How ungulate respond to linear barriers

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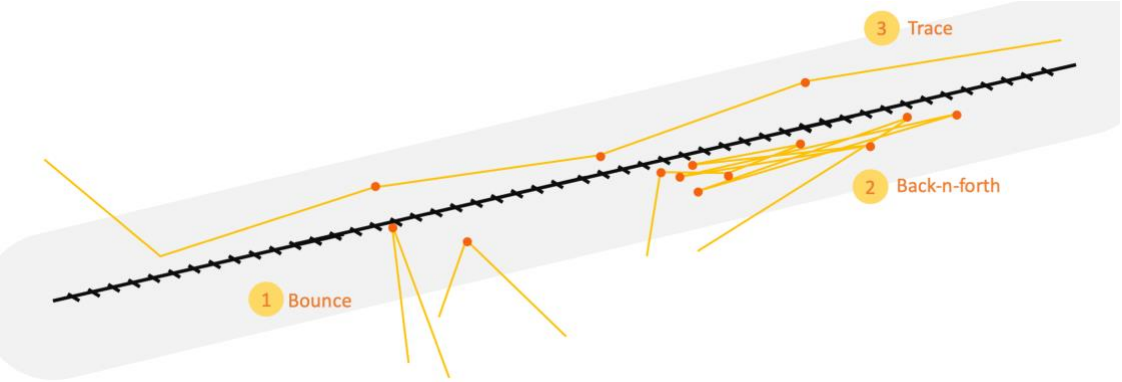
Overview

What are different behaviors animals have when attempting to cross a linear barrier?

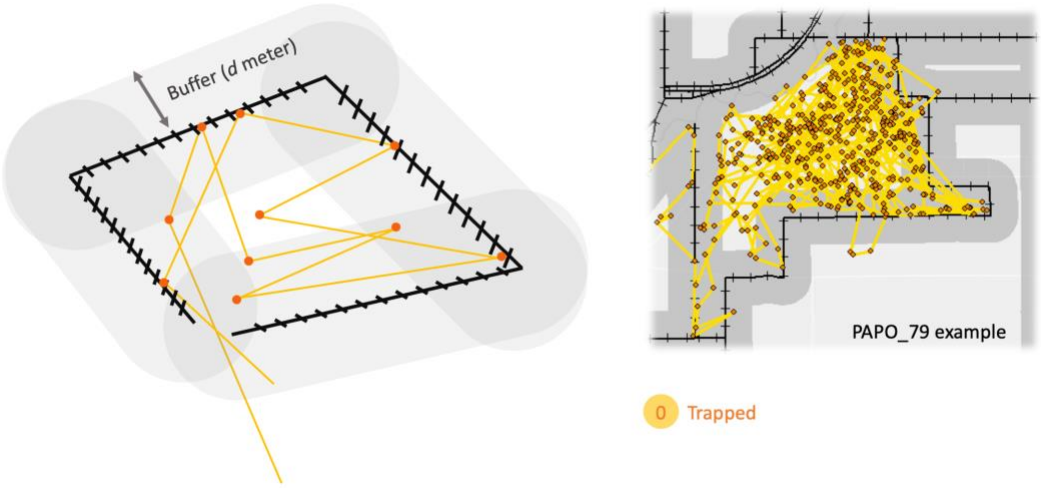


A general objective of this analysis is to offer a **simple** method to examine animal behaviors when encountering a fenceline (or linear barriers in general). The document is to explain the method I am using. The last section fof the document will discuss futher implications of this method.

The classification process. Step 1, detects all "enounter events". One encounter event is defined by all points in a continuous time period that are in a buffer zone with a certain distance. Then based on **1)** whether the animal crosses a fence-line (if so, they are not included in the analysis),**2)** duration of the encounter event and **3)** movement straghtness of the encounter event to classify types of encounter events. Straightness is the ratio of distance between the first point and last point in the trajectory of the encounter event, and the acculated distance of all steps in the trajectory. It has been shown as an effective index to estimate efficiency of an oriented movement (in comparison, tortuosity is for testing random search path).

