AnalysisNote8

March 3, 2024

1 Real distributions vs Permutation

As we have seen, most tricksters exist where corresponding real animals are observed. However, because of cultural transmission, distribusions are more dense in realized tricksters distributions than a null hypothesis (trcikster randomly distributed where real animals are observed).

To avoid the problems of difference in research efforts, we only consider presence/absence in each hex grid.

[1]:
```
import numpy as np
import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt
import geopandas as gpd
import sys
import latlon_utils
#import rioxarray as rxr  we used this function to read tiff, but could cause␣
 ↪conflict with plotting hex grids
import h3
from geopy.distance import geodesic
#from geojson import Feature, Point, FeatureCollection, Polygon
import plotly.express as px
import random
import scipy as sp
from scipy.integrate import cumtrapz
import statsmodels
from statsmodels.stats import multitest
import math
#import statannot
df=pd.read_csv('TrickSter_data3.csv')
df
```

[1]:

	nid	lat	lng	TrickSter	Annu_Mean_Temp	Annu_Prec	\
0	103918	68.72000	158.70000	raven	-13.231120	173.0	
1	103817	64.95187	64.64844	raven	-4.123444	473.0	
2	3926	57.82907	-152.98389	raven	3.271220	1499.0	
3	2434	51.00000	-112.50000	raven	3.957418	342.0	
4	2439	40.00000	-103.00000	raven	9.747086	395.0	

```
..      …       …         …       …              …         …
512    2464  52.00000 -120.00000      wren        1.460037      964.0
513    2466  50.50000 -122.80000      wren        4.090998      822.0
514    2472  47.11975 -123.53846      wren        9.940903     1873.0
515    2477  45.50000 -124.00000      wren       10.183416     2005.0
516    2220  51.50000   14.40000      wren        9.163620      593.0

           hex_index  presence  Norm_Annu_Mean_Temp  Norm_Annu_Prec
0    8104fffffffffff         1             0.050405        0.025701
1    81107ffffffffff         1             0.249975        0.072716
2    810c7ffffffffff         1             0.412010        0.233506
3    8112fffffffffff         1             0.427046        0.052186
4    8126bffffffffff         1             0.553911        0.060492
..               …       …                   …              …
512  8112fffffffffff         1             0.372323        0.149663
513  8128fffffffffff         1             0.429973        0.127409
514  8128fffffffffff         1             0.558158        0.292117
515  8128fffffffffff         1             0.563472        0.312804
516  811f3ffffffffff         1             0.541126        0.091522

[517 rows x 10 columns]
```

[2]:
```
print("Python Current Version:-", sys.version)
# some critical packages
print("H3 package version:-", h3.__version__)
print("Statsmodels package version:-", statsmodels.__version__)
print("Latlon package version:-", latlon_utils.__version__) # retrive data from␣
 ↪World clim
# other used packages
print("Numpy package version:-", np.__version__)
print("Scipy package version:-", sp.__version__)
print("Pandas package version:-", pd.__version__)
print("Geopandas package version:-", gpd.__version__)
```

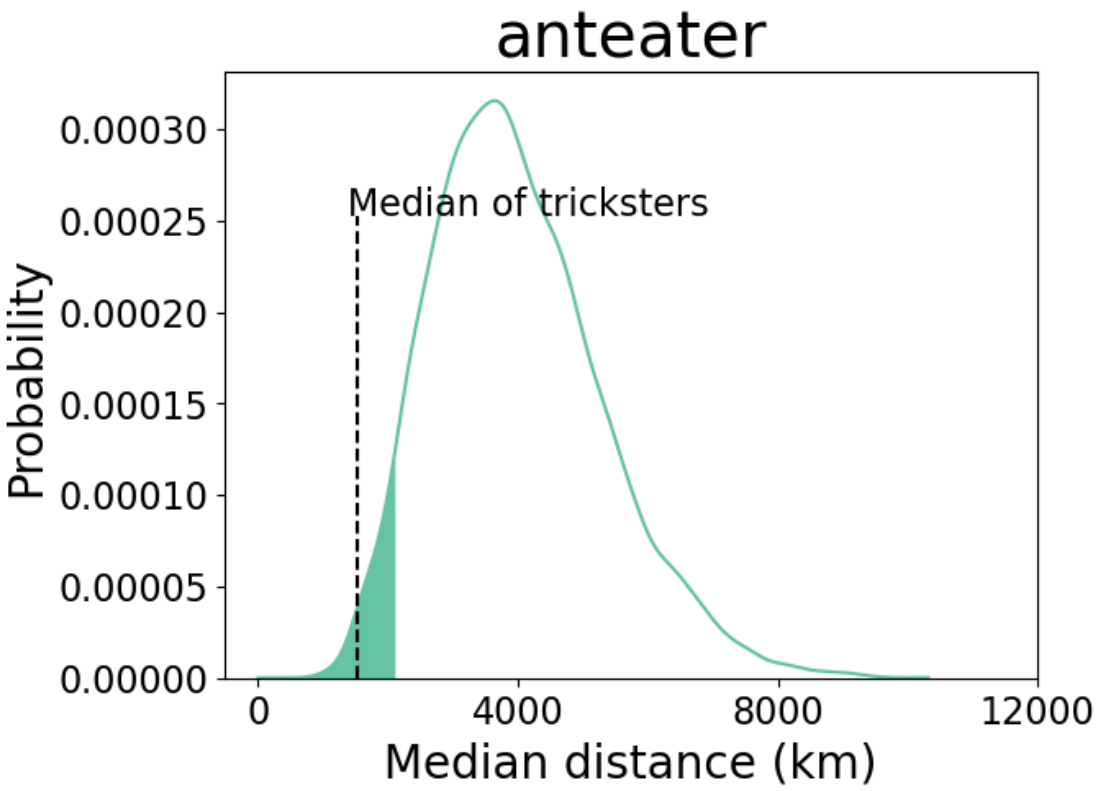
```
Python Current Version:- 3.10.12 | packaged by conda-forge | (main, Jun 23 2023,
22:41:52) [Clang 15.0.7 ]
H3 package version:- 3.7.6
Statsmodels package version:- 0.13.5
Latlon package version:- 0.0.7
Numpy package version:- 1.23.5
Scipy package version:- 1.10.0
Pandas package version:- 1.5.3
Geopandas package version:- 0.9.0
```

