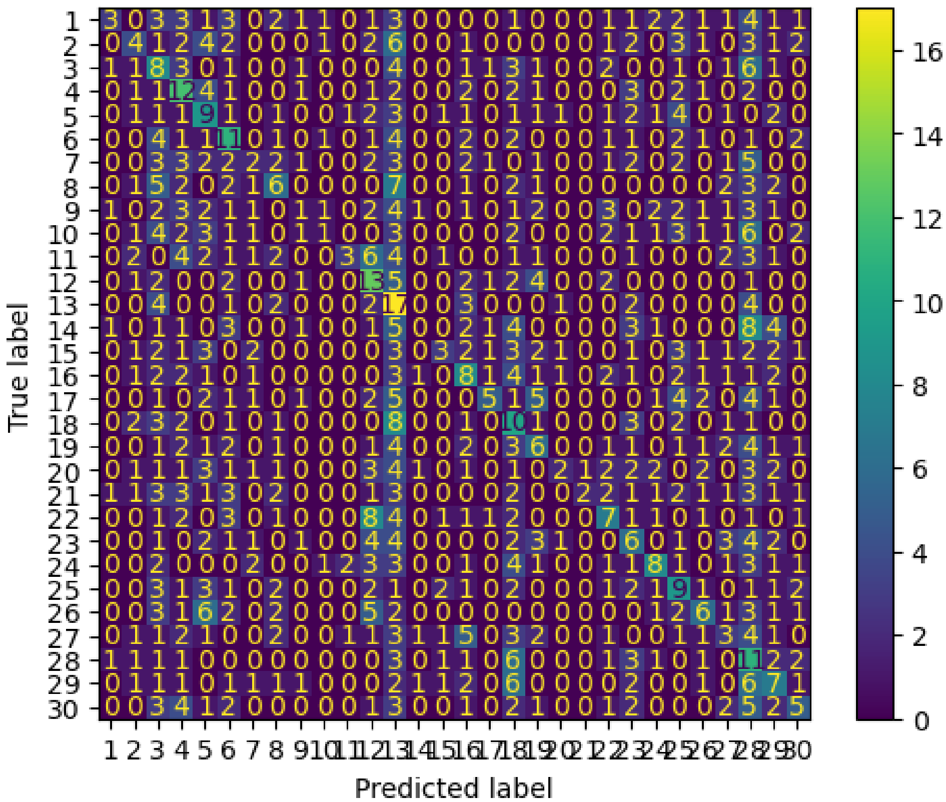
[95]:
```
rf_accuracy_train
```

[95]: 0.17553688141923435

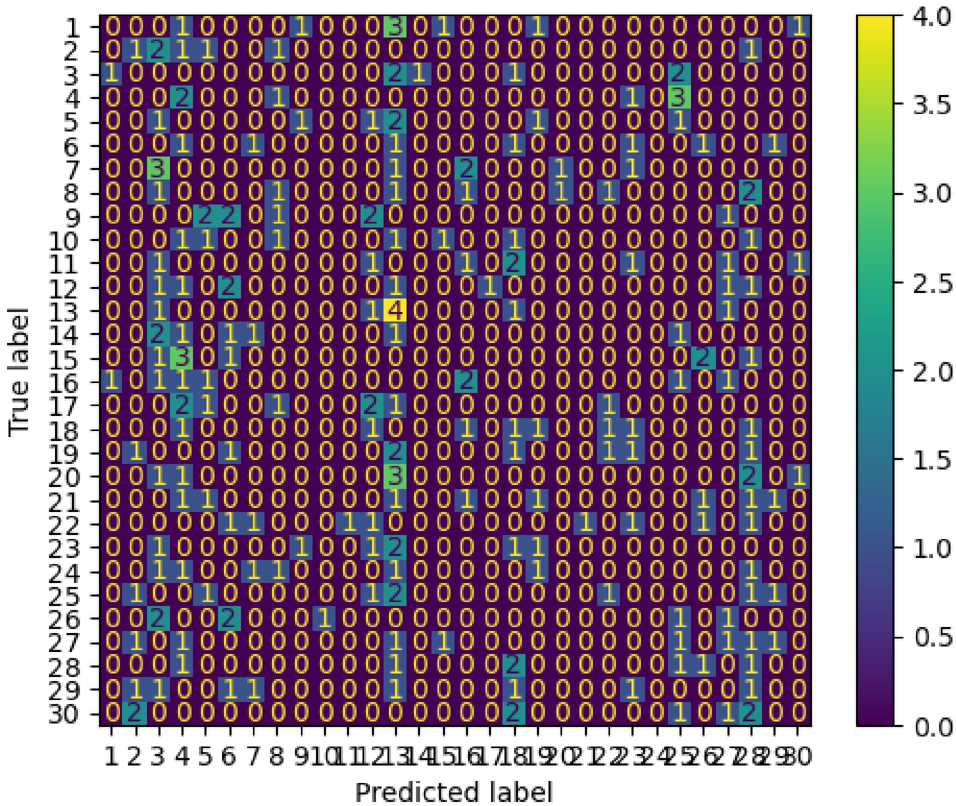
[96]:
```
rf_accuracy_valid
```

[96]: 0.056768558951965066

[97]:
```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[98]:
```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
    display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[99]:
```
rf_precision_train
```

[99]:
```
array([0.375     , 0.19047619, 0.11764706, 0.2       , 0.17307692,
       0.22      , 0.13333333, 0.20689655, 0.09090909, 0.16666667,
       0.42857143, 0.203125  , 0.136     , 0.        , 0.27272727,
       0.18181818, 0.41666667, 0.13888889, 0.17647059, 0.28571429,
       0.66666667, 0.21212121, 0.13636364, 0.34782609, 0.18367347,
       0.24      , 0.11538462, 0.1047619 , 0.17948718, 0.2173913 ])
```

[100]:
```
rf_precision_valid
```

[100]:
```
array([0.        , 0.14285714, 0.        , 0.1       , 0.        ,
       0.        , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.125     , 0.        , 0.        ,
       0.25      , 0.        , 0.07142857, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.125     , 0.05263158, 0.        , 0.        ])
```

[101]:
```
rf_recall_train
```

[101]: array([0.08333333, 0.11111111, 0.22222222, 0.33333333, 0.25   ,
        0.30555556, 0.05714286, 0.17142857, 0.02777778, 0.02777778,
        0.08571429, 0.36111111, 0.47222222, 0.   , 0.08571429,
        0.22222222, 0.13888889, 0.27777778, 0.17142857, 0.05714286,
        0.05714286, 0.19444444, 0.16666667, 0.22222222, 0.25   ,
        0.16666667, 0.08571429, 0.30555556, 0.19444444, 0.14285714])

[102]:
```
rf_recall_valid
```

[102]: array([0.   , 0.14285714, 0.   , 0.28571429, 0.   ,
        0.   , 0.   , 0.125   , 0.   , 0.   ,
        0.   , 0.   , 0.5   , 0.   , 0.   ,
        0.25   , 0.   , 0.125   , 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.14285714, 0.   , 0.   ])

[103]:
```
rf_f1_train
```

[103]: array([0.13636364, 0.14035088, 0.15384615, 0.25   , 0.20454545,
        0.25581395, 0.08   , 0.1875   , 0.04255319, 0.04761905,
        0.14285714, 0.26   , 0.21118012, 0.   , 0.13043478,
        0.2   , 0.20833333, 0.18518519, 0.17391304, 0.0952381 ,
        0.10526316, 0.20289855, 0.15   , 0.27118644, 0.21176471,
        0.19672131, 0.09836066, 0.15602837, 0.18666667, 0.17241379])

[104]:
```
rf_f1_valid
```

[104]: array([0.   , 0.14285714, 0.   , 0.14814815, 0.   ,
        0.   , 0.   , 0.13333333, 0.   , 0.   ,
        0.   , 0.   , 0.2   , 0.   , 0.   ,
        0.25   , 0.   , 0.09090909, 0.   , 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.07692308, 0.   , 0.   ])

[2]:
```
param_grid = {
    'max_features': ['sqrt', 'log2', 0.2, 0.5, None],
    'n_estimators': [10, 50, 100, 150, 200],
}

rf = RandomForestClassifier(random_state = 42)
grid_train = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```
print(grid_train.best_params_)
```

```
{'max_features': None, 'n_estimators': 200}
```

[3]:
```
print(grid_valid.best_params_)
```

```
{'max_features': None, 'n_estimators': 10}
```

[4]:
```
rf = RandomForestClassifier(n_estimators = 200, max_features = None,␣
  ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
  ↪to_numpy().flatten())
```

[4]:
```
RandomForestClassifier(max_features=None, n_estimators=200, random_state=42)
```

[5]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
  ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
  ↪'Color'], axis=1))
```

[6]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
  ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
  ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
  ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
  ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),␣
  ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
  ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,␣
  ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
  ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,␣
  ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,␣
  ↪average=None)
```

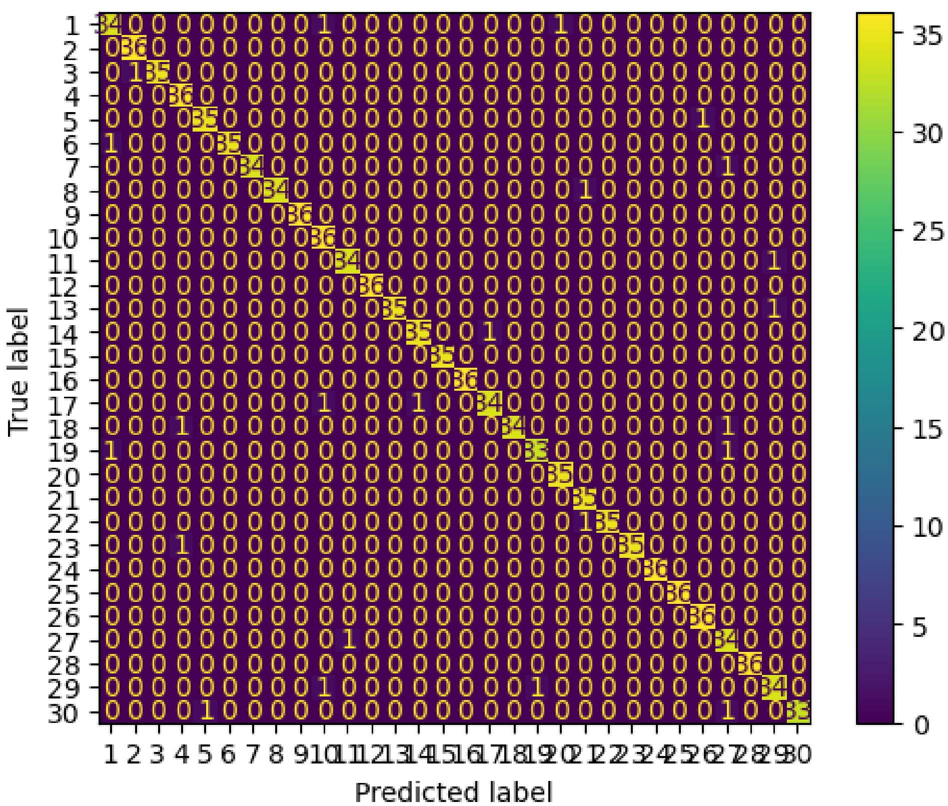
[7]:
```
rf_accuracy_train
```

[7]:
```
0.9785247432306255
```

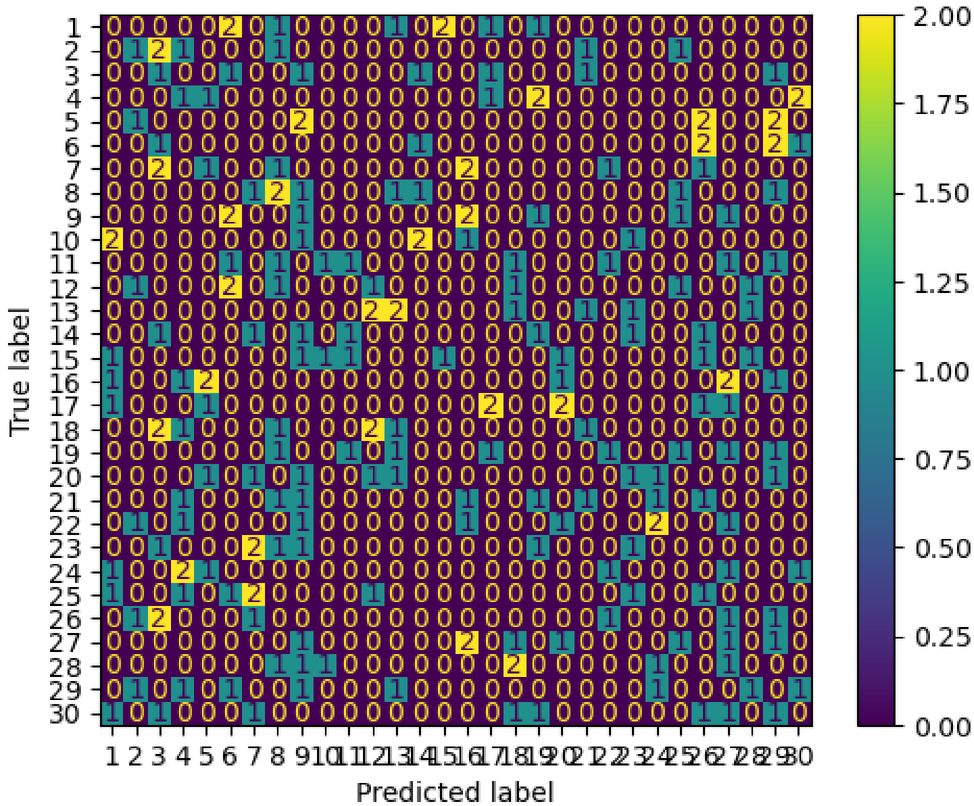
[8]:
```
rf_accuracy_valid
```

[8]:
```
0.06986899563318777
```

```
[9]: disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,
      display_labels=range(1,31))
     disp_rf_train.plot()
     plt.show()
```




```
[10]: disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,
       display_labels=range(1,31))
      disp_rf_valid.plot()
      plt.show()
```



[11]:
```
rf_precision_train
```

[11]:
```
array([0.94444444, 0.97297297, 1.        , 0.94736842, 0.97222222,
       1.        , 1.        , 1.        , 1.        , 0.92307692,
       0.97142857, 1.        , 1.        , 0.97222222, 1.        ,
       1.        , 0.97142857, 1.        , 0.97058824, 0.97222222,
       0.94594595, 1.        , 1.        , 1.        , 1.        ,
       0.97297297, 0.89473684, 1.        , 0.94444444, 1.        ])
```

[12]:
```
rf_precision_valid
```

[12]:
```
array([0.        , 0.16666667, 0.07692308, 0.1       , 0.        ,
       0.        , 0.        , 0.16666667, 0.06666667, 0.        ,
       0.25      , 0.14285714, 0.25      , 0.        , 0.33333333,
       0.        , 0.33333333, 0.        , 0.        , 0.        ,
       0.2       , 0.        , 0.16666667, 0.        , 0.        ,
       0.        , 0.08333333, 0.        , 0.        , 0.        ])
```