Special situations

1. Trapped
   Sometimes the captured "enounter events" do not reflect animals' "response behavior". Animals can be *trapped* in a fenced area. Such situation is featured by a prolonged period that animals spent next to a fence. Sometimes the trapped situation could also be animals at non-migratory stage, such as during the wintering periord. But it is obvious that their home range area is constrained by fences.

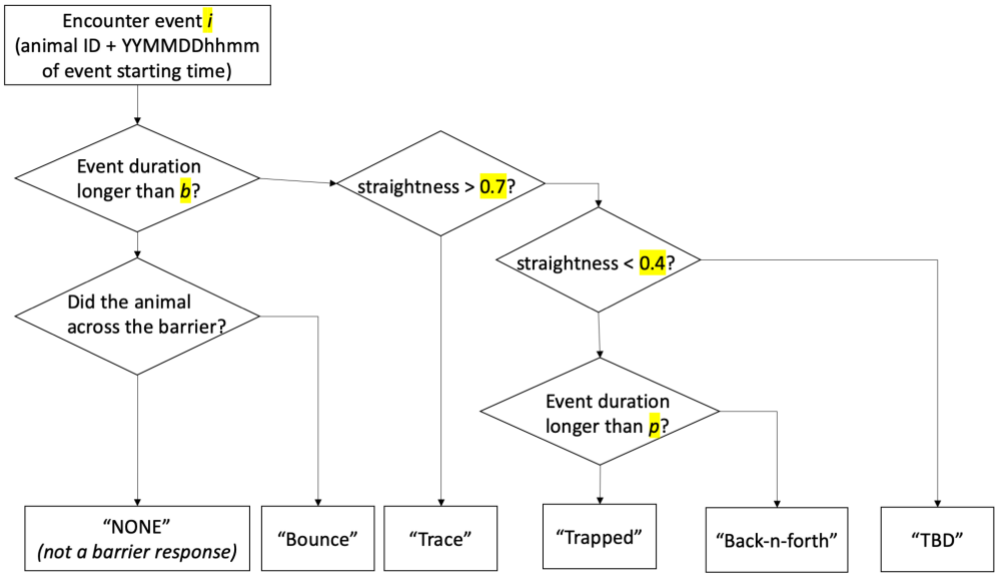


2. TBD
   The drawback of using "straightness" to classify *back-n-forth* and *Trace* is that there is no clear cut-off between these two behaviors (See a histogram below in the *Feedback* section showing the distribution of straightness across many animals). For such situations, I temporally marked them as *TBD* (more discussions at the end of the document).

The parameters that can be customized in the classification

FB.distance: fence buffer distance, to identify encounter events
Interval: specify the temporal interval of the input movement data
b: maximum duration that the event would be considered as "bounce". (if for a long time animals "bounce" with buffer, then it is likely a "back-n-forth" response).
p: minimum duration over which we consider the animals is trapped.
t: tolerance. Sometimes, especially for high temporal resolution data, animals maybe move out of buffer but immediately back to continue the same barrier response. t needs to be smaller than b.

Process flowchart

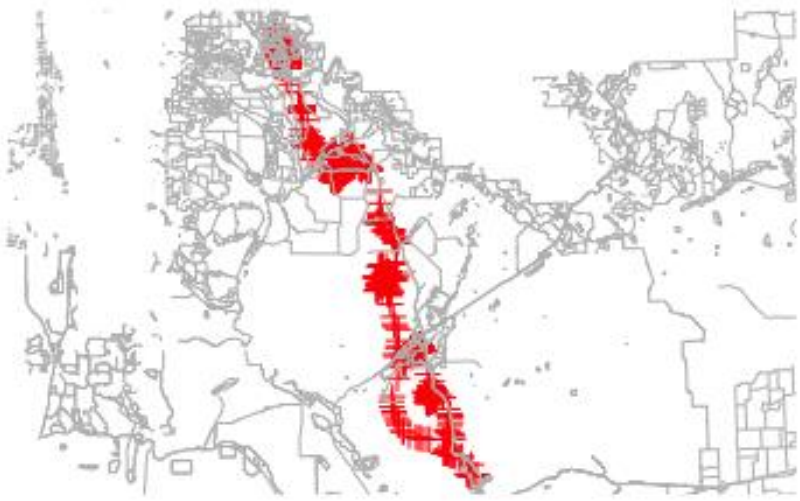


Note, the straightess cut-off is rather random now.