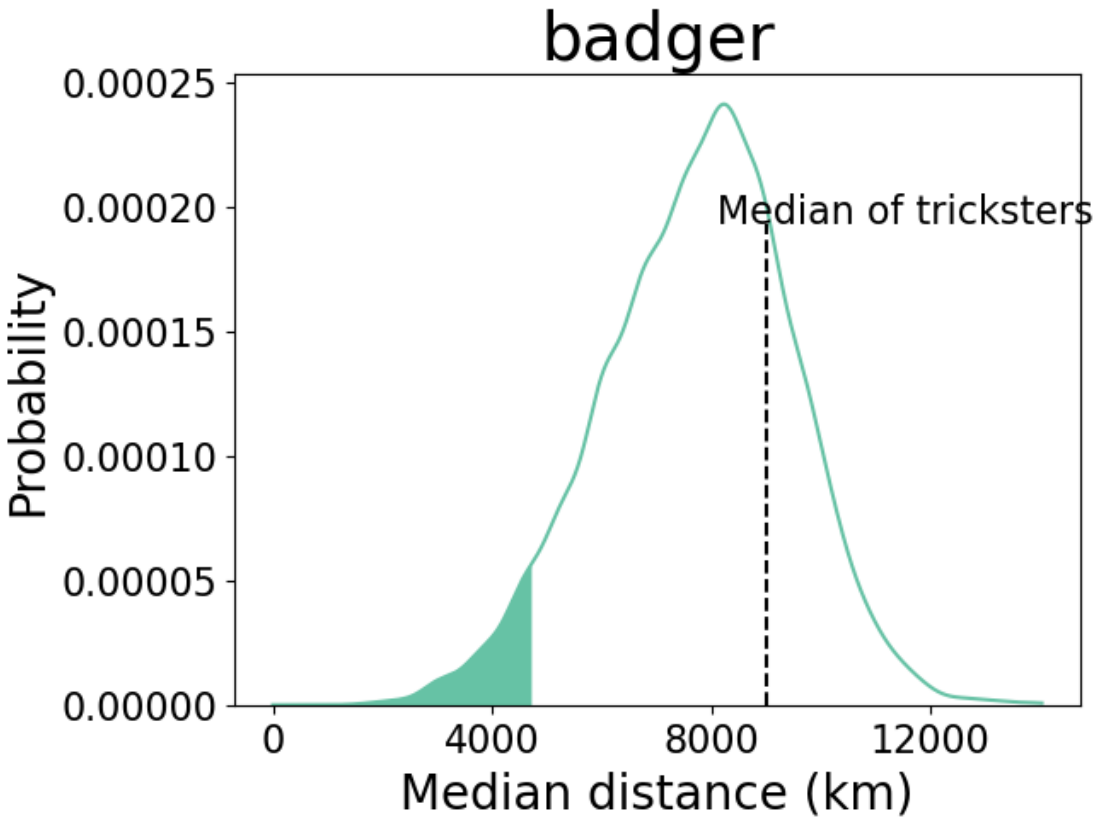
[2]:
```
def MedianDistance(data):
    # calculate median distance given data points
    center_lng=[]
```

```
    center_lat=[]
    for i in range(len(data)):
        x=h3.h3_to_geo_boundary(data[i], True)
        x=np.mean(x, axis=0)
        center_lng.append(x[0])
        center_lat.append(x[1])
    df=pd.DataFrame({'latitude':center_lat, 'longitude':center_lng})
    Distance=[] # realized distances between tricksters
    for i in range(len(df)):
        place1=df.iloc[i, :]
        for j in range(i+1, len(df)):
            place2=df.iloc[j, :]
            Distance.append(geodesic(place1, place2).km)
    return np.median(Distance)

def Distribution_Test(df, target, rep=10000):
    # Test whether TS is more dense than random distributions on RA
    # df: data farme of tricksters. See above as an example
    # target: str of target species
    # rep: int of replications to generate a median distributions under the␣
 ↪null hypothesis
    if target == 'water bird' or target == "monkey" or target ==␣
 ↪'ground_squirrel':
        print ("We ignore this species")
        return np.nan
    else:
        ␣
 ↪#-------------------------------------------------------------------------------------
        # Step  1: calculate distances between tricksters
        hex_TS=np.unique(df[df['TrickSter']==target]['hex_index']) # hex_grids␣
 ↪of focal Tricksters
        median_TS=MedianDistance(hex_TS)
        ␣
 ↪#-------------------------------------------------------------------------------------
        # Step  2: calculate distances under null hypothesis (random␣
 ↪distirbutions of TS given RA exist)
        df_meta=pd.read_csv('./GBIF/For_gbif_trickstar.xlsx - Sheet1.csv') #␣
 ↪meta file
        taxa=df_meta[df_meta['Category']==target]['Taxa'].reset_index(drop=True)
        for i in range(len(taxa)):
            if i==0:
                data=pd.read_csv('./GBIF/'+target+'/'+taxa[i]+'_cleaned.csv')
            else:
                dd=pd.read_csv('./GBIF/'+target+'/'+taxa[i]+'_cleaned.csv')
                data=pd.concat([data,dd])
        #print(data)
```

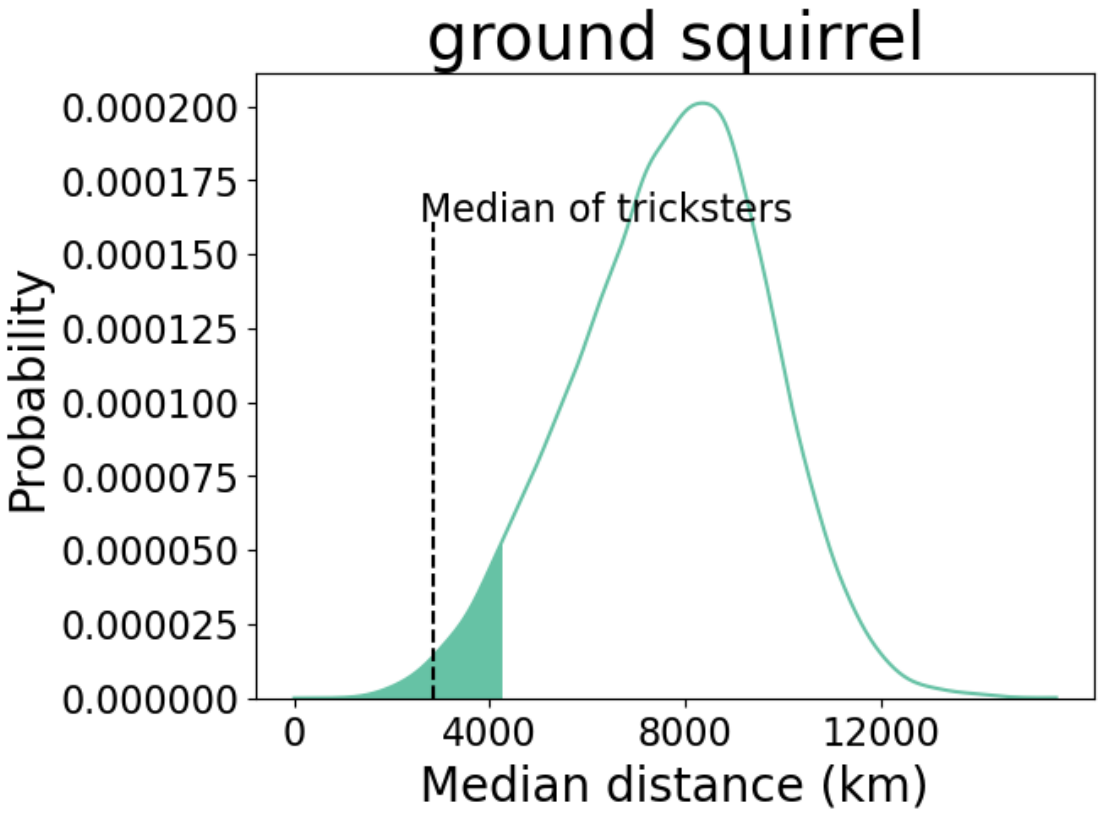
```
        hex_RA=np.unique(data['hex_index'])
        Median_RA=[]
        for k in range(rep):
            hex_extract=np.random.choice(hex_RA, len(hex_TS), replace=False)
            Median_RA.append(MedianDistance(hex_extract))
        kernel=sp.stats.gaussian_kde(Median_RA)
        x=np.linspace(0, max(Median_RA), 5000)
        y=kernel(x)
        cum_y= cumtrapz(y, x)
        idx_d= np.searchsorted(cum_y, 0.05) # index of x that gives cum~0.0.5
        p_val= cum_y[np.searchsorted(x, median_TS, side='right')]
        plt.plot(x, y, color='#66c2a5')
        plt.vlines(x=median_TS, ymin=0, ymax=max(y)*0.8, color='k',␣
↪linestyle='--')
        plt.ylim(0, max(y)*1.05)
        plt.fill_between(x[:idx_d], np.zeros([np.size(x[:idx_d])]), y[:idx_d],␣
↪color='#66c2a5')
        plt.xlabel("Median distance (km)", fontsize=20)
        plt.xticks([0, 4000, 8000, 12000], fontsize=16)
        plt.ylabel("Probability", fontsize=20)
        plt.yticks(fontsize=16)
        plt.text(x=median_TS*0.9, y=0.8*(max(y)), s='Median of tricksters',␣
↪fontsize=16)
        plt.title(target, fontsize=28)
        plt.savefig("CompareDistance_Earth"+target+".pdf", bbox_inches='tight',␣
↪pad_inches=0.05)
        plt.show()
        return p_val # significance
```