[13]:
```
rf_recall_train
```

```
[13]: array([0.94444444, 1.        , 0.97222222, 1.        , 0.97222222,
        0.97222222, 0.97142857, 0.97142857, 1.        , 1.        ,
        0.97142857, 1.        , 0.97222222, 0.97222222, 1.        ,
        1.        , 0.94444444, 0.94444444, 0.94285714, 1.        ,
        1.        , 0.97222222, 0.97222222, 1.        , 1.        ,
        1.        , 0.97142857, 1.        , 0.94444444, 0.94285714])
```

```
[14]: rf_recall_valid
```

```
[14]: array([0.        , 0.14285714, 0.14285714, 0.14285714, 0.        ,
        0.        , 0.        , 0.25      , 0.125     , 0.        ,
        0.125     , 0.125     , 0.25      , 0.        , 0.125     ,
        0.        , 0.25      , 0.        , 0.        , 0.        ,
        0.125     , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.125     , 0.        , 0.        , 0.        ])
```

```
[15]: rf_f1_train
```

```
[15]: array([0.94444444, 0.98630137, 0.98591549, 0.97297297, 0.97222222,
        0.98591549, 0.98550725, 0.98550725, 1.        , 0.96      ,
        0.97142857, 1.        , 0.98591549, 0.97222222, 1.        ,
        1.        , 0.95774648, 0.97142857, 0.95652174, 0.98591549,
        0.97222222, 0.98591549, 0.98591549, 1.        , 1.        ,
        0.98630137, 0.93150685, 1.        , 0.94444444, 0.97058824])
```

```
[16]: rf_f1_valid
```

```
[16]: array([0.        , 0.15384615, 0.1       , 0.11764706, 0.        ,
        0.        , 0.        , 0.2       , 0.08695652, 0.        ,
        0.16666667, 0.13333333, 0.25      , 0.        , 0.18181818,
        0.        , 0.28571429, 0.        , 0.        , 0.        ,
        0.15384615, 0.        , 0.15384615, 0.        , 0.        ,
        0.        , 0.1       , 0.        , 0.        , 0.        ])
```

```
[17]: param_grid = {
          'max_leaf_nodes': [5, 10, 20, 50, 100, None],
          'n_estimators': [10, 50, 100, 150, 200],
      }

      rf = RandomForestClassifier(random_state = 42)
      grid_train = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
      grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
       ↪y_train.to_numpy().flatten())
      grid_valid = GridSearchCV(rf, param_grid, cv = 5, scoring = 'accuracy')
      grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
       ↪y_valid.to_numpy().flatten())
```

```
print(grid_train.best_params_)
```

{'max_leaf_nodes': 20, 'n_estimators': 50}

[18]:
```
print(grid_valid.best_params_)
```

{'max_leaf_nodes': 5, 'n_estimators': 10}

[19]:
```
rf = RandomForestClassifier(n_estimators = 50, max_leaf_nodes = 20,
 ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[19]: RandomForestClassifier(max_leaf_nodes=20, n_estimators=50, random_state=42)

[20]:
```
rf_predict_train = rf.predict(X_train.drop(['Age (Years)', 'Weight (kg)',
 ↪'Color'], axis=1))
rf_predict_valid = rf.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',
 ↪'Color'], axis=1))
```

[21]:
```
rf_accuracy_train = rf.score(X_train.drop(['Age (Years)', 'Weight (kg)',
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
rf_accuracy_valid = rf.score(X_valid.drop(['Age (Years)', 'Weight (kg)',
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
rf_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),
 ↪rf_predict_train)
rf_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),
 ↪rf_predict_valid)
rf_precision_train = precision_score(y_train.to_numpy().flatten(),
 ↪rf_predict_train, average=None)
rf_precision_valid = precision_score(y_valid.to_numpy().flatten(),
 ↪rf_predict_valid, average=None)
rf_recall_train = recall_score(y_train.to_numpy().flatten(), rf_predict_train,
 ↪average=None)
rf_recall_valid = recall_score(y_valid.to_numpy().flatten(), rf_predict_valid,
 ↪average=None)
rf_f1_train = f1_score(y_train.to_numpy().flatten(), rf_predict_train,
 ↪average=None)
rf_f1_valid = f1_score(y_valid.to_numpy().flatten(), rf_predict_valid,
 ↪average=None)
```

[22]:
```
rf_accuracy_train
```

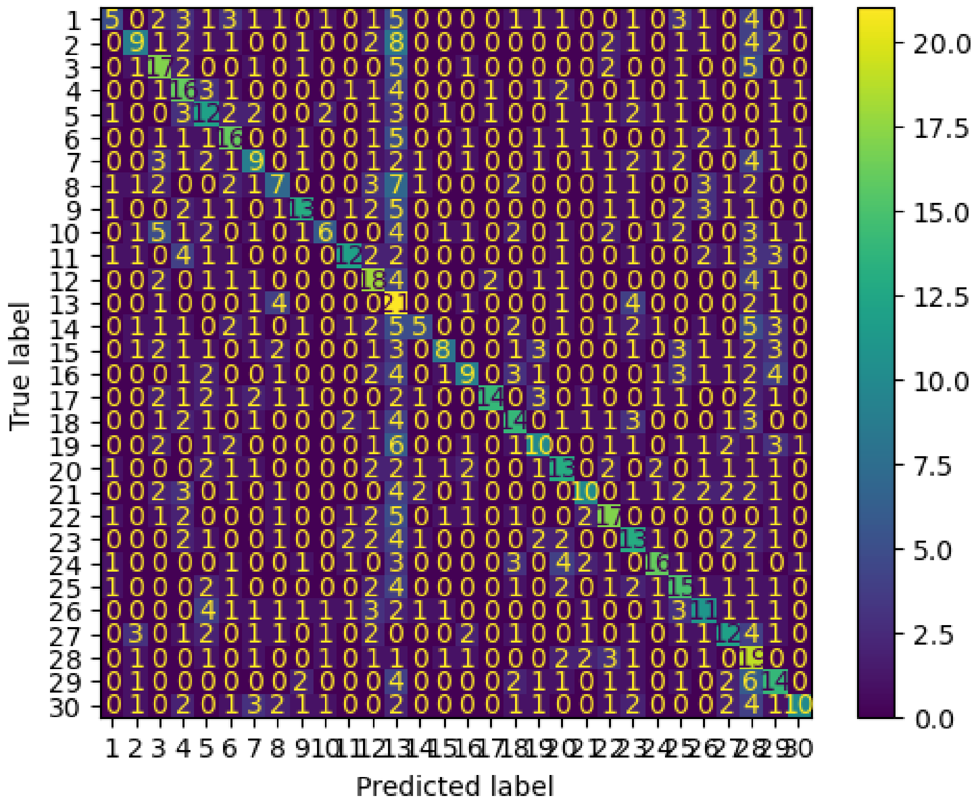
[22]: 0.3464052287581699

[23]:
```
rf_accuracy_valid
```

[23]: 0.048034934497816595

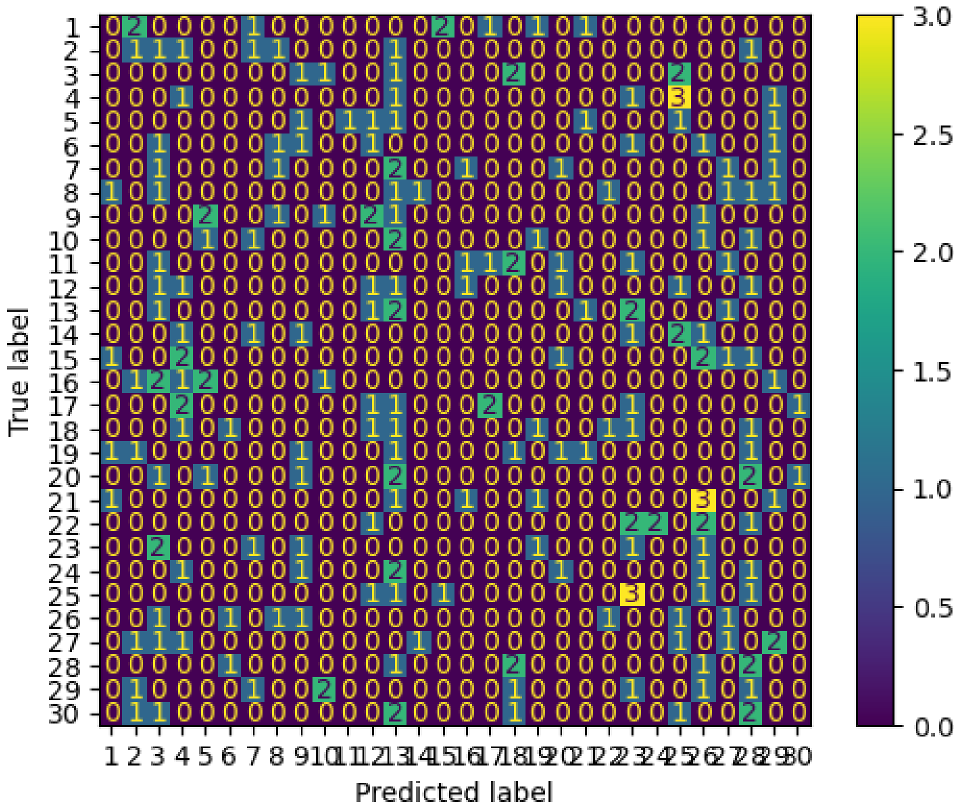
[24]:

```
disp_rf_train = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_train,␣
    ↪display_labels=range(1,31))
disp_rf_train.plot()
plt.show()
```



[25]:

```
disp_rf_valid = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_valid,␣
    ↪display_labels=range(1,31))
disp_rf_valid.plot()
plt.show()
```



[27]:
```
rf_precision_train
```

[27]:
```
array([0.38461538, 0.42857143, 0.36956522, 0.31372549, 0.27272727,
       0.4       , 0.31034483, 0.29166667, 0.52      , 0.46153846,
       0.54545455, 0.33962264, 0.16153846, 0.38461538, 0.53333333,
       0.40909091, 0.77777778, 0.4       , 0.37037037, 0.37142857,
       0.43478261, 0.43589744, 0.30952381, 0.57142857, 0.33333333,
       0.32352941, 0.375     , 0.21590909, 0.29166667, 0.625     ])
```

[28]:
```
rf_precision_valid
```

[28]:
```
array([0.        , 0.125     , 0.        , 0.08333333, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.1       , 0.08      , 0.        , 0.        ,
       0.        , 0.5       , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.06666667, 0.        , 0.        ,
       0.        , 0.14285714, 0.11764706, 0.        , 0.        ])
```

[29]:
```
rf_recall_train
```

[29]: array([0.13888889, 0.25   , 0.47222222, 0.44444444, 0.33333333,
        0.44444444, 0.25714286, 0.2   , 0.36111111, 0.16666667,
        0.34285714, 0.5   , 0.58333333, 0.13888889, 0.22857143,
        0.25   , 0.38888889, 0.38888889, 0.28571429, 0.37142857,
        0.28571429, 0.47222222, 0.36111111, 0.44444444, 0.41666667,
        0.30555556, 0.34285714, 0.52777778, 0.38888889, 0.28571429])

[30]:
```
rf_recall_valid
```

[30]: array([0.   , 0.14285714, 0.   , 0.14285714, 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.125   , 0.25   , 0.   , 0.   ,
        0.   , 0.25   , 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.14285714, 0.   , 0.   ,
        0.   , 0.125   , 0.28571429, 0.   , 0.   ])

[31]:
```
rf_f1_train
```

[31]: array([0.20408163, 0.31578947, 0.41463415, 0.36781609, 0.3   ,
        0.42105263, 0.28125   , 0.23728814, 0.42622951, 0.24489796,
        0.42105263, 0.40449438, 0.25301205, 0.20408163, 0.32   ,
        0.31034483, 0.51851852, 0.3943662 , 0.32258065, 0.37142857,
        0.34482759, 0.45333333, 0.33333333, 0.5   , 0.37037037,
        0.31428571, 0.35820896, 0.30645161, 0.33333333, 0.39215686])

[32]:
```
rf_f1_valid
```

[32]: array([0.   , 0.13333333, 0.   , 0.10526316, 0.   ,
        0.   , 0.   , 0.   , 0.   , 0.   ,
        0.   , 0.11111111, 0.12121212, 0.   , 0.   ,
        0.   , 0.33333333, 0.   , 0.   , 0.   ,
        0.   , 0.   , 0.09090909, 0.   , 0.   ,
        0.   , 0.13333333, 0.16666667, 0.   , 0.   ])

[2]:
```
#Testing the final Random Forest

rf = RandomForestClassifier(n_estimators = 200, max_features = None,␣
 ↪random_state = 42)
rf.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[2]: RandomForestClassifier(max_features=None, n_estimators=200, random_state=42)

[3]:
```
rf_predict_test = rf.predict(X_test.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

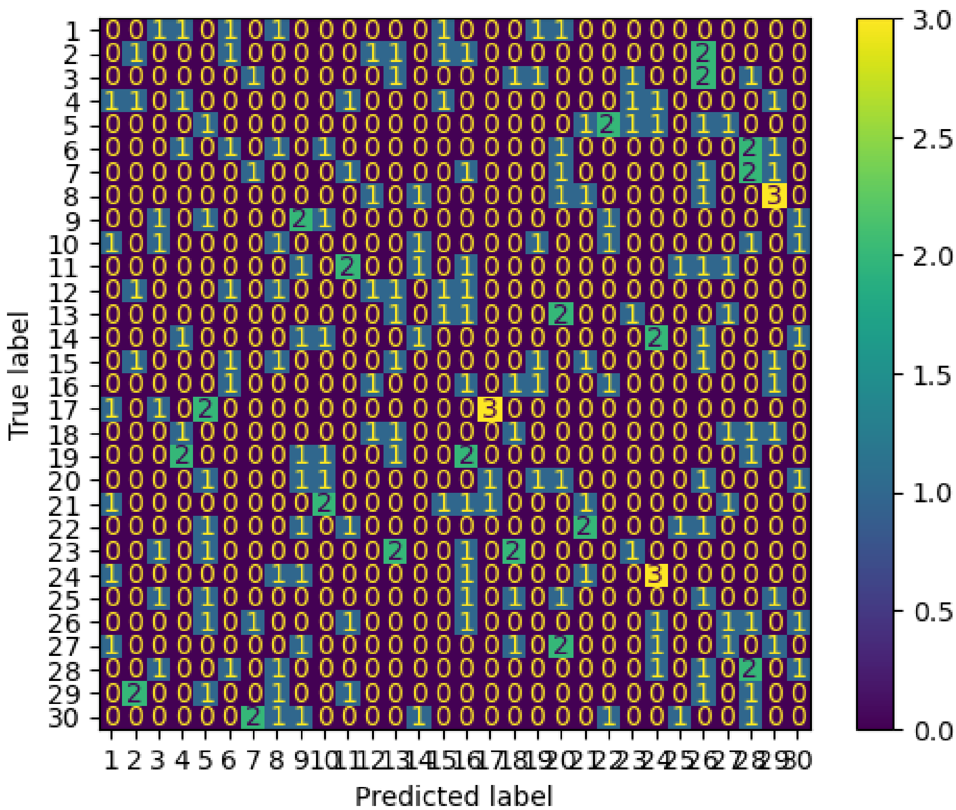
[4]:
```
rf_accuracy_test = rf.score(X_test.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_test.to_numpy().flatten())
```

```
rf_confusion_test = confusion_matrix(y_test.to_numpy().flatten(),␣
  ↪rf_predict_test)
rf_precision_test = precision_score(y_test.to_numpy().flatten(),␣
  ↪rf_predict_test, average=None)
rf_recall_test = recall_score(y_test.to_numpy().flatten(), rf_predict_test,␣
  ↪average=None)
rf_f1_test = f1_score(y_test.to_numpy().flatten(), rf_predict_test,␣
  ↪average=None)
```

[5]:
```
rf_accuracy_test
```

[5]: 0.11304347826086956

[6]:
```
disp_rf_test = ConfusionMatrixDisplay(confusion_matrix=rf_confusion_test,␣
  ↪display_labels=range(1,31))
disp_rf_test.plot()
plt.show()
```



[7]:
```
rf_precision_test
```

[7]:
```
array([0.        , 0.16666667, 0.        , 0.14285714, 0.1       ,
       0.14285714, 0.2       , 0.        , 0.2       , 0.        ,
       0.28571429, 0.2       , 0.11111111, 0.2       , 0.        ,
       0.07692308, 0.6       , 0.14285714, 0.        , 0.1       ,
       0.14285714, 0.        , 0.2       , 0.3       , 0.        ,
       0.        , 0.14285714, 0.15384615, 0.        , 0.        ])
```

[8]:
```
rf_recall_test
```

[8]:
```
array([0.        , 0.125     , 0.        , 0.125     , 0.125     ,
       0.125     , 0.125     , 0.        , 0.28571429, 0.        ,
       0.25      , 0.14285714, 0.14285714, 0.125     , 0.        ,
       0.14285714, 0.42857143, 0.14285714, 0.        , 0.125     ,
       0.125     , 0.        , 0.125     , 0.375     , 0.        ,
       0.        , 0.125     , 0.25      , 0.        , 0.        ])
```

[9]:
```
rf_f1_test
```

[9]:
```
array([0.        , 0.14285714, 0.        , 0.13333333, 0.11111111,
       0.13333333, 0.15384615, 0.        , 0.23529412, 0.        ,
       0.26666667, 0.16666667, 0.125     , 0.15384615, 0.        ,
       0.1       , 0.5       , 0.14285714, 0.        , 0.11111111,
       0.13333333, 0.        , 0.15384615, 0.33333333, 0.        ,
       0.        , 0.13333333, 0.19047619, 0.        , 0.        ])
```

[40]:
```
# Logistic Regression
from sklearn.linear_model import LogisticRegression

lr = LogisticRegression(random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[40]:
```
LogisticRegression(random_state=42)
```