Example: PAPO079

Take one individual PAPO_79 from the Pinedale population as an example.

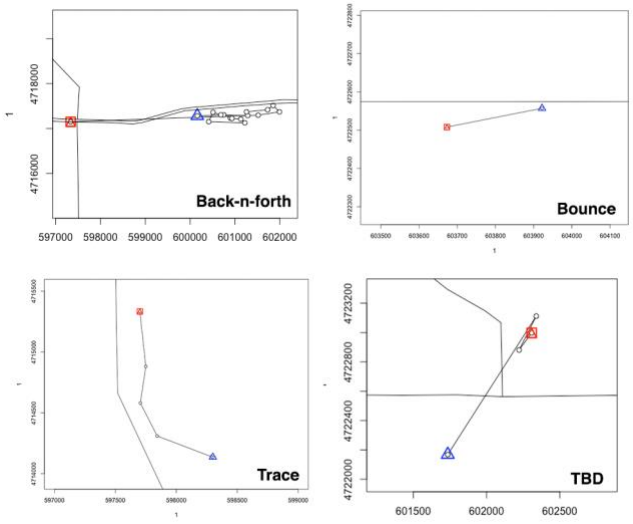
```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/Mushy/Google Drive
(wenjing.xu@berkeley.edu)/RESEARCH/Pronghorn/Analysis/FenceBehavior/Individua
lTrial", layer: "Fence062219"
## with 9778 features
## It has 3 fields
## Integer64 fields read as strings:  OBJECTID

## OGR data source with driver: ESRI Shapefile
## Source: "/Users/Mushy/Google Drive
(wenjing.xu@berkeley.edu)/RESEARCH/Pronghorn/Analysis/FenceBehavior/Individua
lTrial", layer: "PAPO_79"
## with 2921 features
## It has 9 fields
```



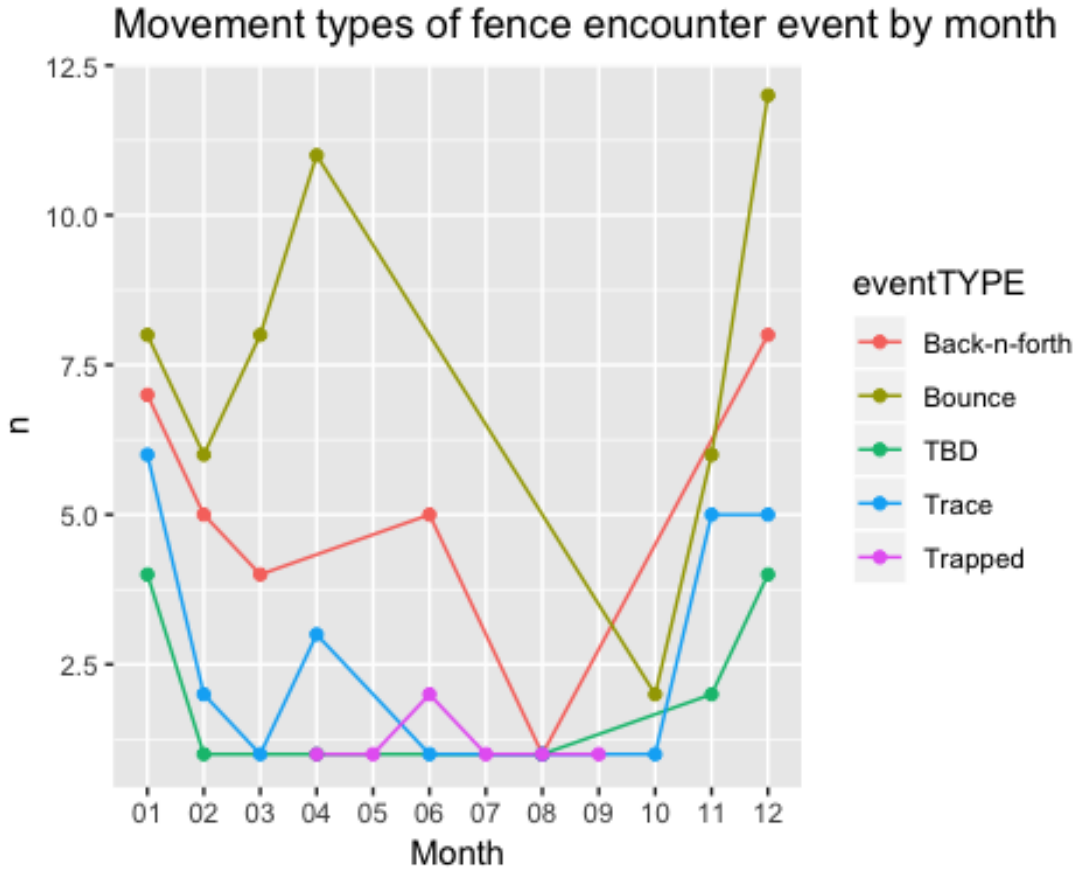
```
##    Length     Class      Mode
##      1890 character character
```