[3]:
```
species=np.sort(np.unique(df["TrickSter"]))
P_vals=[]
for i in range(len(species)):
    target=species[i]
    print(i)
    P_vals.append(Distribution_Test(df, target, rep=10000))

df_result=pd.DataFrame({'Tricksters':species, 'P values':P_vals})
df_result
```

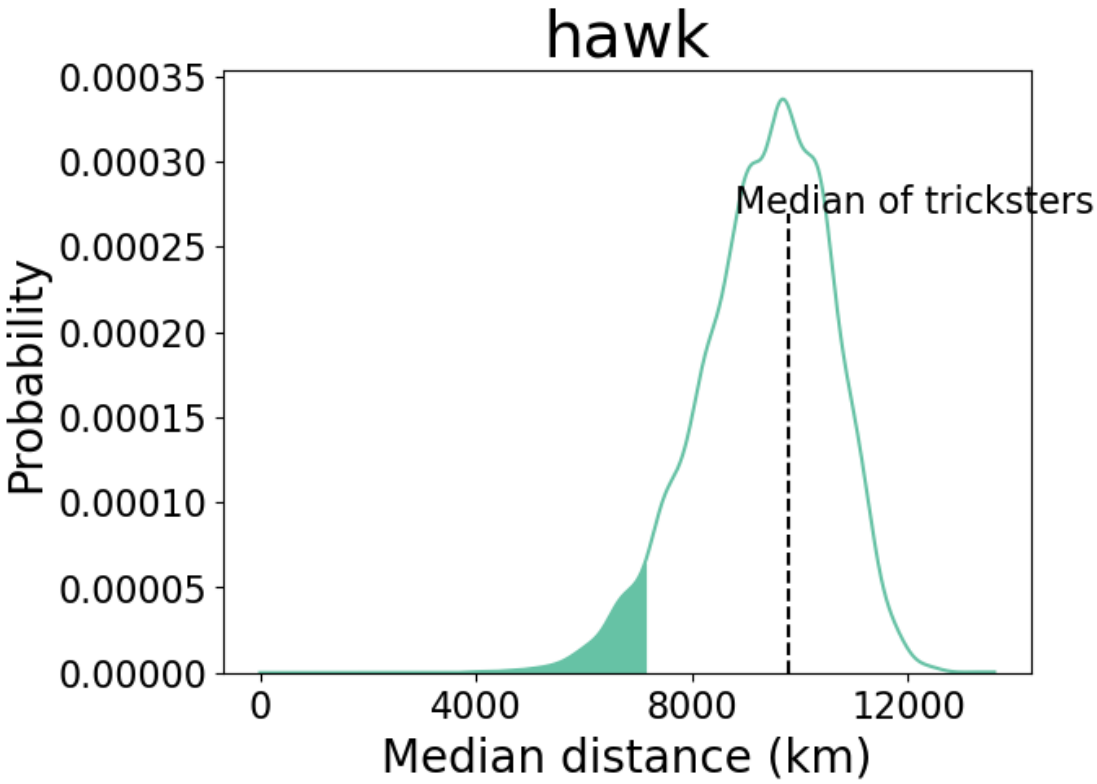

anteater
Median of tricksters
Probability
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)


badger
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
Probability
Median of tricksters
0
4000
8000
12000
Median distance (km)

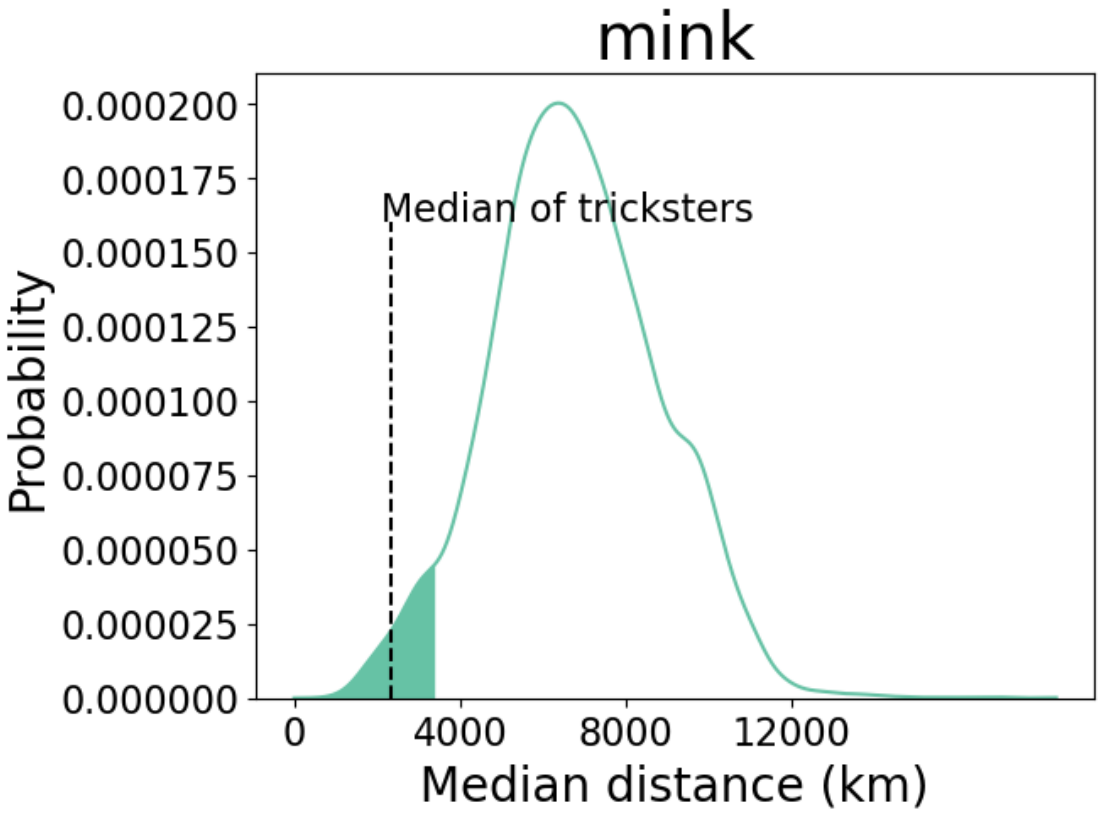
2


ground squirrel
Median of tricksters
Probability
0.000200
0.000175
0.000150
0.000125
0.000100
0.000075
0.000050
0.000025
0.000000
0
4000
8000
12000
Median distance (km)