[41]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[42]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid)
```

```
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

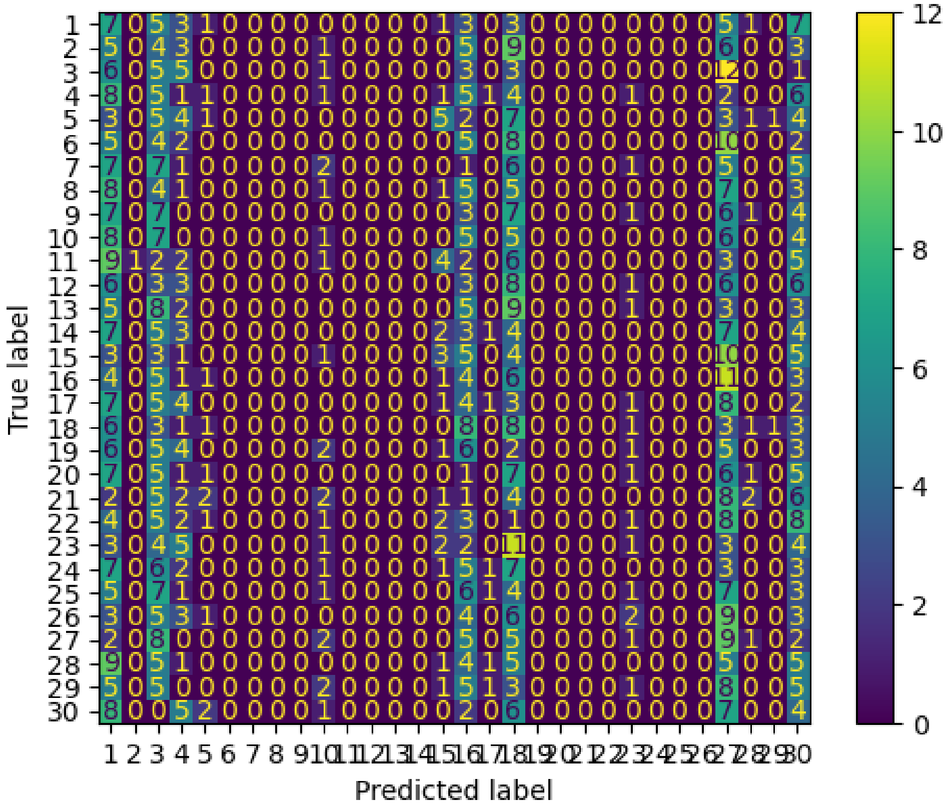
[43]:
```
lr_accuracy_train
```

[43]: 0.04201680672268908

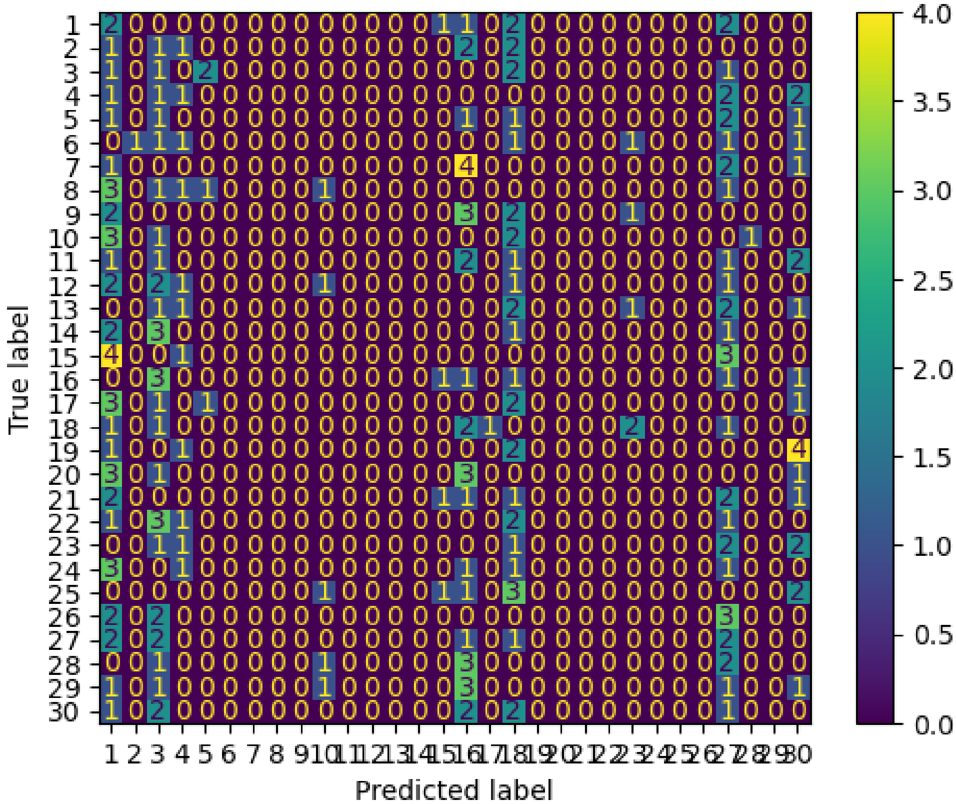
[44]:
```
lr_accuracy_valid
```

[44]: 0.03056768558951965

[45]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[46]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[47]:
```
lr_precision_train
```

[47]:
```
array([0.04069767, 0.        , 0.03401361, 0.01587302, 0.08333333,
       0.        , 0.        , 0.        , 0.        , 0.04545455,
       0.        , 0.        , 0.        , 0.        , 0.10714286,
       0.03478261, 0.14285714, 0.04819277, 0.        , 0.        ,
       0.        , 0.        , 0.0625    , 0.        , 0.        ,
       0.        , 0.04712042, 0.        , 0.        , 0.03305785])
```

[48]:
```
lr_precision_valid
```

[48]:
```
array([0.04545455, 0.        , 0.03125   , 0.09090909, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.03225806, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05555556, 0.        , 0.        , 0.        ])
```

[49]:
```
lr_recall_train
```

[49]: array([0.19444444, 0.   , 0.13888889, 0.02777778, 0.02777778,
       0.   , 0.   , 0.   , 0.   , 0.02777778,
       0.   , 0.   , 0.   , 0.   , 0.08571429,
       0.11111111, 0.02777778, 0.22222222, 0.   , 0.   ,
       0.   , 0.   , 0.02777778, 0.   , 0.   ,
       0.   , 0.25714286, 0.   , 0.   , 0.11428571])

```
[50]: lr_recall_valid
```

[50]: array([0.25   , 0.   , 0.14285714, 0.14285714, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.125   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.25   , 0.   , 0.   , 0.   ])

```
[51]: lr_f1_train
```

[51]: array([0.06730769, 0.   , 0.05464481, 0.02020202, 0.04166667,
       0.   , 0.   , 0.   , 0.   , 0.03448276,
       0.   , 0.   , 0.   , 0.   , 0.0952381 ,
       0.05298013, 0.04651163, 0.07920792, 0.   , 0.   ,
       0.   , 0.   , 0.03846154, 0.   , 0.   ,
       0.   , 0.07964602, 0.   , 0.   , 0.05128205])

```
[52]: lr_f1_valid
```

[52]: array([0.07692308, 0.   , 0.05128205, 0.11111111, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.05128205, 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.09090909, 0.   , 0.   , 0.   ])

```
[53]: lr = LogisticRegression(fit_intercept = False, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[53]: LogisticRegression(fit_intercept=False, random_state=42)

```
[54]: lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

```
[55]: lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
```

```
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

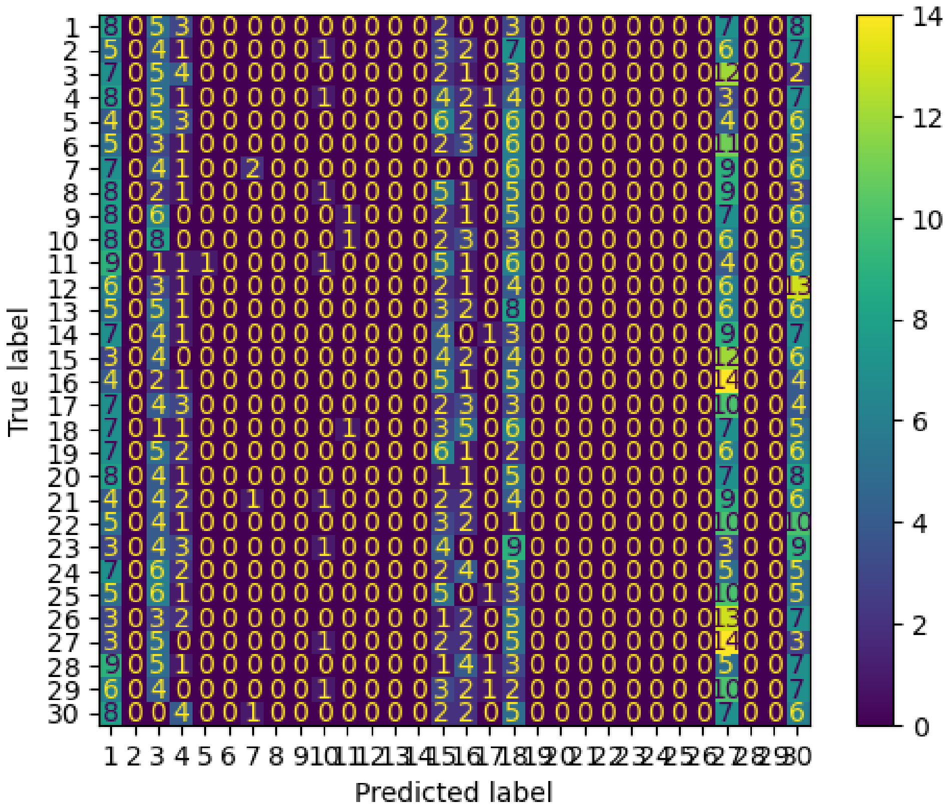
[56]:
```
lr_accuracy_train
```

[56]: 0.04388422035480859

[57]:
```
lr_accuracy_valid
```

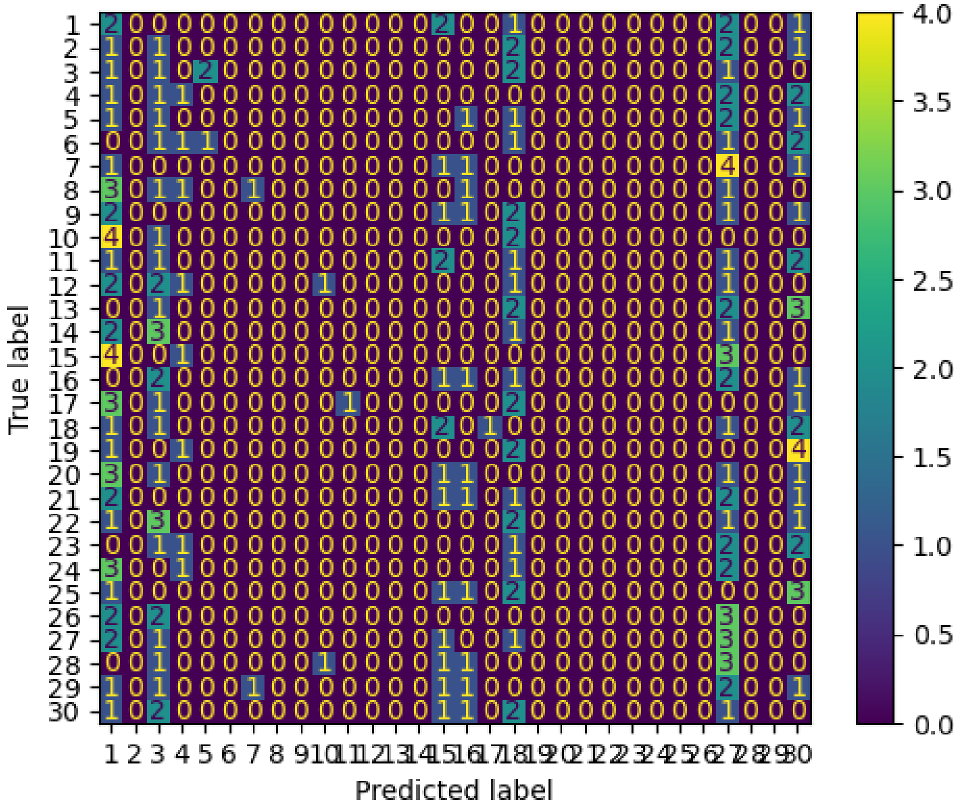
[57]: 0.034934497816593885

[58]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[59]:

```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[60]:
```
lr_precision_train
```

[60]:
```
array([0.04347826, 0.        , 0.04132231, 0.02325581, 0.        ,
       0.        , 0.5       , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.04545455,
       0.01923077, 0.        , 0.04411765, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05809129, 0.        , 0.        , 0.03243243])
```

[61]:
```
lr_precision_valid
```

[61]:
```
array([0.04347826, 0.        , 0.03333333, 0.125     , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.09090909, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.06382979, 0.        , 0.        , 0.        ])
```

[62]:
```
lr_recall_train
```

[62]:
```
array([0.22222222, 0.        , 0.13888889, 0.02777778, 0.        ,
       0.        , 0.05714286, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.11428571,
       0.02777778, 0.        , 0.16666667, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.4       , 0.        , 0.        , 0.17142857])
```

[63]:
```
lr_recall_valid
```

[63]:
```
array([0.25      , 0.        , 0.14285714, 0.14285714, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.125     , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.375     , 0.        , 0.        , 0.        ])
```

[64]:
```
lr_f1_train
```

[64]:
```
array([0.07272727, 0.        , 0.06369427, 0.02531646, 0.        ,
       0.        , 0.1025641 , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.06504065,
       0.02272727, 0.        , 0.06976744, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.10144928, 0.        , 0.        , 0.05454545])
```

[65]:
```
lr_f1_valid
```

[65]:
```
array([0.07407407, 0.        , 0.05405405, 0.13333333, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.10526316, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.10909091, 0.        , 0.        , 0.        ])
```

[68]:
```
scores_train = []
scores_valid = []
c_values = [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110]

for c in c_values:
    lr = LogisticRegression(C = c, random_state = 42)
    score_train = cross_val_score(lr, X_train.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_train.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    score_valid = cross_val_score(lr, X_valid.drop(['Age (Years)', 'Weight␣
 ↪(kg)', 'Color'], axis=1), y_valid.to_numpy().flatten(), cv=5,␣
 ↪scoring='accuracy').mean()
    scores_train.append(score_train)
```

```
    scores_valid.append(score_valid)

plt.plot(c_values, scores_train)
plt.plot(c_values, scores_valid)
plt.xlabel('C')
plt.ylabel('CV Accuracy')
plt.title('Logistic Regression Performance vs Inverse of Regularization␣
↪Strength')
plt.show()

#10 is the best
```

[69]:
```
lr = LogisticRegression(C = 100, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
↪to_numpy().flatten())
```

[69]: LogisticRegression(C=100, random_state=42)