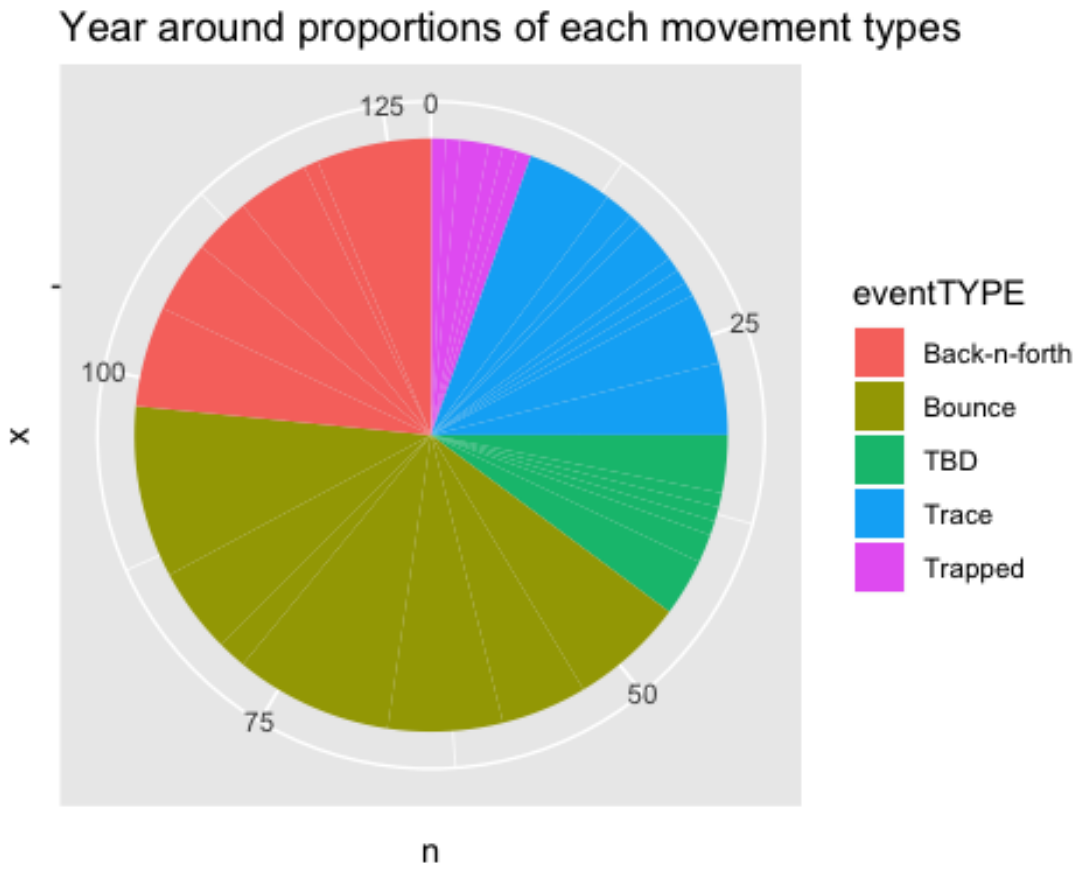
Then run classification based on the classification tree presented earlier. Here is the code I use.