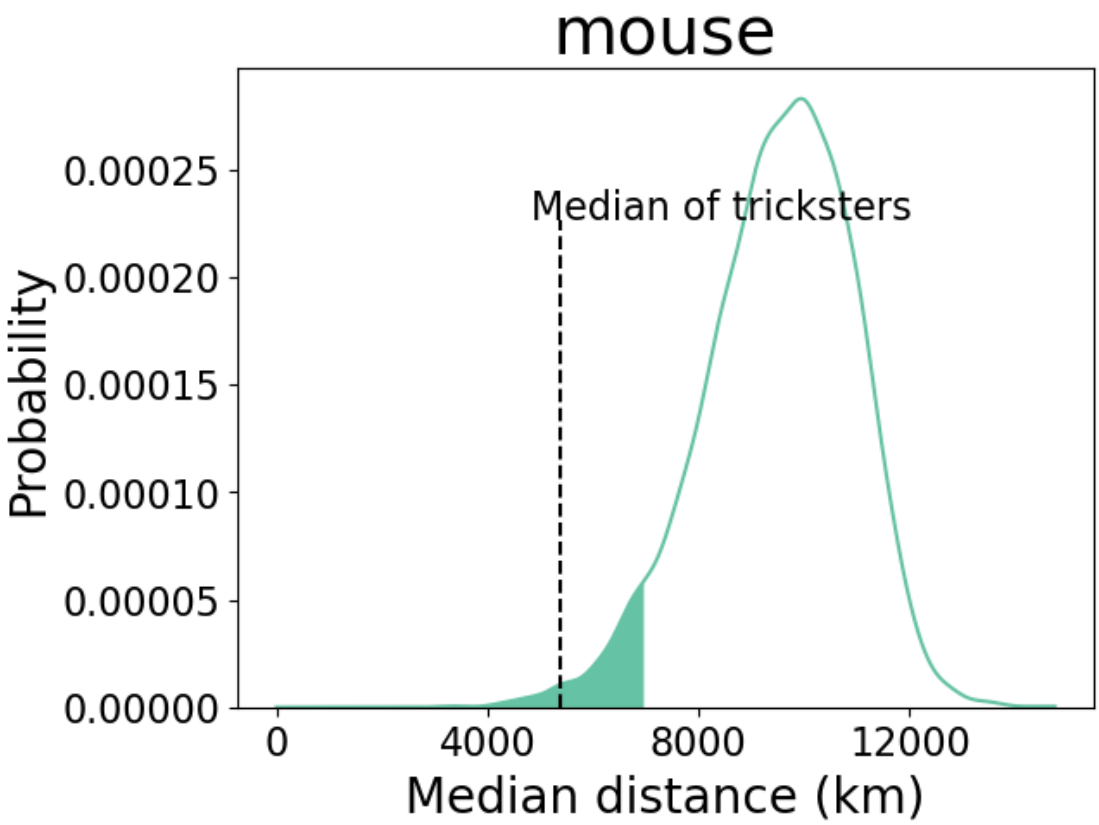
3


hawk
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
Probability
Median of tricksters
0
4000
8000
12000
Median distance (km)