[70]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

```
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[71]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

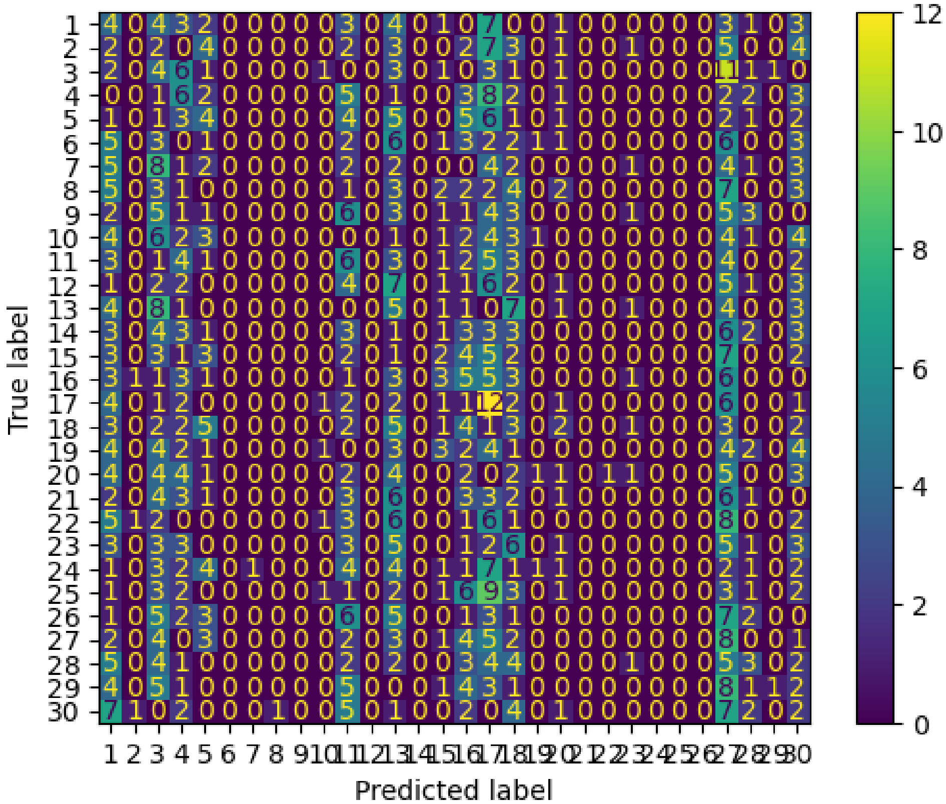
[72]:
```
lr_accuracy_train
```

[72]: 0.06162464985994398

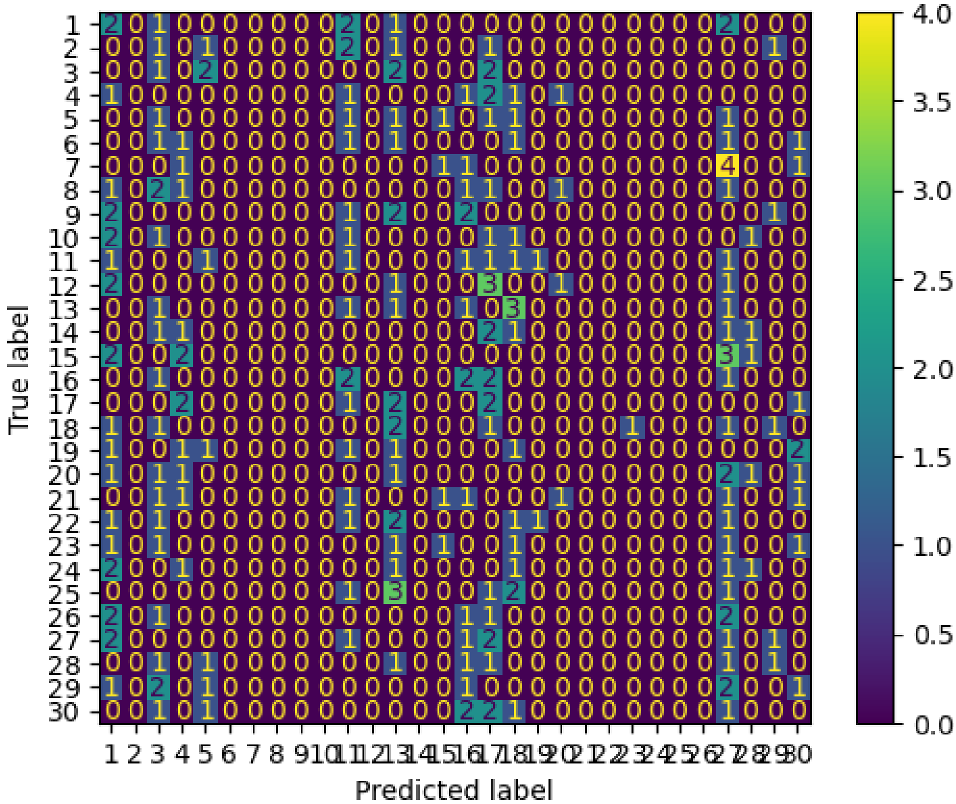
[73]:
```
lr_accuracy_valid
```

[73]: 0.043668122270742356

[74]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
 ↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[75]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,
 ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[77]:
```
lr_precision_train
```

[77]:
```
array([0.04301075, 0.        , 0.04      , 0.0952381 , 0.09090909,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.07407407, 0.        , 0.05050505, 0.        , 0.08      ,
       0.07246377, 0.09230769, 0.04054054, 0.        , 0.05263158,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05063291, 0.11111111, 0.5       , 0.03125   ])
```

[78]:
```
lr_precision_valid
```

[78]:
```
array([0.08      , 0.        , 0.04761905, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05263158, 0.        , 0.04166667, 0.        , 0.        ,
       0.125     , 0.07692308, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03125   , 0.        , 0.        , 0.        ])
```

[79]:
```
lr_recall_train
```

[79]:
```
array([0.11111111, 0.        , 0.11111111, 0.16666667, 0.11111111,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.17142857, 0.        , 0.13888889, 0.        , 0.05714286,
       0.13888889, 0.33333333, 0.08333333, 0.        , 0.02857143,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.22857143, 0.08333333, 0.02777778, 0.05714286])
```

[80]:
```
lr_recall_valid
```

[80]:
```
array([0.25      , 0.        , 0.14285714, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.125     , 0.        , 0.125     , 0.        , 0.        ,
       0.25      , 0.25      , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.125     , 0.        , 0.        , 0.        ])
```

[81]:
```
lr_f1_train
```

[81]:
```
array([0.0620155 , 0.        , 0.05882353, 0.12121212, 0.1       ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.10344828, 0.        , 0.07407407, 0.        , 0.06666667,
       0.0952381 , 0.14457831, 0.05454545, 0.        , 0.03703704,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.08290155, 0.0952381 , 0.05263158, 0.04040404])
```

[82]:
```
lr_f1_valid
```

[82]:
```
array([0.12121212, 0.        , 0.07142857, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.07407407, 0.        , 0.0625    , 0.        , 0.        ,
       0.16666667, 0.11764706, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05      , 0.        , 0.        , 0.        ])
```

[86]:
```
param_grid = {
    'penalty': ['l2', None],
    'C': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110],
    'fit_intercept': [True, False]
}

lr = LogisticRegression(random_state = 42)
grid_train = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```python
print(grid_train.best_params_)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
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penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
```

```
{'C': 0.0001, 'fit_intercept': False, 'penalty': None}
```

[87]:
```
print(grid_valid.best_params_)
```

```
{'C': 100, 'fit_intercept': True, 'penalty': 'l2'}
```

[165]:
```
lr = LogisticRegression(fit_intercept = False, penalty = None, random_state =
 ↪42)
```

```
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
    ↪to_numpy().flatten())
```

[165]:
```
LogisticRegression(fit_intercept=False, penalty=None, random_state=42)
```

[122]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
```

[123]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
    ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
    ↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
    ↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
    ↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
    ↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
    ↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
    ↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
    ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

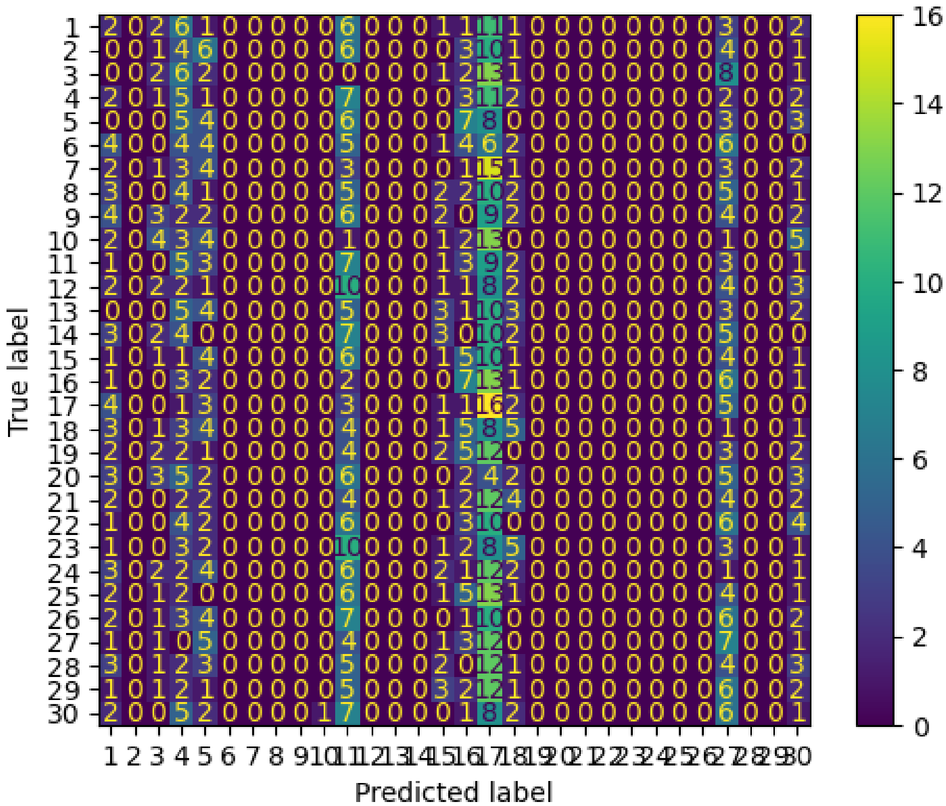
[124]:
```
lr_accuracy_train
```

[124]:
```
0.05322128851540616
```

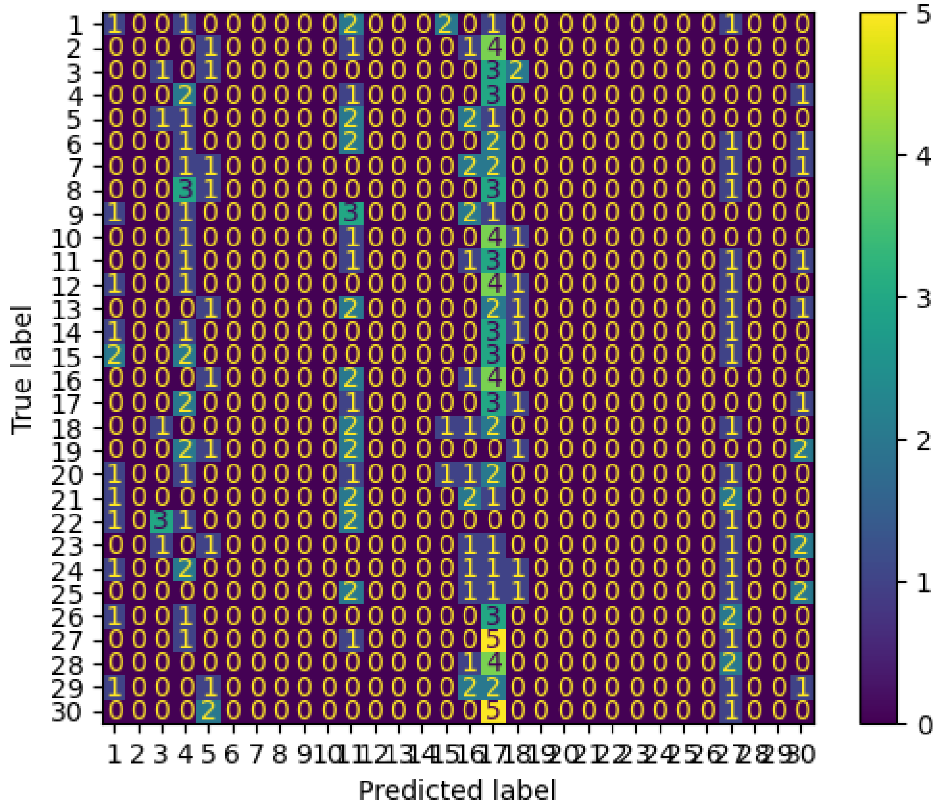
[125]:
```
lr_accuracy_valid
```

[125]: 0.043668122270742356

[126]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
 ↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[129]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
 ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[127]:
```
lr_precision_train
```

[127]:
```
array([0.03508772, 0.        , 0.0625    , 0.05102041, 0.05128205,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.04402516, 0.        , 0.        , 0.        , 0.03125   ,
       0.09333333, 0.05079365, 0.10416667, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.056     , 0.        , 0.        , 0.01960784])
```

[97]:
```
lr_precision_valid
```

[97]:
```
array([0.08333333, 0.        , 0.14285714, 0.07692308, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.03333333, 0.        , 0.        , 0.        , 0.        ,
       0.05263158, 0.04109589, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.04166667, 0.        , 0.        , 0.        ])
```

[98]:
```
lr_recall_train
```

[98]: array([0.05555556, 0.   , 0.05555556, 0.13888889, 0.11111111,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.2   , 0.   , 0.   , 0.   , 0.02857143,
       0.19444444, 0.44444444, 0.13888889, 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.2   , 0.   , 0.   , 0.02857143])

[99]:
```
lr_recall_valid
```

[99]: array([0.125   , 0.   , 0.14285714, 0.28571429, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.125   , 0.   , 0.   , 0.   , 0.   ,
       0.125   , 0.375   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.125   , 0.   , 0.   , 0.   ])

[100]:
```
lr_f1_train
```

[100]: array([0.04301075, 0.   , 0.05882353, 0.07462687, 0.07017544,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.07216495, 0.   , 0.   , 0.   , 0.02985075,
       0.12612613, 0.09116809, 0.11904762, 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.0875   , 0.   , 0.   , 0.02325581])

[101]:
```
lr_f1_valid
```

[101]: array([0.1   , 0.   , 0.14285714, 0.12121212, 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.05263158, 0.   , 0.   , 0.   , 0.   ,
       0.07407407, 0.07407407, 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.0625   , 0.   , 0.   , 0.   ])

[102]:
```
param_grid = {
    'penalty': ['l2', None],
    'C': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110],
    'fit_intercept': [True, False]
}

lr = LogisticRegression(solver = 'newton-cg', random_state = 42)
grid_train = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```python
print(grid_train.best_params_)
```

```
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```
{'C': 0.0001, 'fit_intercept': False, 'penalty': None}
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[103]:
```
print(grid_valid.best_params_)
```

```
{'C': 100, 'fit_intercept': True, 'penalty': 'l2'}
```

[164]:
```
lr = LogisticRegression(solver = 'newton-cg', fit_intercept = False, penalty =␣
↪None, random_state = 42)
```

```
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[164]:
```
LogisticRegression(fit_intercept=False, penalty=None, random_state=42,
                   solver='newton-cg')
```

[131]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[132]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