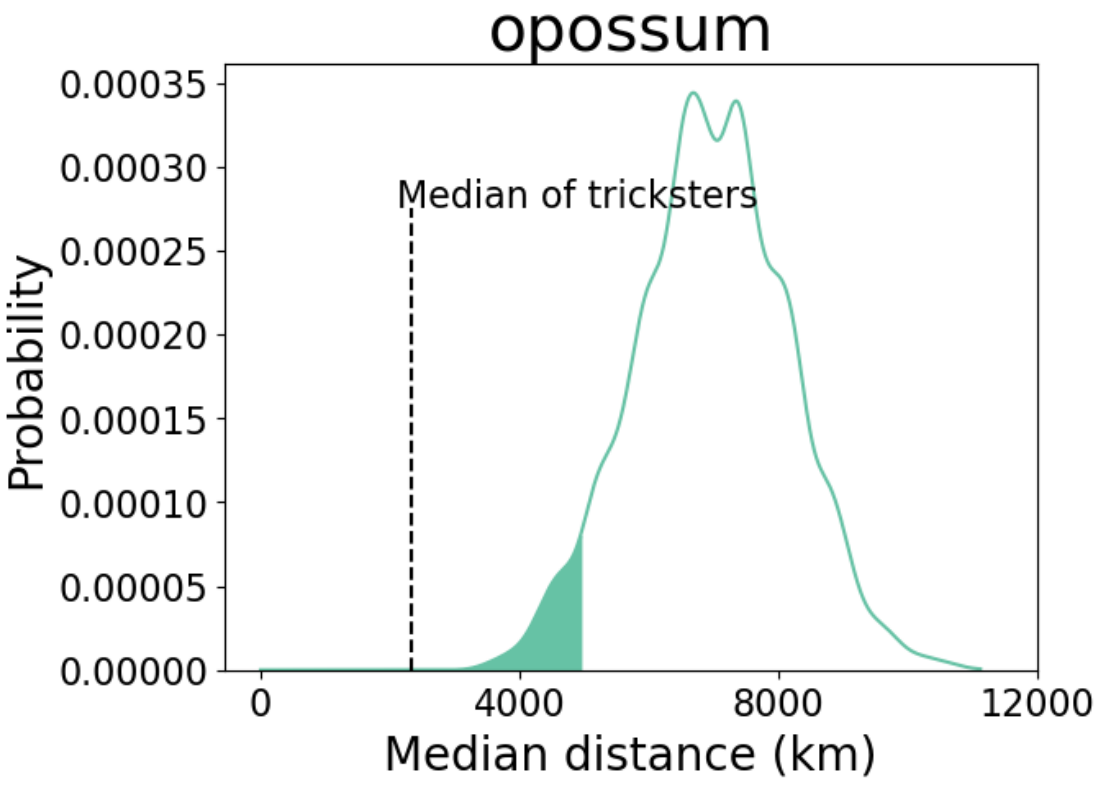
4



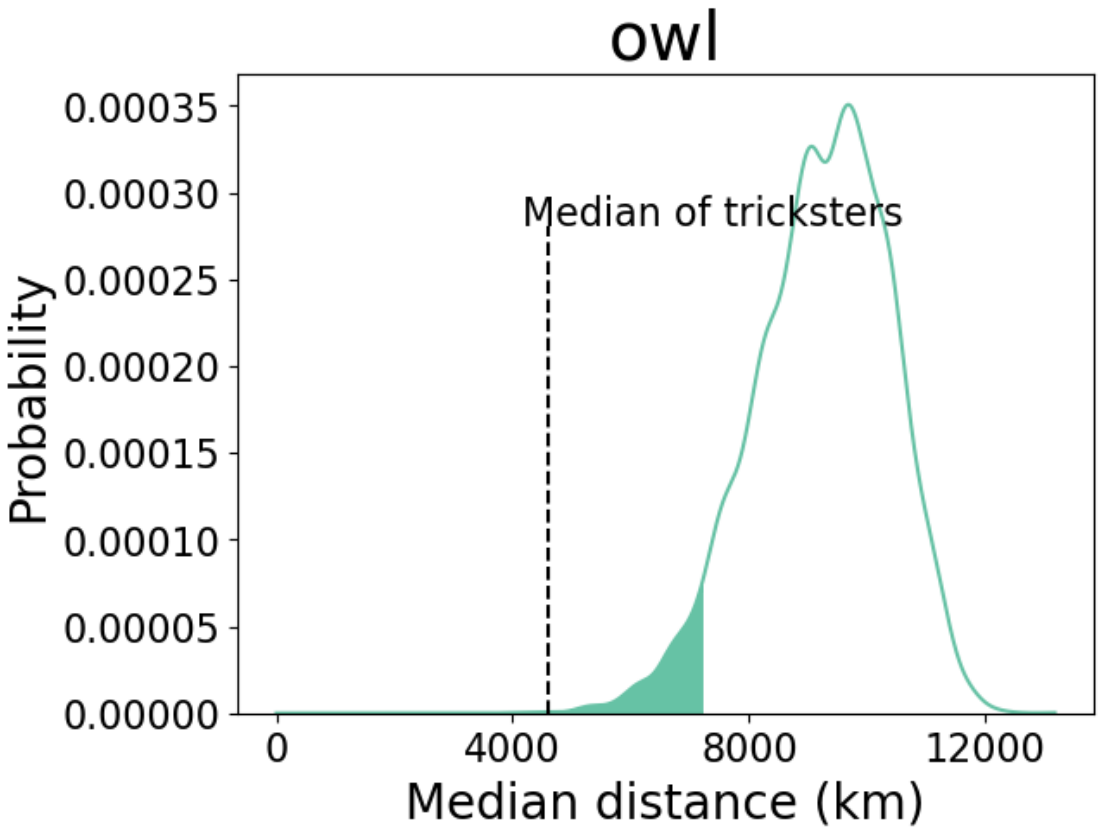

```
5
We ignore this species
6
```


mouse
Median of tricksters
Probability
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)

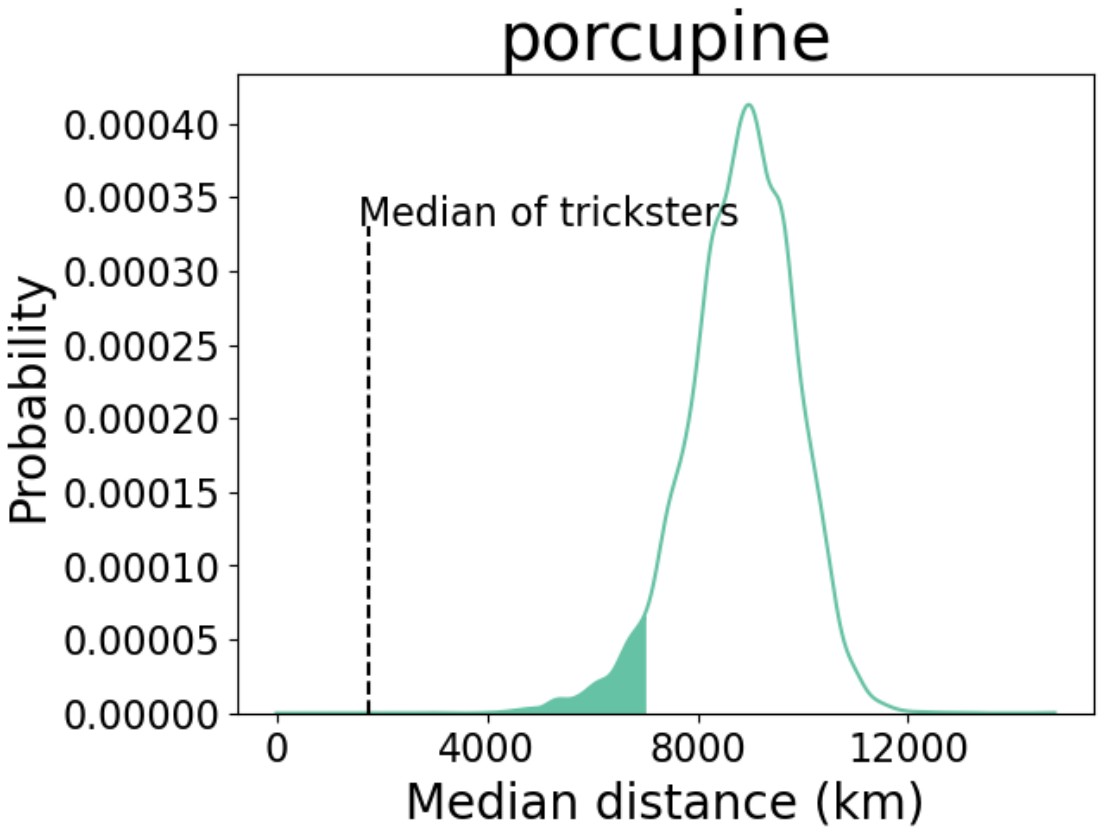
7


opossum
Median of tricksters
Probability
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)

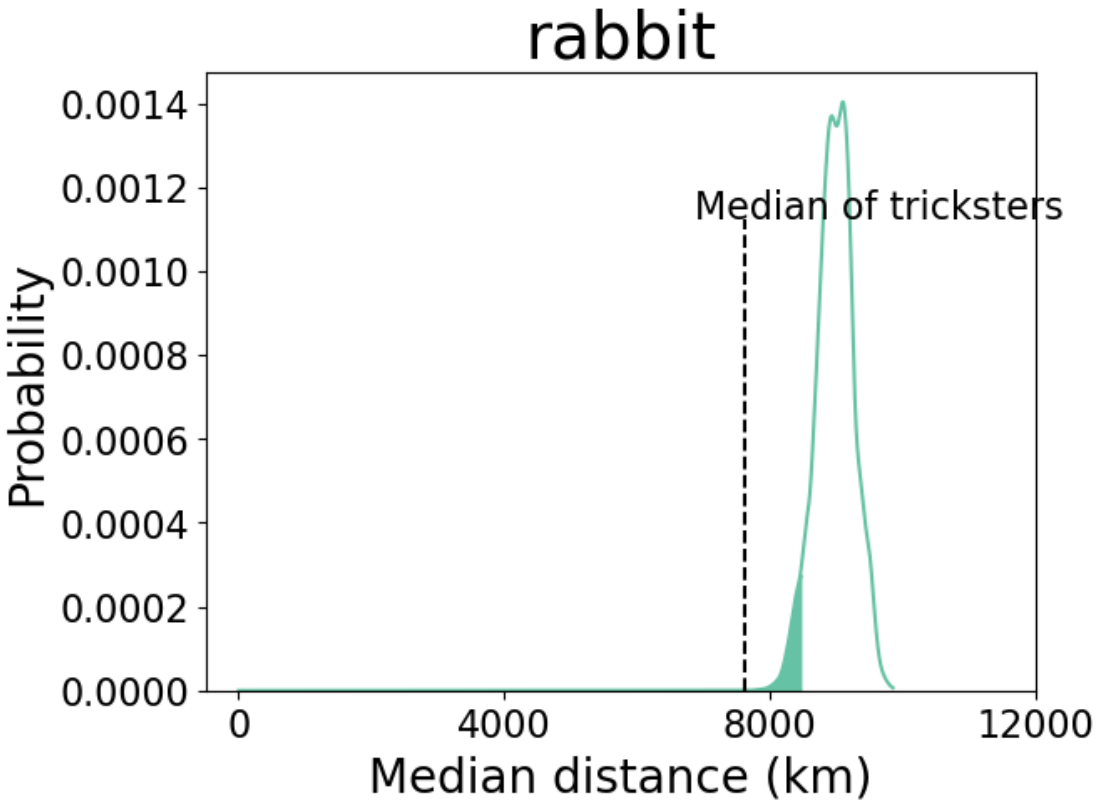
8


owl
Median of tricksters
Probability
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)

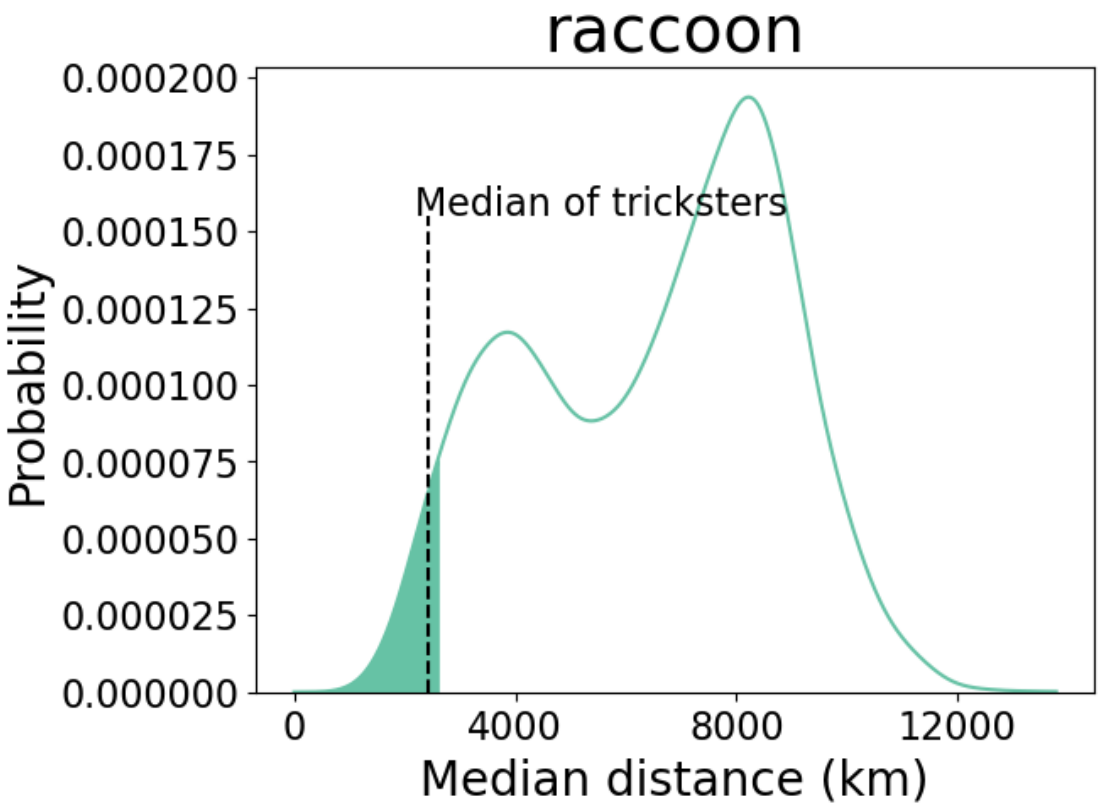
9


porcupine
Median of tricksters
Probability
0.00040
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)

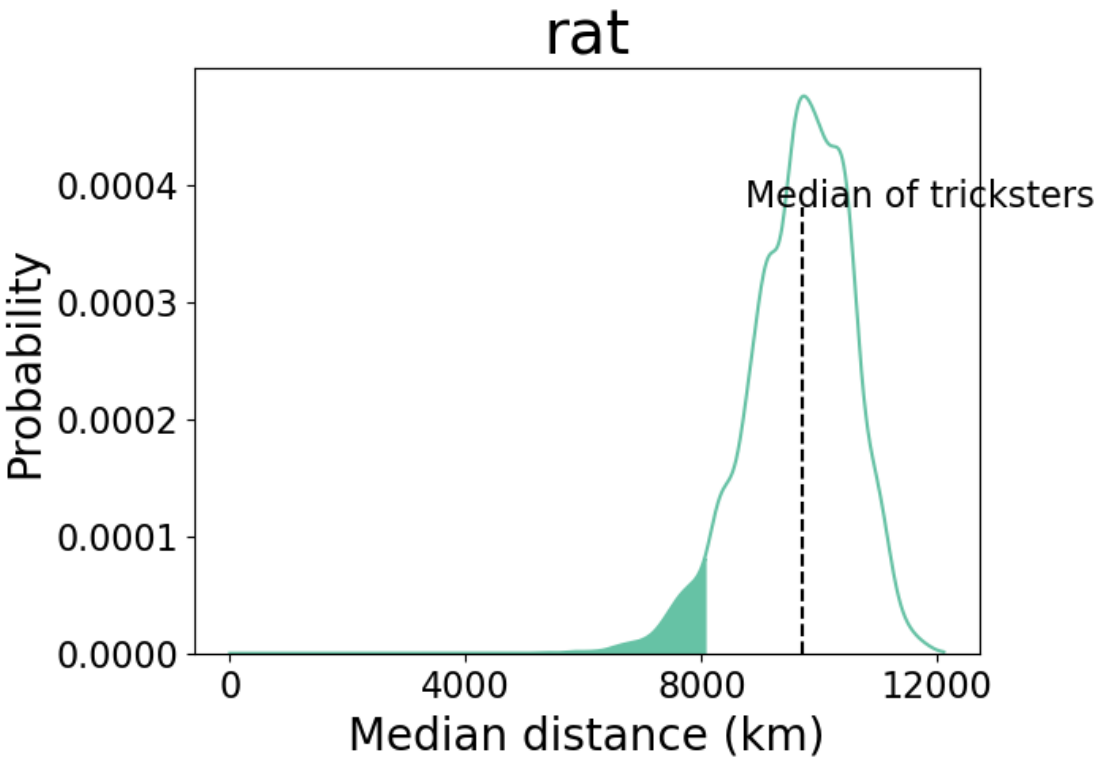
10


rabbit
Median of tricksters
Probability
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
0
4000
8000
12000
Median distance (km)