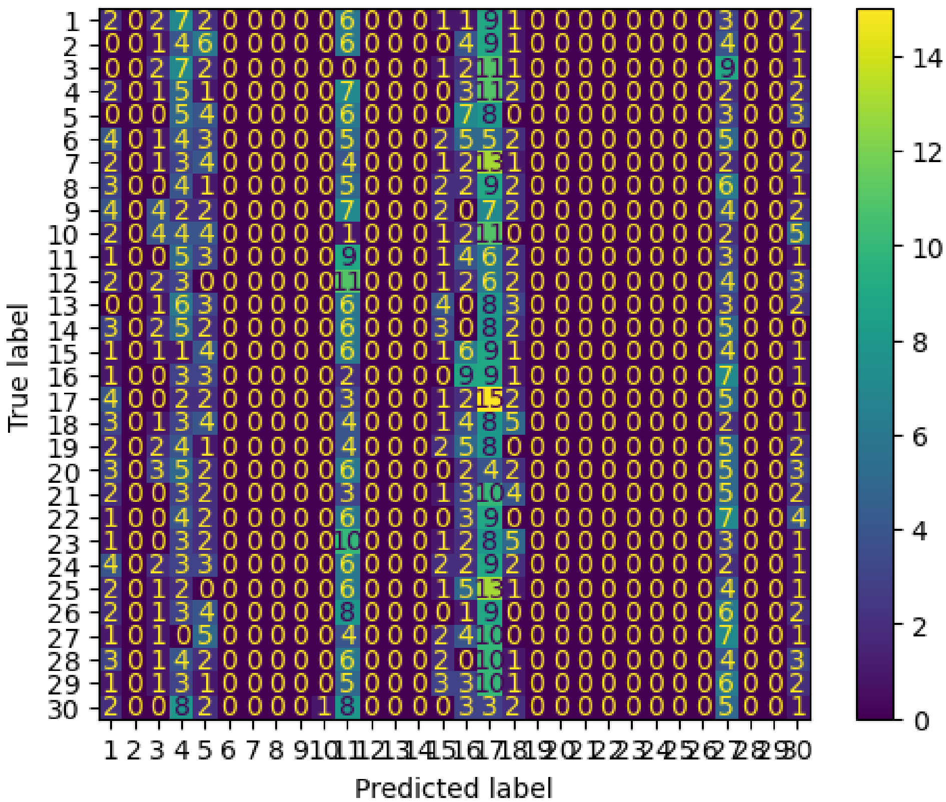
[107]:
```
lr_accuracy_train
```

[107]:
```
0.056022408963585436
```

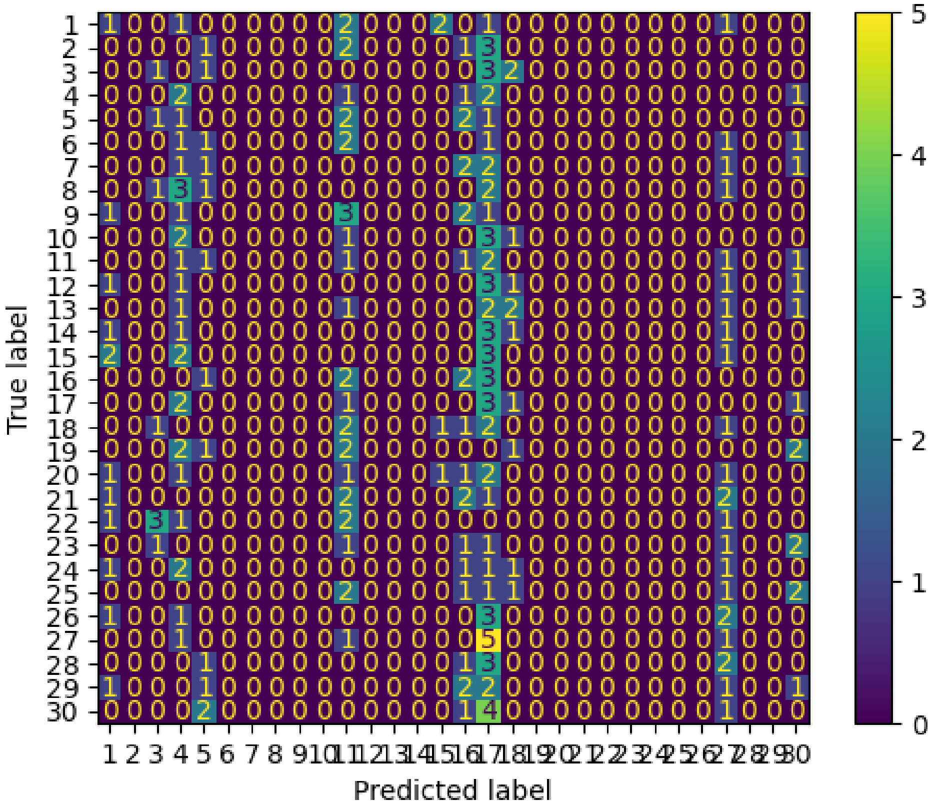
[108]:
```
lr_accuracy_valid
```

[108]: 0.048034934497816595

[133]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[134]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```




```
[109]: lr_precision_train
```

```
[109]: array([0.03448276, 0.        , 0.05714286, 0.04347826, 0.05263158,
              0.        , 0.        , 0.        , 0.        , 0.        ,
              0.05421687, 0.        , 0.        , 0.        , 0.02777778,
              0.10227273, 0.05660377, 0.10416667, 0.        , 0.        ,
              0.        , 0.        , 0.        , 0.        , 0.        ,
              0.        , 0.0530303 , 0.        , 0.        , 0.01960784])
```

```
[110]: lr_precision_valid
```

```
[110]: array([0.08333333, 0.        , 0.125     , 0.07142857, 0.        ,
              0.        , 0.        , 0.        , 0.        , 0.        ,
              0.03225806, 0.        , 0.        , 0.        , 0.        ,
              0.09090909, 0.04761905, 0.        , 0.        , 0.        ,
              0.        , 0.        , 0.        , 0.        , 0.        ,
              0.        , 0.04166667, 0.        , 0.        , 0.        ])
```

```
[111]: lr_recall_train
```

[111]:
```
array([0.05555556, 0.        , 0.05555556, 0.13888889, 0.11111111,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.25714286, 0.        , 0.        , 0.        , 0.02857143,
       0.25      , 0.41666667, 0.13888889, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.2       , 0.        , 0.        , 0.02857143])
```

[112]:
```
lr_recall_valid
```

[112]:
```
array([0.125     , 0.        , 0.14285714, 0.28571429, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.125     , 0.        , 0.        , 0.        , 0.        ,
       0.25      , 0.375     , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.125     , 0.        , 0.        , 0.        ])
```

[113]:
```
lr_f1_train
```

[113]:
```
array([0.04255319, 0.        , 0.05633803, 0.06622517, 0.07142857,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.08955224, 0.        , 0.        , 0.        , 0.02816901,
       0.14516129, 0.09966777, 0.11904762, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.08383234, 0.        , 0.        , 0.02325581])
```

[114]:
```
lr_f1_train
```

[114]:
```
array([0.04255319, 0.        , 0.05633803, 0.06622517, 0.07142857,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.08955224, 0.        , 0.        , 0.        , 0.02816901,
       0.14516129, 0.09966777, 0.11904762, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.08383234, 0.        , 0.        , 0.02325581])
```

[115]:
```
lr_f1_valid
```

[115]:
```
array([0.1       , 0.        , 0.13333333, 0.11428571, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05128205, 0.        , 0.        , 0.        , 0.        ,
       0.13333333, 0.08450704, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.0625    , 0.        , 0.        , 0.        ])
```

[135]:
```
lr = LogisticRegression(solver = 'newton-cg', C = 100, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[135]:
```
LogisticRegression(C=100, random_state=42, solver='newton-cg')
```

[136]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[137]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

[119]:
```
lr_accuracy_train
```

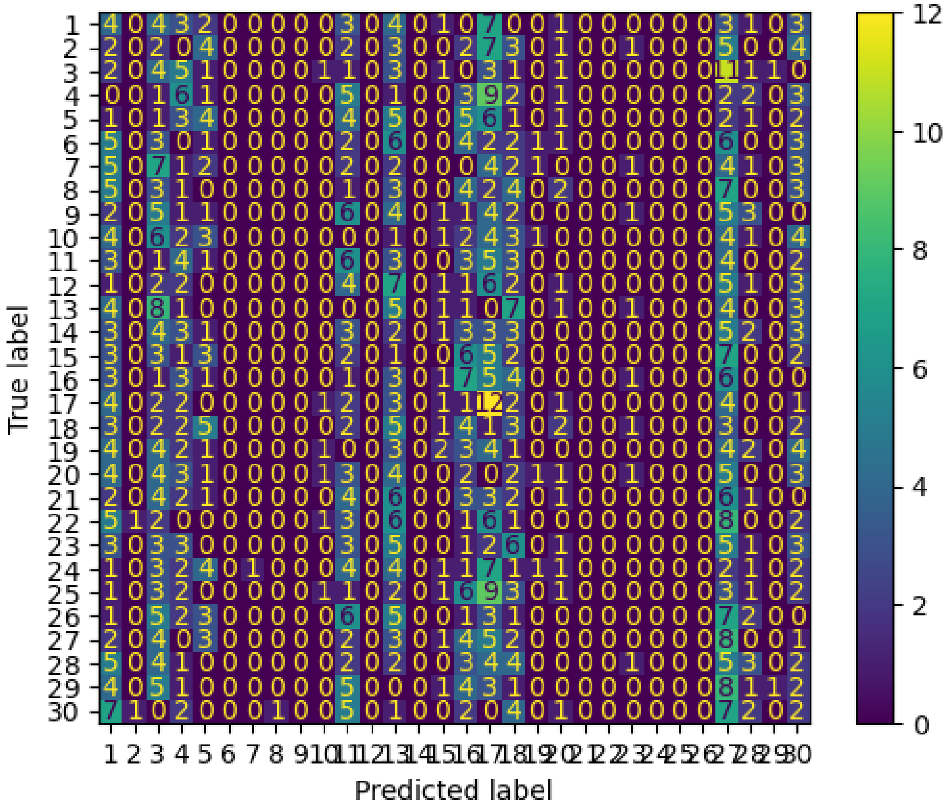
[119]: 0.06162464985994398

[120]:
```
lr_accuracy_valid
```

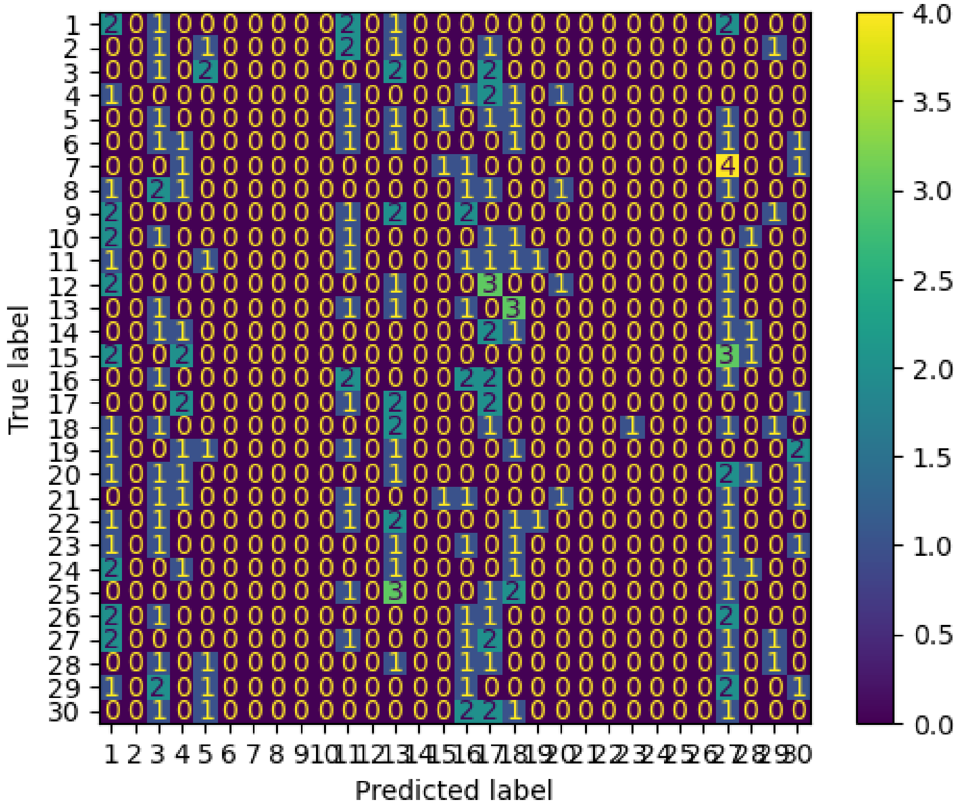
[120]: 0.043668122270742356

[138]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
```

```
disp_lr_train.plot()
plt.show()
```



[139]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,
    display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[140]:
```
lr_precision_train
```

[140]:
```
array([0.04301075, 0.        , 0.04      , 0.1       , 0.09302326,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.07142857, 0.        , 0.04901961, 0.        , 0.        ,
       0.08974359, 0.09160305, 0.04054054, 0.        , 0.05263158,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.0516129 , 0.11111111, 0.5       , 0.03125   ])
```

[141]:
```
lr_precision_valid
```

[141]:
```
array([0.08      , 0.        , 0.04761905, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05263158, 0.        , 0.04166667, 0.        , 0.        ,
       0.11764706, 0.07692308, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03125   , 0.        , 0.        , 0.        ])
```

[142]:
```
lr_recall_train
```

[142]: array([0.11111111, 0.   , 0.11111111, 0.16666667, 0.11111111,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.17142857, 0.   , 0.13888889, 0.   , 0.   ,
       0.19444444, 0.33333333, 0.08333333, 0.   , 0.02857143,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.22857143, 0.08333333, 0.02777778, 0.05714286])

[143]:
```
lr_recall_valid
```

[143]: array([0.25   , 0.   , 0.14285714, 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.125   , 0.   , 0.125   , 0.   , 0.   ,
       0.25   , 0.25   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.125   , 0.   , 0.   , 0.   ])

[144]:
```
lr_f1_train
```

[144]: array([0.0620155 , 0.   , 0.05882353, 0.125   , 0.10126582,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.10084034, 0.   , 0.07246377, 0.   , 0.   ,
       0.12280702, 0.14371257, 0.05454545, 0.   , 0.03703704,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.08421053, 0.0952381 , 0.05263158, 0.04040404])

[145]:
```
lr_f1_valid
```

[145]: array([0.12121212, 0.   , 0.07142857, 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.07407407, 0.   , 0.0625   , 0.   , 0.   ,
       0.16   , 0.11764706, 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.05   , 0.   , 0.   , 0.   ])

[146]:
```
param_grid = {
    'penalty': ['l2', None],
    'C': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110],
    'fit_intercept': [True, False]
}

lr = LogisticRegression(solver = 'newton-cholesky', random_state = 42)
grid_train = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```python
print(grid_train.best_params_)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
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C:\ProgramData\anaconda3\Lib\site-
```

```
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```
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```

```
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```

```
{'C': 110, 'fit_intercept': False, 'penalty': 'l2'}
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
```

[148]:

```
print(grid_valid.best_params_)
```

```
{'C': 0.0001, 'fit_intercept': False, 'penalty': None}
```

[150]:

```
lr = LogisticRegression(solver = 'newton-cholesky', fit_intercept = False, C =
 ↪110, random_state = 42)
```

```
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
    ↪to_numpy().flatten())
```

[150]:
```
LogisticRegression(C=110, fit_intercept=False, random_state=42,
                   solver='newton-cholesky')
```