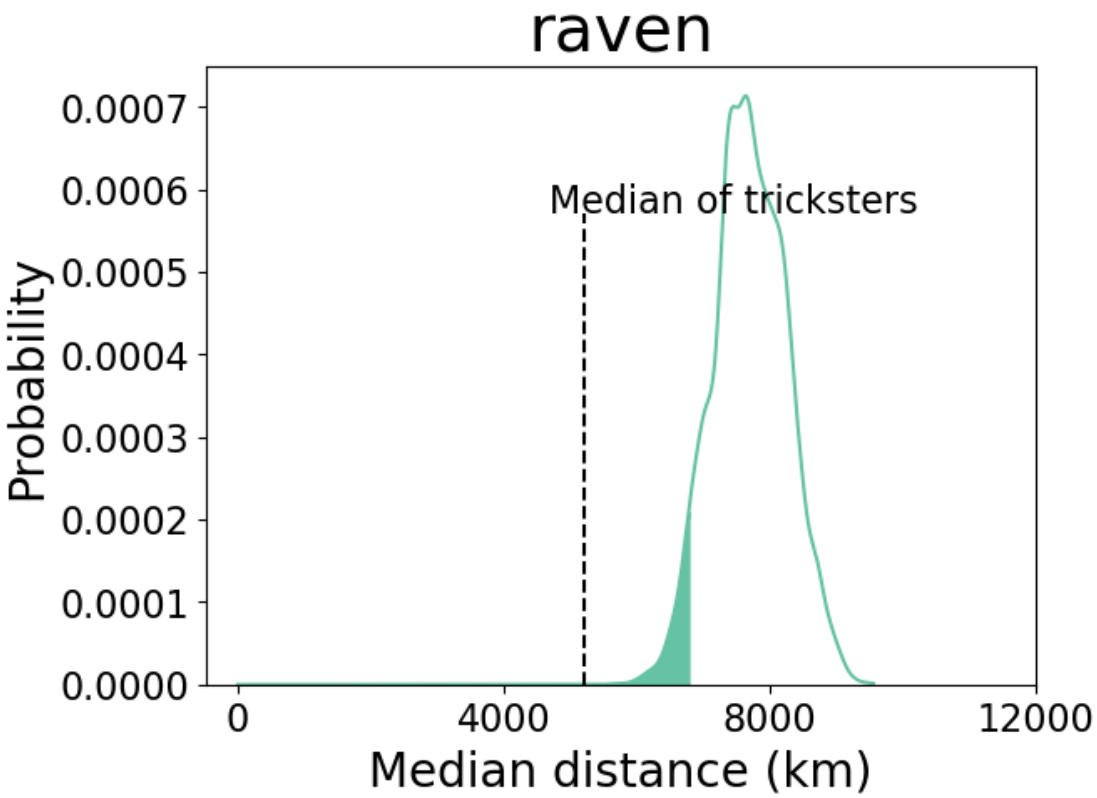
11


raccoon
Median of tricksters
Probability
0.000200
0.000175
0.000150
0.000125
0.000100
0.000075
0.000050
0.000025
0.000000
0
4000
8000
12000
Median distance (km)

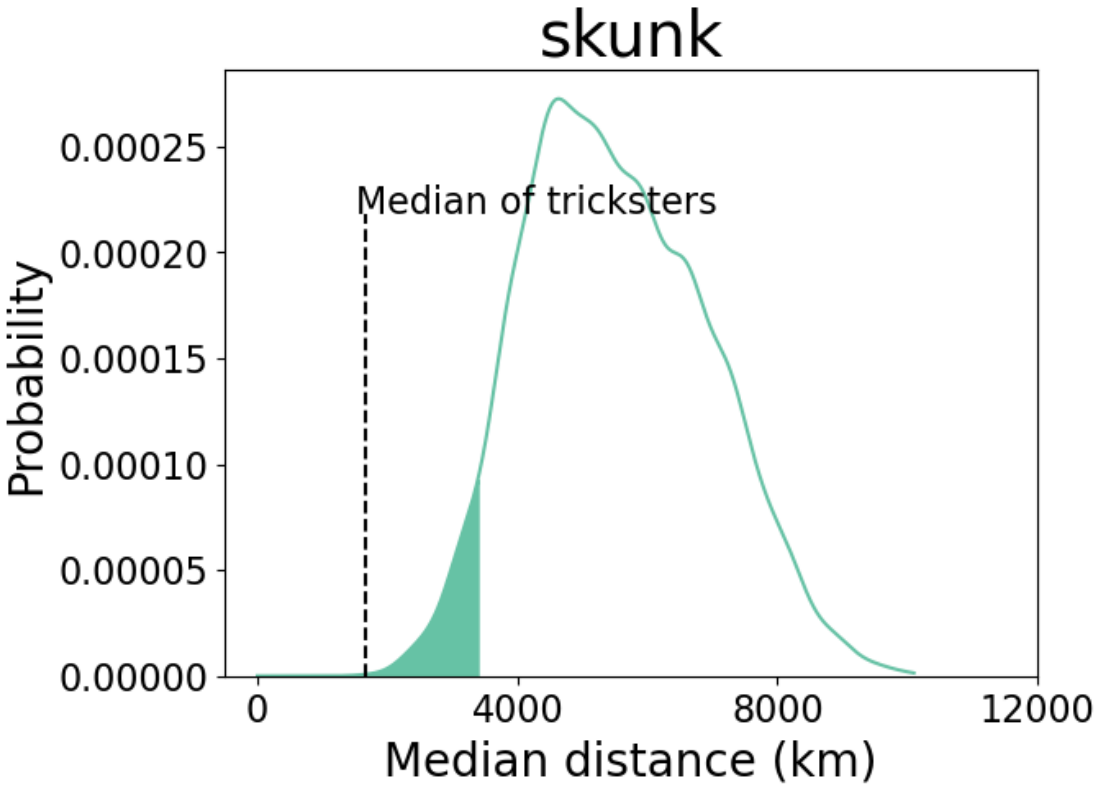
12


rat
Median of tricksters
Probability
0.0004
0.0003
0.0002
0.0001
0.0000
0
4000
8000
12000
Median distance (km)

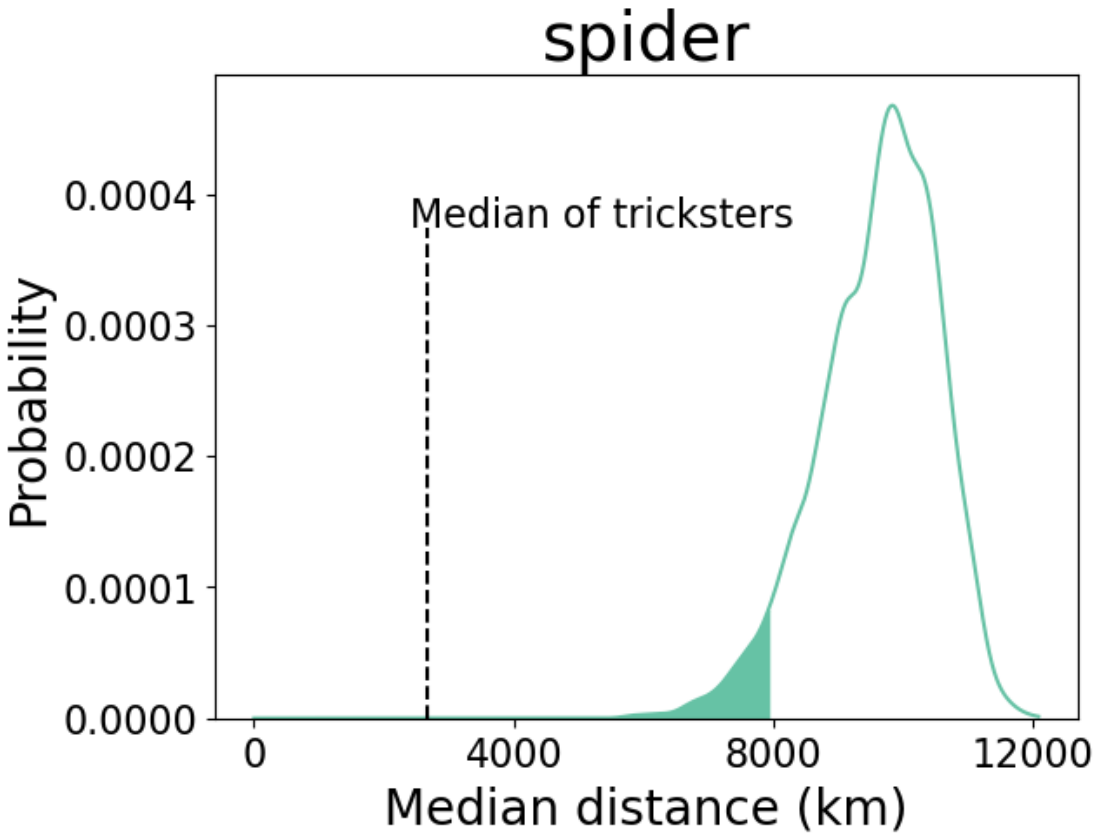
13


raven
Median of tricksters
Probability
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
0
4000
8000
12000
Median distance (km)

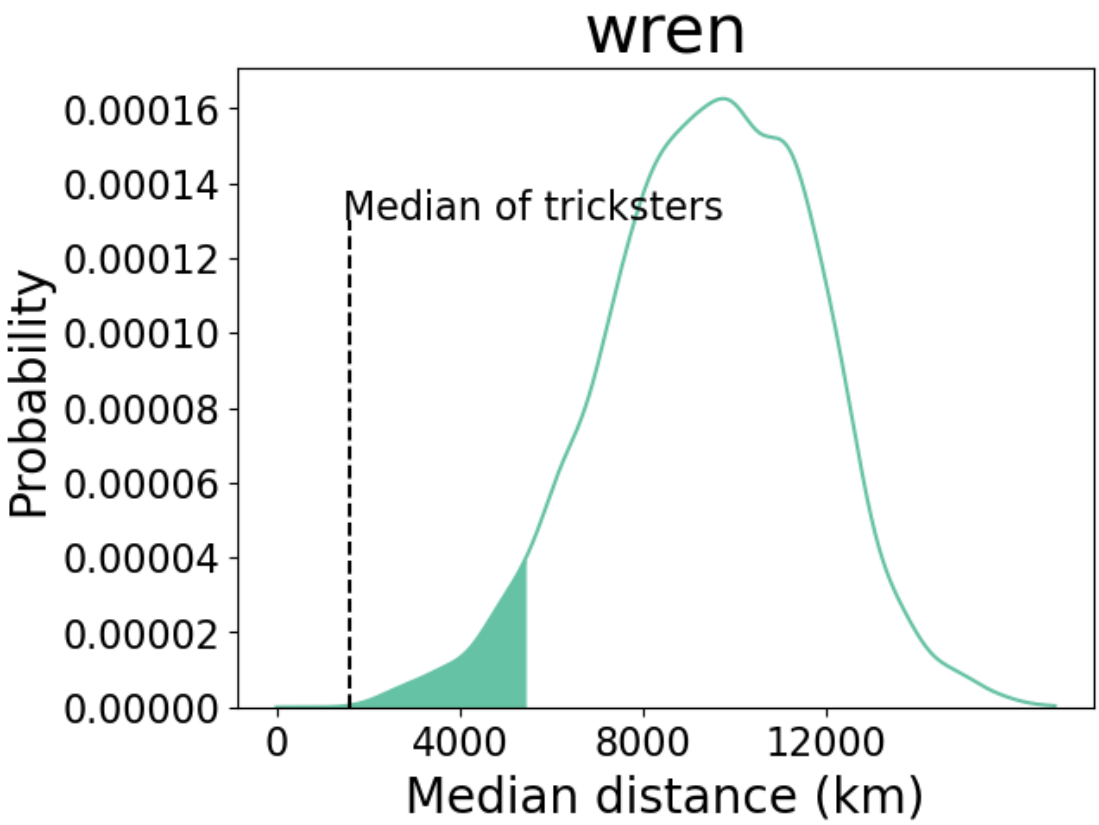
14


skunk
Median of tricksters
Probability
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0
4000
8000
12000
Median distance (km)

15




```
16
We ignore this species
17
```



[3]:

	Tricksters	P values
0	anteater	9.175249e-03
1	badger	7.667480e-01
2	ground squirrel	8.617822e-03
3	hawk	6.091850e-01
4	mink	1.435613e-02
5	monkey	NaN
6	mouse	6.633914e-03
7	opossum	3.893430e-12
8	owl	3.726845e-04
9	porcupine	9.084544e-17
10	rabbit	7.392047e-05
11	raccoon	3.768113e-02
12	rat	4.943719e-01
13	raven	2.117432e-11
14	skunk	1.407489e-04
15	spider	2.793762e-103
16	water bird	NaN
17	wren	1.129938e-04

[4]:
```
df_result=pd.DataFrame({'Tricksters':species, 'P values':P_vals})
df_result=df_result.drop(index=[5, 16])
```

[5]:
```
# need to remove monkey bird and GS

a, b=multitest.fdrcorrection(df_result['P values'])
df_result['FDR']=a
df_result
```

[5]:

	Tricksters	P values	FDR
0	anteater	9.175249e-03	True
1	badger	7.667480e-01	False
2	ground squirrel	8.617822e-03	True
3	hawk	6.091850e-01	False
4	mink	1.435613e-02	True
6	mouse	6.633914e-03	True
7	opossum	3.893430e-12	True
8	owl	3.726845e-04	True
9	porcupine	9.084544e-17	True
10	rabbit	7.392047e-05	True
11	raccoon	3.768113e-02	True
12	rat	4.943719e-01	False
13	raven	2.117432e-11	True
14	skunk	1.407489e-04	True
15	spider	2.793762e-103	True
17	wren	1.129938e-04	True

[7]:
```
13/16
```

[7]:
```
0.8125
```

Mote that the pvalues may sligtly differ from the manuscript due to the stochasticity of the permutation analysis.

As we can see above, about 80% data (where we remove three species from the analysis) suggest that TS is more clugged than the null hypothsis. The exceptions are badger, hawk, racoonm, and rat. RA distribution of racoon is clugged while that of badger hawk, and rat are as broad as those of TS, respectively (see Analysis Note 6). In the above figures, these three species show median >8000km

[ ]:
```

```