[151]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1))
```

[152]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
    ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
    ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
    ↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
    ↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
    ↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
    ↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
    ↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
    ↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
    ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

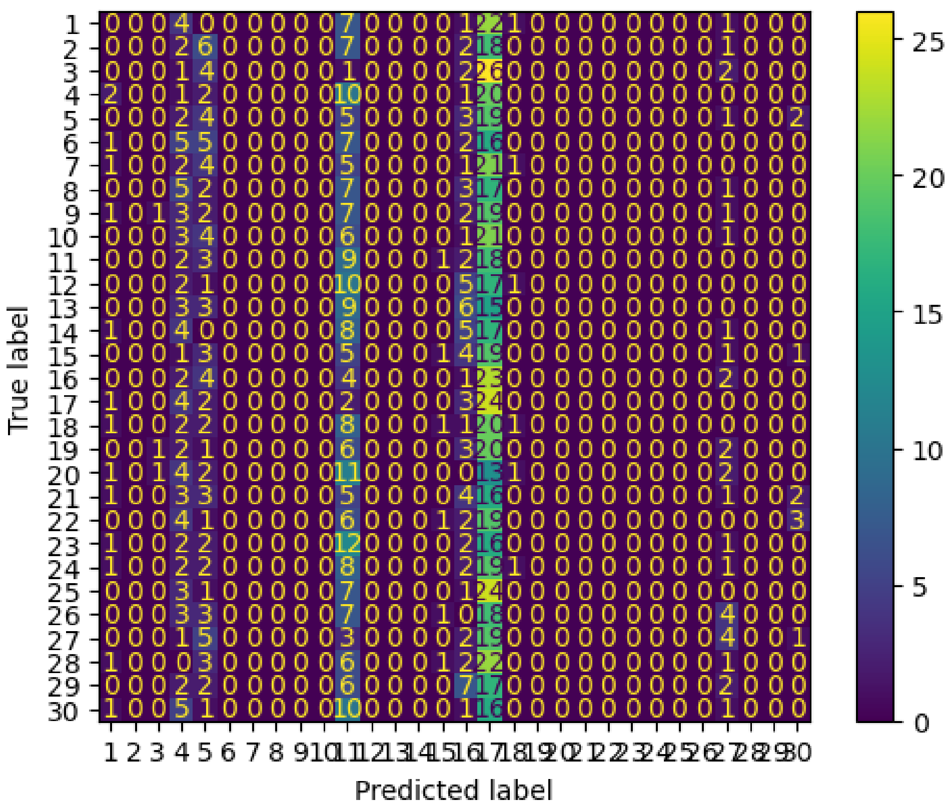
[153]:
```
lr_accuracy_train
```

[153]:
```
0.04201680672268908
```

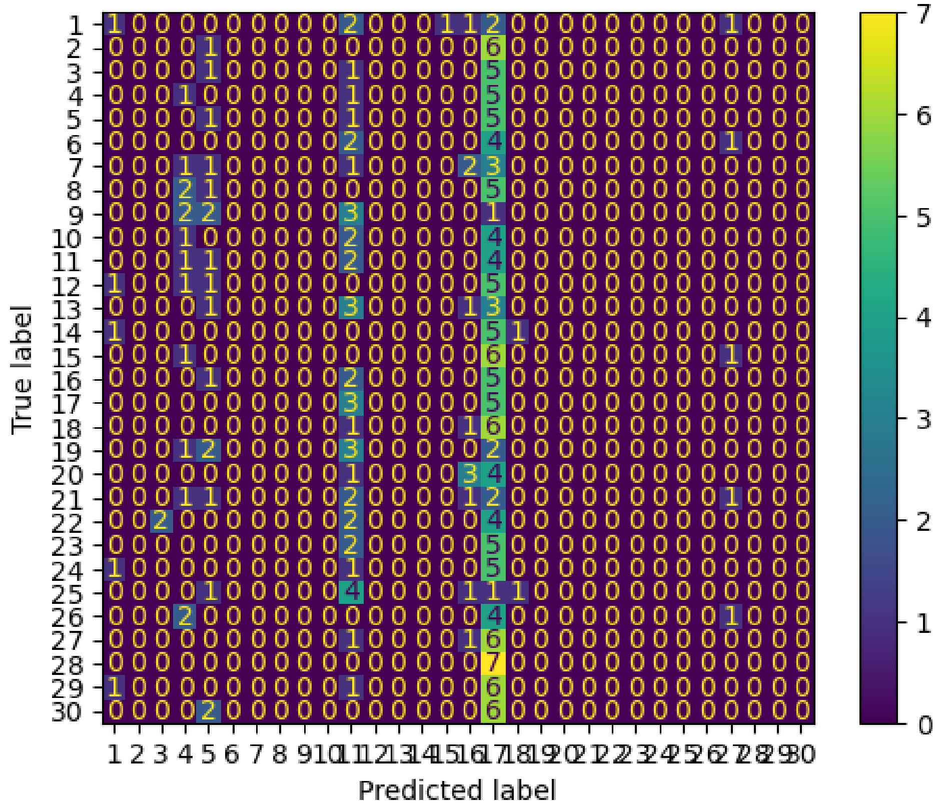
[154]:
```
lr_accuracy_valid
```

[154]: 0.043668122270742356

[155]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[156]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[157]:
```
lr_precision_train
```

[157]:
```
array([0.        , 0.        , 0.        , 0.01265823, 0.05194805,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.04411765, 0.        , 0.        , 0.        , 0.16666667,
       0.01408451, 0.04203152, 0.16666667, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.12903226, 0.        , 0.        , 0.        ])
```

[158]:
```
lr_precision_valid
```

[158]:
```
array([0.2       , 0.        , 0.        , 0.07142857, 0.05882353,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.04878049, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03816794, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[159]:
```
lr_recall_train
```

[159]:
```
array([0.        , 0.        , 0.        , 0.02777778, 0.11111111,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.25714286, 0.        , 0.        , 0.        , 0.02857143,
       0.02777778, 0.66666667, 0.02777778, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.11428571, 0.        , 0.        , 0.        ])
```

[160]:
```
lr_recall_valid
```

[160]:
```
array([0.125     , 0.        , 0.        , 0.14285714, 0.14285714,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.25      , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.625     , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[161]:
```
lr_f1_train
```

[161]:
```
array([0.        , 0.        , 0.        , 0.0173913 , 0.07079646,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.07531381, 0.        , 0.        , 0.        , 0.04878049,
       0.01869159, 0.07907743, 0.04761905, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.12121212, 0.        , 0.        , 0.        ])
```

[162]:
```
lr_f1_valid
```

[162]:
```
array([0.15384615, 0.        , 0.        , 0.0952381 , 0.08333333,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.08163265, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.07194245, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[166]:
```
lr = LogisticRegression(solver = 'newton-cholesky', fit_intercept = False,␣
 ↪penalty = None, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[166]:
```
LogisticRegression(fit_intercept=False, penalty=None, random_state=42,
                   solver='newton-cholesky')
```

[167]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[168]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

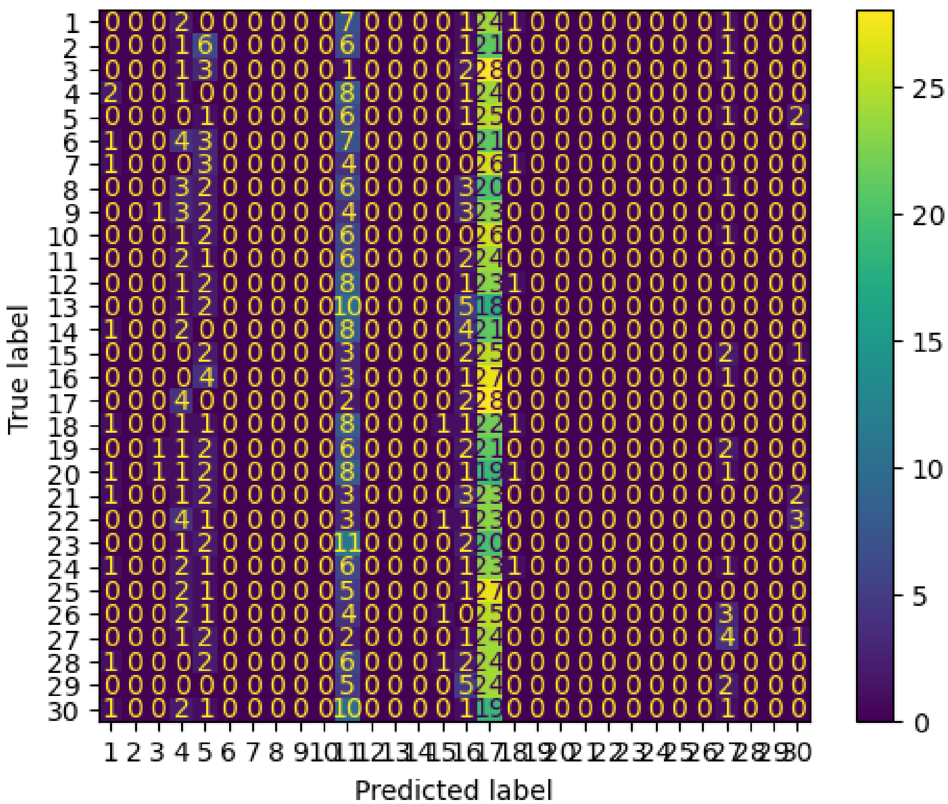
[169]:
```
lr_accuracy_train
```

[169]: 0.0392156862745098

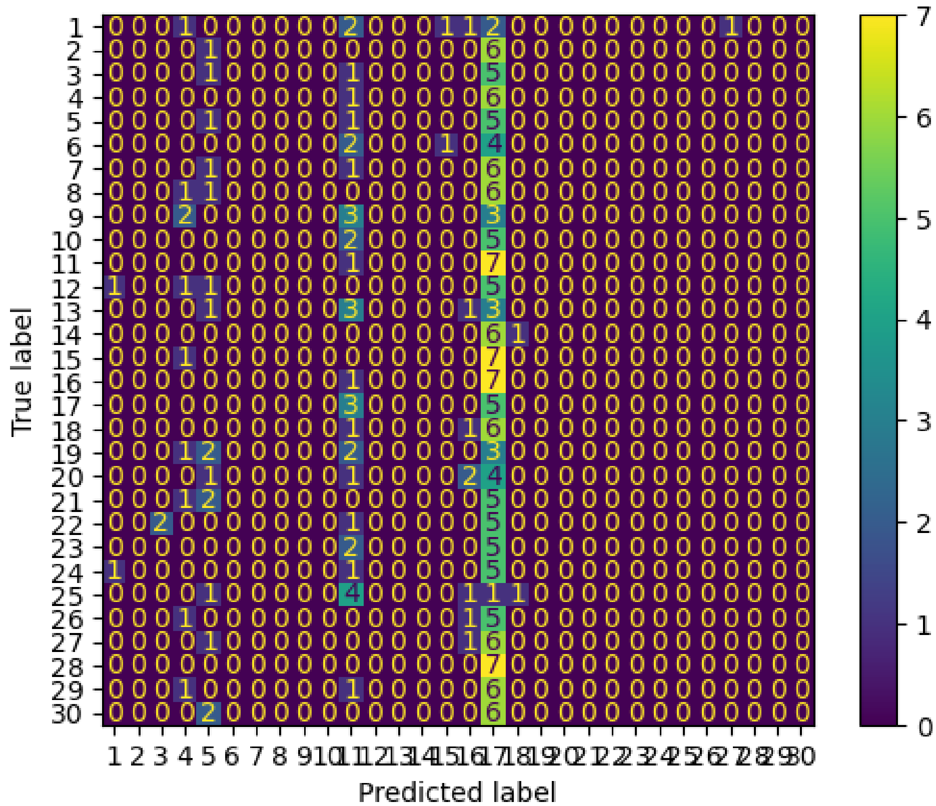
[170]:
```
lr_accuracy_valid
```

[170]: 0.03056768558951965

[171]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```




```
[172]: disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,
         display_labels=range(1,31))
       disp_lr_valid.plot()
       plt.show()
```



[173]:
```
lr_precision_train
```

[173]:
```
array([0.        , 0.        , 0.        , 0.02272727, 0.01960784,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.03488372, 0.        , 0.        , 0.        , 0.        ,
       0.02      , 0.04011461, 0.16666667, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.17391304, 0.        , 0.        , 0.        ])
```

[174]:
```
lr_precision_valid
```

[174]:
```
array([0.        , 0.        , 0.        , 0.        , 0.0625    ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.02941176, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03289474, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[175]:
```
lr_recall_train
```

[175]:
```
array([0.        , 0.        , 0.        , 0.02777778, 0.02777778,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.17142857, 0.        , 0.        , 0.        , 0.        ,
       0.02777778, 0.77777778, 0.02777778, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.11428571, 0.        , 0.        , 0.        ])
```

[176]:
```
lr_recall_valid
```

[176]:
```
array([0.        , 0.        , 0.        , 0.        , 0.14285714,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.125     , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.625     , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[177]:
```
lr_f1_train
```

[177]:
```
array([0.        , 0.        , 0.        , 0.025     , 0.02298851,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05797101, 0.        , 0.        , 0.        , 0.        ,
       0.02325581, 0.07629428, 0.04761905, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.13793103, 0.        , 0.        , 0.        ])
```

[178]:
```
lr_f1_valid
```

[178]:
```
array([0.        , 0.        , 0.        , 0.        , 0.08695652,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.04761905, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.0625    , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[203]:
```
param_grid = {
    'penalty': ['l2', None],
    'C': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110],
    'fit_intercept': [True, False],
}

lr = LogisticRegression(solver = 'sag', random_state = 42)
grid_train = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```python
print(grid_train.best_params_)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
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packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
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C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
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C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
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C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
```

```
{'C': 100, 'fit_intercept': True, 'penalty': 'l2'}
```

```
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
```

[204]:

```python
print(grid_valid.best_params_)
```

```
{'C': 0.0001, 'fit_intercept': True, 'penalty': None}
```

[189]:

```python
lr = LogisticRegression(solver = 'sag', C = 100, max_iter = 1000, random_state␣
↪= 42)
```

```
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
↪to_numpy().flatten())
```

[189]: LogisticRegression(C=100, max_iter=1000, random_state=42, solver='sag')

[190]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1))
```

[191]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

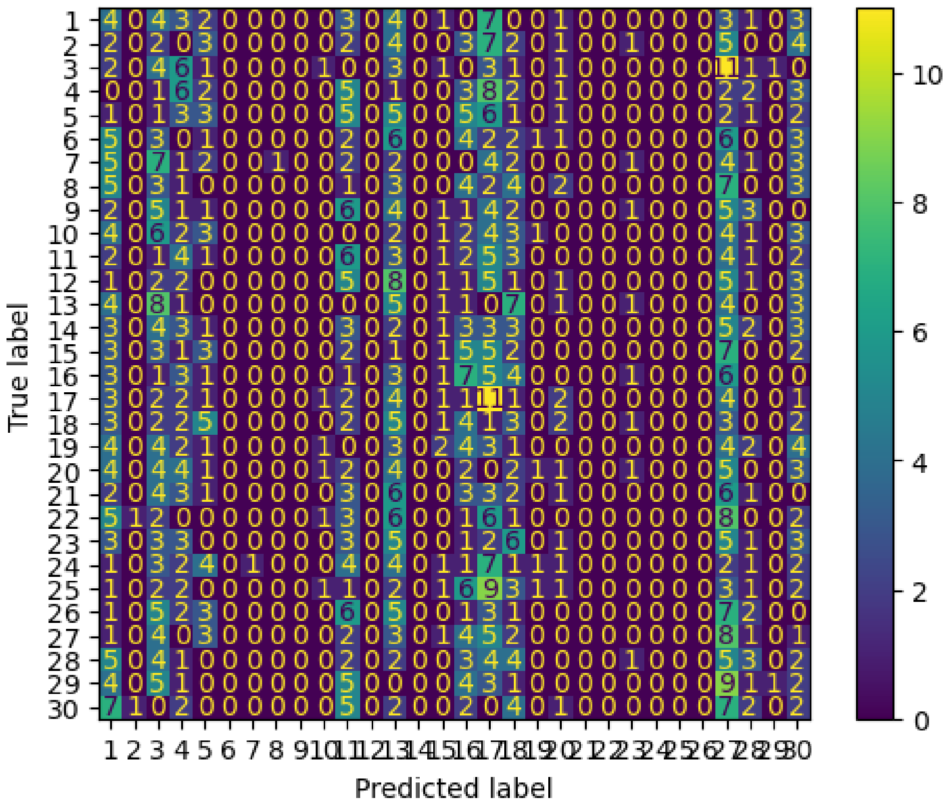
[192]:
```
lr_accuracy_train
```

[192]: 0.06069094304388422

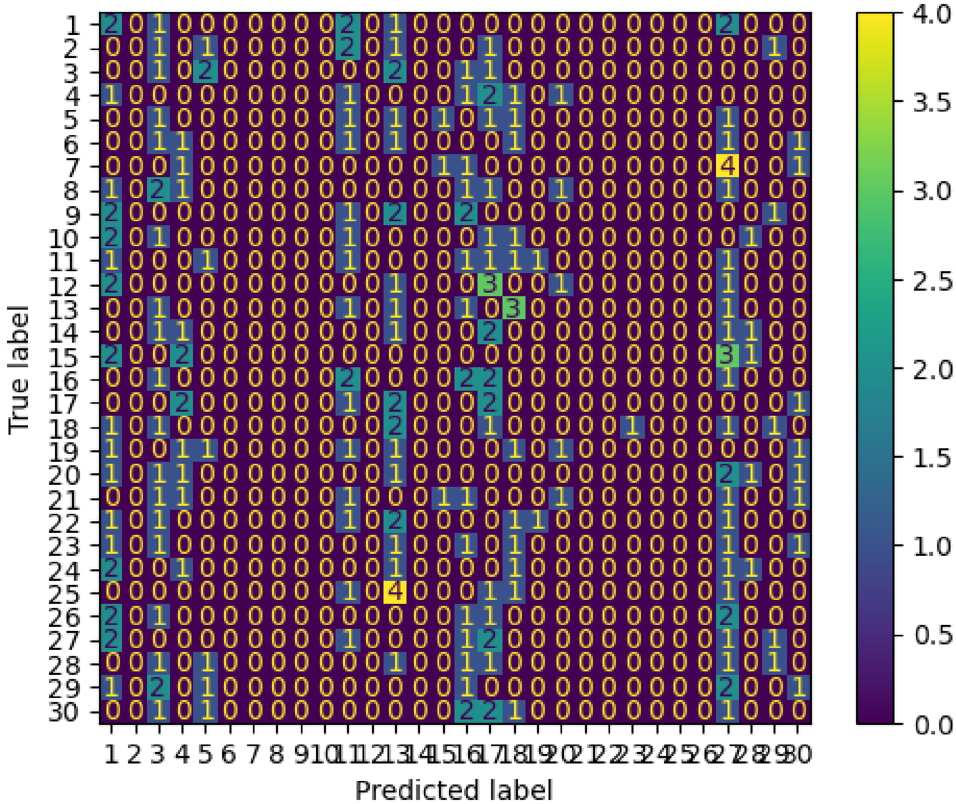
[193]:
```
lr_accuracy_valid
```

[193]: 0.043668122270742356

[194]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
    ↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[195]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
    ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[196]:
```
lr_precision_train
```

[196]:
```
array([0.04444444, 0.        , 0.04040404, 0.0952381 , 0.06976744,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.07228916, 0.        , 0.04672897, 0.        , 0.05882353,
       0.08974359, 0.08661417, 0.04225352, 0.        , 0.05      ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05128205, 0.10344828, 0.5       , 0.03174603])
```

[197]:
```
lr_precision_valid
```

[197]:
```
array([0.08      , 0.        , 0.04761905, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05263158, 0.        , 0.03846154, 0.        , 0.        ,
       0.11111111, 0.08      , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03125   , 0.        , 0.        , 0.        ])
```

[198]:
```
lr_recall_train
```

```
[198]: array([0.11111111, 0.        , 0.11111111, 0.16666667, 0.08333333,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.17142857, 0.        , 0.13888889, 0.        , 0.02857143,
        0.19444444, 0.30555556, 0.08333333, 0.        , 0.02857143,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.22857143, 0.08333333, 0.02777778, 0.05714286])
```

```
[199]: lr_recall_valid
```

```
[199]: array([0.25      , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.125     , 0.        , 0.125     , 0.        , 0.        ,
        0.25      , 0.25      , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.125     , 0.        , 0.        , 0.        ])
```

```
[200]: lr_f1_train
```

```
[200]: array([0.06349206, 0.        , 0.05925926, 0.12121212, 0.07594937,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.10169492, 0.        , 0.06993007, 0.        , 0.03846154,
        0.12280702, 0.13496933, 0.05607477, 0.        , 0.03636364,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.08376963, 0.09230769, 0.05263158, 0.04081633])
```

```
[201]: lr_f1_valid
```

```
[201]: array([0.12121212, 0.        , 0.07142857, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.07407407, 0.        , 0.05882353, 0.        , 0.        ,
        0.15384615, 0.12121212, 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.05      , 0.        , 0.        , 0.        ])
```

```
[206]: lr = LogisticRegression(solver = 'sag', penalty = None, max_iter = 1000,␣
         ↪random_state = 42)
       lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
         ↪to_numpy().flatten())
```

```
[206]: LogisticRegression(max_iter=1000, penalty=None, random_state=42, solver='sag')
```

```
[207]: lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
         ↪'Color'], axis=1))
       lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
         ↪'Color'], axis=1))
```

[208]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

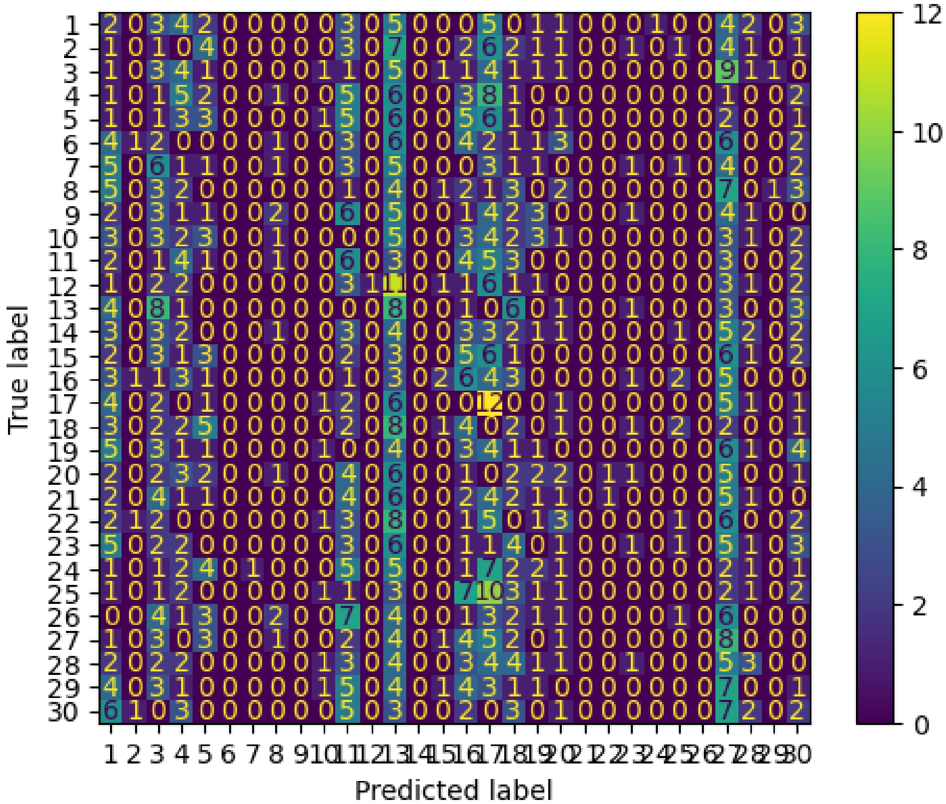
[209]:
```
lr_accuracy_train
```

[209]: 0.06069094304388422

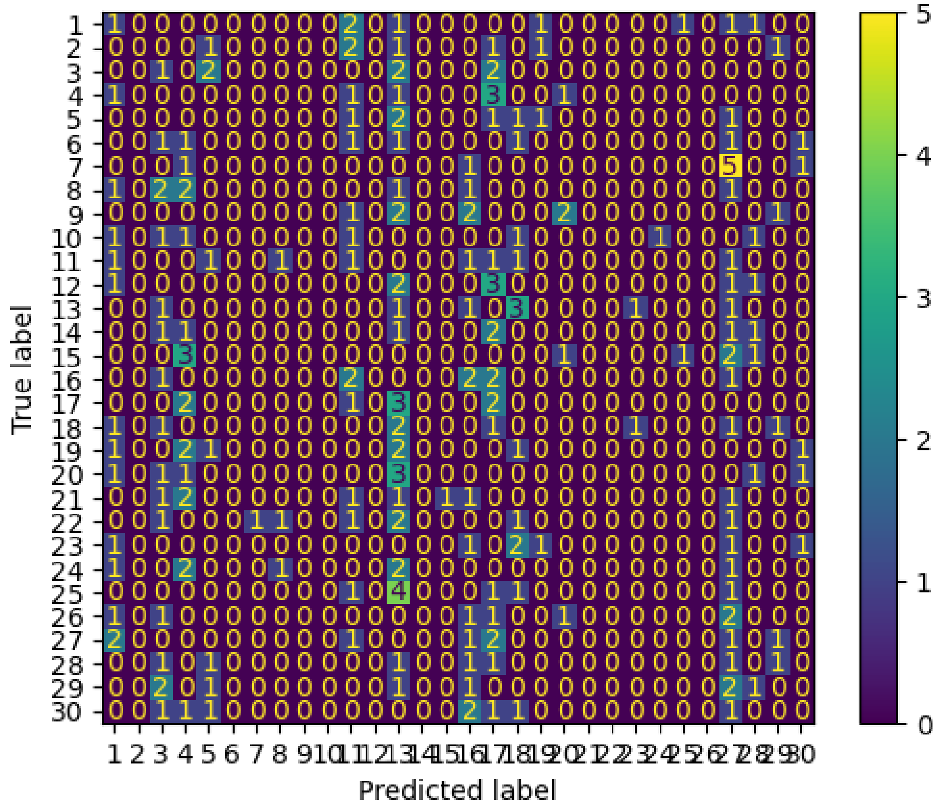
[210]:
```
lr_accuracy_valid
```

[210]: 0.039301310043668124

[211]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[212]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,
  ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[213]:
```
lr_precision_train
```

[213]:
```
array([0.02564103, 0.        , 0.04      , 0.09090909, 0.07142857,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.06593407, 1.        , 0.05095541, 0.        , 0.        ,
       0.08      , 0.096     , 0.03448276, 0.04166667, 0.07407407,
       0.        , 0.        , 0.11111111, 0.        , 0.        ,
       0.        , 0.05714286, 0.14285714, 0.        , 0.04444444])
```

[214]:
```
lr_precision_valid
```

[214]:
```
array([0.07142857, 0.        , 0.05882353, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05882353, 0.        , 0.02777778, 0.        , 0.        ,
       0.125     , 0.08333333, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.03448276, 0.        , 0.        , 0.        ])
```

[215]:
```
lr_recall_train
```

```
[215]: array([0.05555556, 0.        , 0.08333333, 0.13888889, 0.08333333,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.17142857, 0.02777778, 0.22222222, 0.        , 0.        ,
        0.16666667, 0.33333333, 0.05555556, 0.02857143, 0.05714286,
        0.        , 0.        , 0.02777778, 0.        , 0.        ,
        0.        , 0.22857143, 0.08333333, 0.        , 0.05714286])
```

```
[216]: lr_recall_valid
```

```
[216]: array([0.125     , 0.        , 0.14285714, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.125     , 0.        , 0.125     , 0.        , 0.        ,
        0.25      , 0.25      , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.125     , 0.        , 0.        , 0.        ])
```

```
[217]: lr_f1_train
```

```
[217]: array([0.03508772, 0.        , 0.05405405, 0.10989011, 0.07692308,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.0952381 , 0.05405405, 0.08290155, 0.        , 0.        ,
        0.10810811, 0.14906832, 0.04255319, 0.03389831, 0.06451613,
        0.        , 0.        , 0.04444444, 0.        , 0.        ,
        0.        , 0.09142857, 0.10526316, 0.        , 0.05      ])
```

```
[218]: lr_f1_valid
```

```
[218]: array([0.09090909, 0.        , 0.08333333, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.08      , 0.        , 0.04545455, 0.        , 0.        ,
        0.16666667, 0.125     , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.05405405, 0.        , 0.        , 0.        ])
```

```
[221]: param_grid = {
    'penalty': ['elasticnet', 'l1','l2', None],
    'C': [0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 110],
    'fit_intercept': [True, False],
    'l1_ratio': [0, 0.25, 0.5, 0.75, 1]
}

lr = LogisticRegression(solver = 'saga', random_state = 42)
grid_train = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_train.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_train.to_numpy().flatten())
grid_valid = GridSearchCV(lr, param_grid, cv = 5, scoring = 'accuracy')
grid_valid.fit(X_valid.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1),␣
 ↪y_valid.to_numpy().flatten())
```

```python
print(grid_train.best_params_)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=None)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
```

```
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=None)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
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is only used when penalty is 'elasticnet'. Got (penalty=None)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=None)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=None)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
```

```
packages\sklearn\linear_model\_logistic.py:1208: UserWarning: Setting
penalty=None will ignore the C and l1_ratio parameters
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
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packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
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  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
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  warnings.warn(
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packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
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packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
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C:\ProgramData\anaconda3\Lib\site-
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  warnings.warn(
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penalty=None will ignore the C and l1_ratio parameters
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```

```
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is only used when penalty is 'elasticnet'. Got (penalty=l1)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
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C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
```

```
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
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C:\ProgramData\anaconda3\Lib\site-
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packages\sklearn\linear_model\_logistic.py:1197: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  warnings.warn(
```

```
{'C': 0.0001, 'fit_intercept': False, 'l1_ratio': 0, 'penalty': None}
```

```
C:\ProgramData\anaconda3\Lib\site-packages\sklearn\linear_model\_sag.py:349:
ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
C:\ProgramData\anaconda3\Lib\site-
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ConvergenceWarning: The max_iter was reached which means the coef_ did not
converge
  warnings.warn(
```

[222]:
```
print(grid_valid.best_params_)
```

```
{'C': 0.1, 'fit_intercept': False, 'l1_ratio': 0.5, 'penalty': 'elasticnet'}
```

[225]:
```
lr = LogisticRegression(solver = 'saga', penalty = None, fit_intercept = False,␣
 ↪max_iter = 1000, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[225]:
```
LogisticRegression(fit_intercept=False, max_iter=1000, penalty=None,
                   random_state=42, solver='saga')
```

[226]:
```
lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[227]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
 ↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
 ↪lr_predict_valid, average=None)
```

```
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
 ↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
 ↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

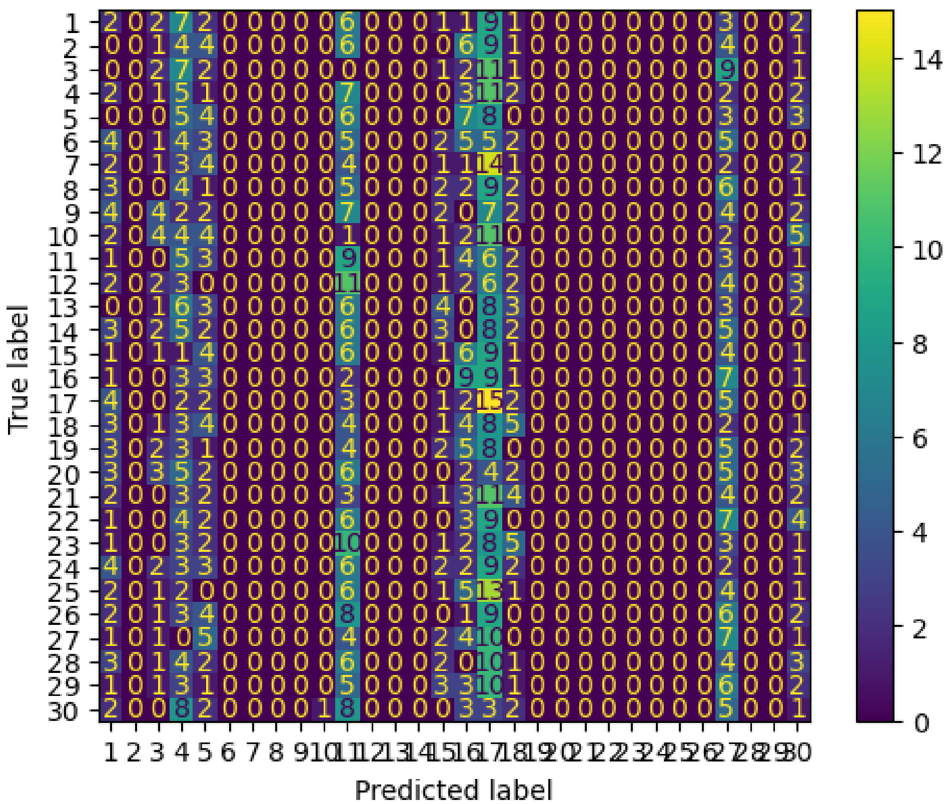
[228]:
```
lr_accuracy_train
```

[228]: 0.056022408963585436

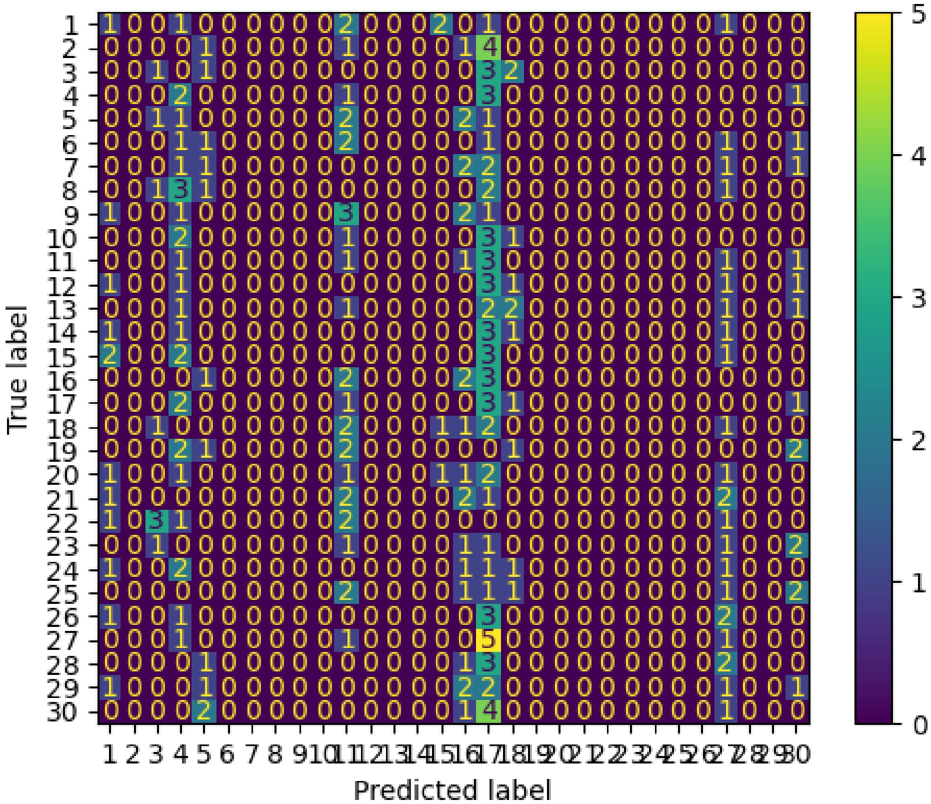
[229]:
```
lr_accuracy_valid
```

[229]: 0.048034934497816595

[230]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
 ↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[231]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,␣
    ↪display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[232]:
```
lr_precision_train
```

[232]:
```
array([0.03389831, 0.        , 0.05714286, 0.04385965, 0.05405405,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.05421687, 0.        , 0.        , 0.        , 0.02777778,
       0.1011236 , 0.05617978, 0.10416667, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.05343511, 0.        , 0.        , 0.01960784])
```

[233]:
```
lr_precision_valid
```

[233]:
```
array([0.08333333, 0.        , 0.125     , 0.07142857, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.03333333, 0.        , 0.        , 0.        , 0.        ,
       0.0952381 , 0.04545455, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.04166667, 0.        , 0.        , 0.        ])
```

[234]:
```
lr_recall_train
```

```
[234]: array([0.05555556, 0.        , 0.05555556, 0.13888889, 0.11111111,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.25714286, 0.        , 0.        , 0.        , 0.02857143,
               0.25      , 0.41666667, 0.13888889, 0.        , 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.        , 0.2       , 0.        , 0.        , 0.02857143])
```

```
[235]: lr_recall_valid
```

```
[235]: array([0.125     , 0.        , 0.14285714, 0.28571429, 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.125     , 0.        , 0.        , 0.        , 0.        ,
               0.25      , 0.375     , 0.        , 0.        , 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.        , 0.125     , 0.        , 0.        , 0.        ])
```

```
[236]: lr_f1_train
```

```
[236]: array([0.04210526, 0.        , 0.05633803, 0.06666667, 0.07272727,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.08955224, 0.        , 0.        , 0.        , 0.02816901,
               0.144     , 0.0990099 , 0.11904762, 0.        , 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.        , 0.08433735, 0.        , 0.        , 0.02325581])
```

```
[237]: lr_f1_valid
```

```
[237]: array([0.1       , 0.        , 0.13333333, 0.11428571, 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.05263158, 0.        , 0.        , 0.        , 0.        ,
               0.13793103, 0.08108108, 0.        , 0.        , 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.        , 0.0625    , 0.        , 0.        , 0.        ])
```

```
[239]: lr = LogisticRegression(solver = 'saga', penalty = 'elasticnet', fit_intercept␣
        ↪= False, l1_ratio = 0.5, C = 0.1, random_state = 42)
       lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
        ↪to_numpy().flatten())
```

```
[239]: LogisticRegression(C=0.1, fit_intercept=False, l1_ratio=0.5,
                          penalty='elasticnet', random_state=42, solver='saga')
```

```
[240]: lr_predict_train = lr.predict(X_train.drop(['Age (Years)', 'Weight (kg)',␣
        ↪'Color'], axis=1))
       lr_predict_valid = lr.predict(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
        ↪'Color'], axis=1))
```

[241]:
```
lr_accuracy_train = lr.score(X_train.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_train.to_numpy().flatten())
lr_accuracy_valid = lr.score(X_valid.drop(['Age (Years)', 'Weight (kg)',␣
↪'Color'], axis=1), y_valid.to_numpy().flatten())
lr_confusion_train = confusion_matrix(y_train.to_numpy().flatten(),␣
↪lr_predict_train)
lr_confusion_valid = confusion_matrix(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid)
lr_precision_train = precision_score(y_train.to_numpy().flatten(),␣
↪lr_predict_train, average=None)
lr_precision_valid = precision_score(y_valid.to_numpy().flatten(),␣
↪lr_predict_valid, average=None)
lr_recall_train = recall_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_recall_valid = recall_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
lr_f1_train = f1_score(y_train.to_numpy().flatten(), lr_predict_train,␣
↪average=None)
lr_f1_valid = f1_score(y_valid.to_numpy().flatten(), lr_predict_valid,␣
↪average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

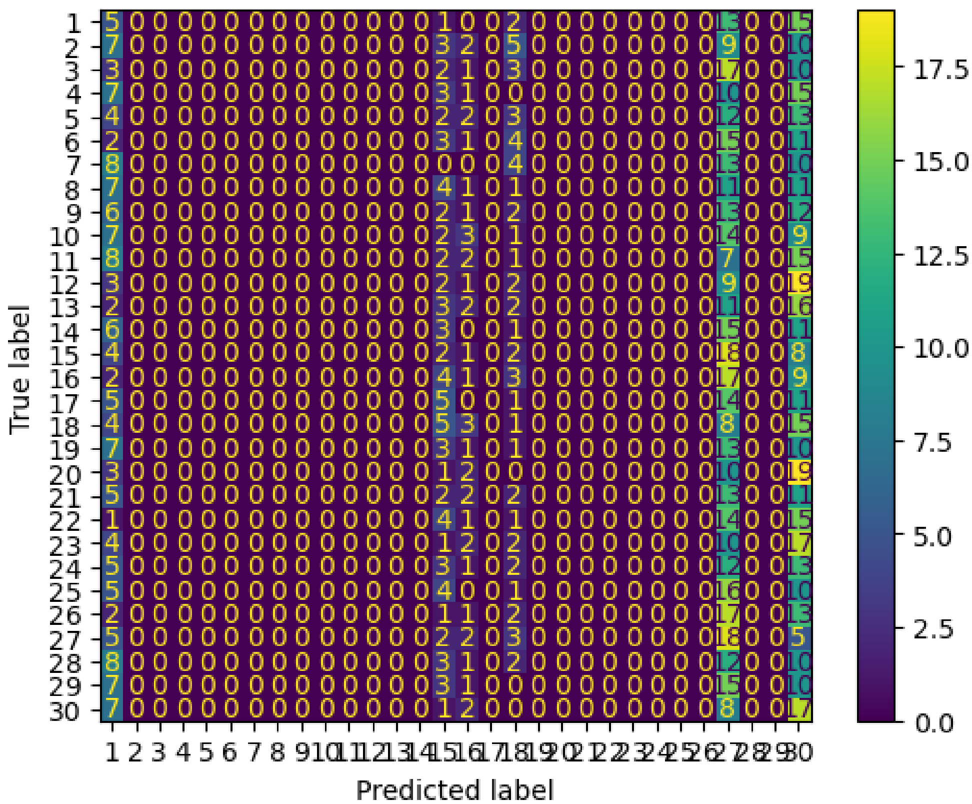
[242]:
```
lr_accuracy_train
```

[242]: 0.04108309990662932

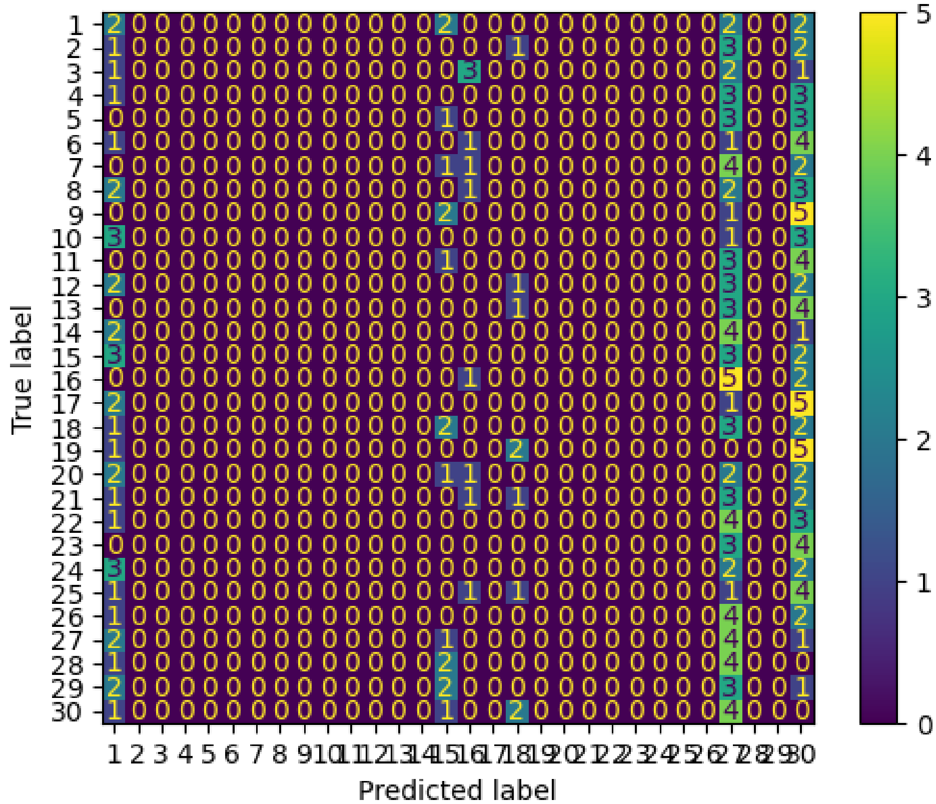
[243]:
```
lr_accuracy_valid
```

[243]: 0.03056768558951965

[244]:
```
disp_lr_train = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_train,␣
↪display_labels=range(1,31))
disp_lr_train.plot()
plt.show()
```



[245]:
```
disp_lr_valid = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_valid,
    display_labels=range(1,31))
disp_lr_valid.plot()
plt.show()
```



[246]:
```
lr_precision_train
```

[246]:
```
array([0.03355705, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.02631579,
       0.02631579, 0.        , 0.01851852, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.046875  , 0.        , 0.        , 0.04594595])
```

[247]:
```
lr_precision_valid
```

[247]:
```
array([0.05405405, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.1       , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.04938272, 0.        , 0.        , 0.        ])
```

[248]:
```
lr_recall_train
```

[248]:
```
array([0.13888889, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.05714286,
       0.02777778, 0.        , 0.02777778, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.51428571, 0.        , 0.        , 0.48571429])
```

[249]:
```
lr_recall_valid
```

[249]:
```
array([0.25 , 0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.125, 0.   , 0.   ,
       0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.   , 0.5  ,
       0.   , 0.   , 0.   ])
```

[250]:
```
lr_f1_train
```

[250]:
```
array([0.05405405, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.03603604,
       0.02702703, 0.        , 0.02222222, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.08591885, 0.        , 0.        , 0.08395062])
```

[251]:
```
lr_f1_valid
```

[251]:
```
array([0.08888889, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.11111111, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.08988764, 0.        , 0.        , 0.        ])
```

[3]:
```
# Testing the final Logistic Regression model.

lr = LogisticRegression(solver = 'saga', penalty = None, fit_intercept = False,␣
 ↪max_iter = 1000, random_state = 42)
lr.fit(X_train.drop(['Age (Years)', 'Weight (kg)', 'Color'], axis=1), y_train.
 ↪to_numpy().flatten())
```

[3]:
```
LogisticRegression(fit_intercept=False, max_iter=1000, penalty=None,
                   random_state=42, solver='saga')
```

[4]:
```
lr_predict_test = lr.predict(X_test.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1))
```

[5]:
```
lr_accuracy_test = lr.score(X_test.drop(['Age (Years)', 'Weight (kg)',␣
 ↪'Color'], axis=1), y_test.to_numpy().flatten())
```

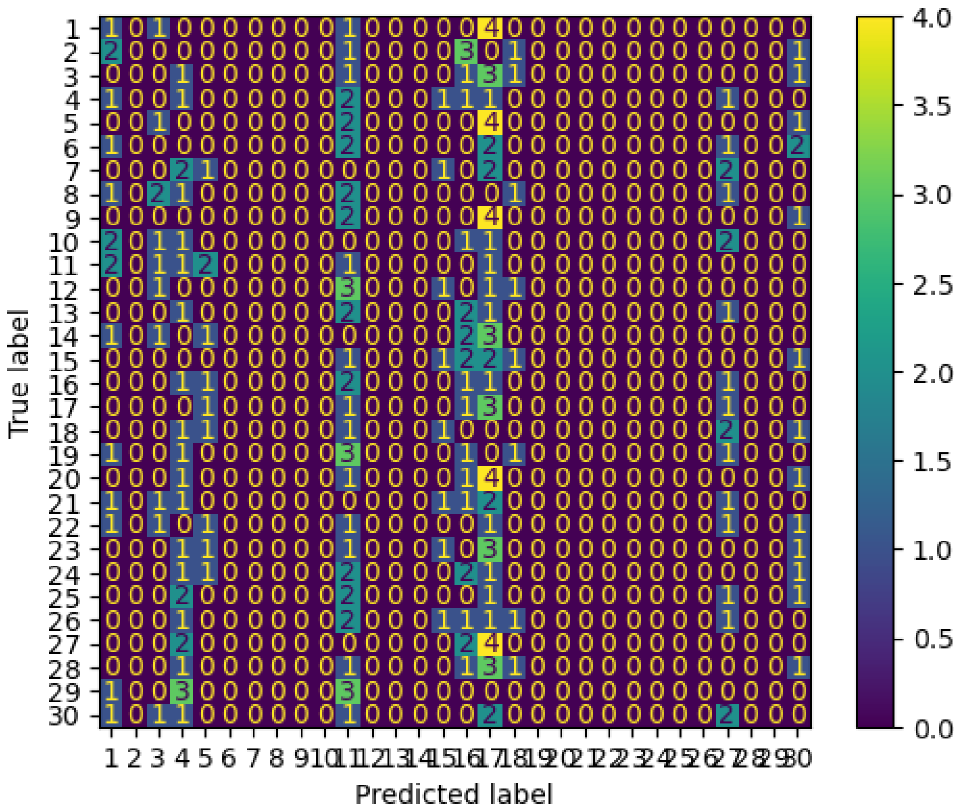
```
lr_confusion_test = confusion_matrix(y_test.to_numpy().flatten(), lr_predict_test)
lr_precision_test = precision_score(y_test.to_numpy().flatten(), lr_predict_test, average=None)
lr_recall_test = recall_score(y_test.to_numpy().flatten(), lr_predict_test, average=None)
lr_f1_test = f1_score(y_test.to_numpy().flatten(), lr_predict_test, average=None)
```

```
C:\ProgramData\anaconda3\Lib\site-
packages\sklearn\metrics\_classification.py:1531: UndefinedMetricWarning:
Precision is ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

[6]:
```
lr_accuracy_test
```

[6]: 0.034782608695652174

[7]:
```
disp_lr_test = ConfusionMatrixDisplay(confusion_matrix=lr_confusion_test, display_labels=range(1,31))
disp_lr_test.plot()
plt.show()
```



[8]:
```
lr_precision_test
```

[8]:
```
array([0.0625    , 0.        , 0.        , 0.04      , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.02439024, 0.        , 0.        , 0.        , 0.125     ,
       0.04347826, 0.05454545, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[9]:
```
lr_recall_test
```

[9]:
```
array([0.14285714, 0.        , 0.        , 0.125     , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.125     , 0.        , 0.        , 0.        , 0.125     ,
       0.14285714, 0.42857143, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[10]:
```
lr_f1_test
```

[10]:
```
array([0.08695652, 0.        , 0.        , 0.06060606, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.04081633, 0.        , 0.        , 0.        , 0.125     ,
       0.06666667, 0.09677419, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ])
```

[ ]:
```

```