Here are some examples of resulted classification of the individual PAPO_79



A summary of the classification results of individual PAPO_79

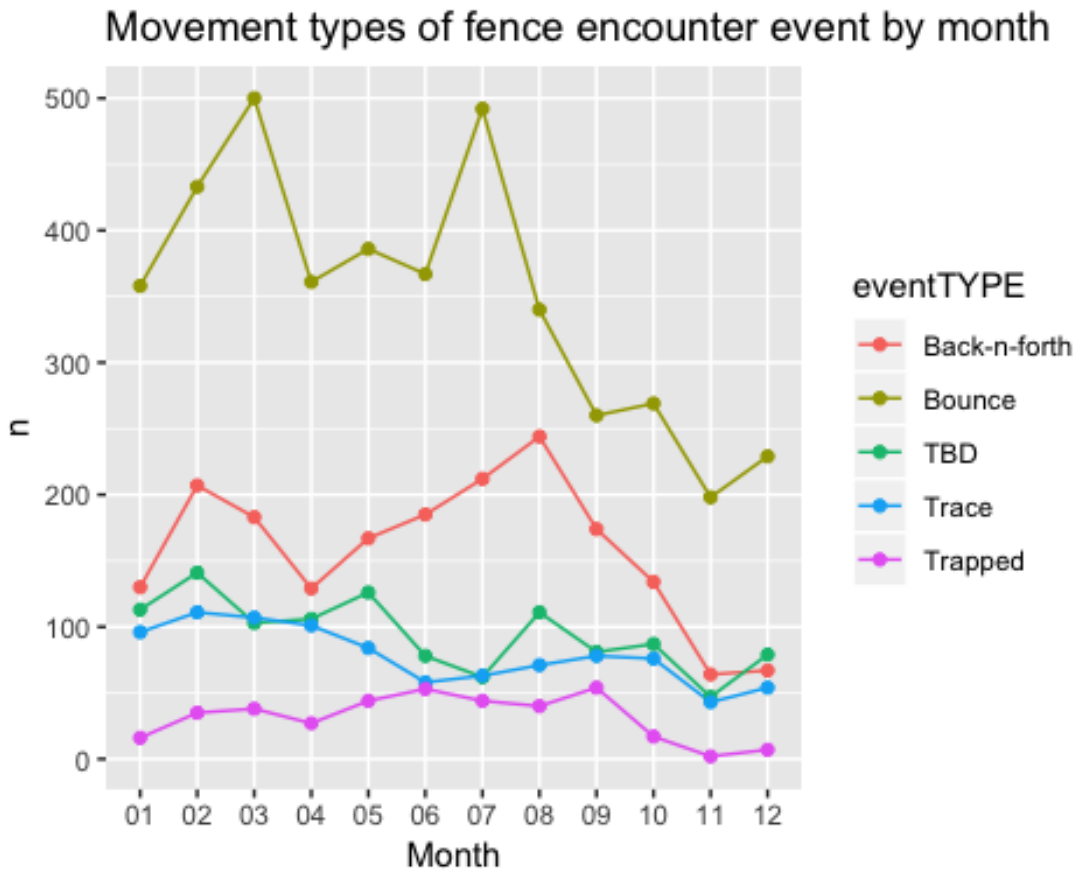


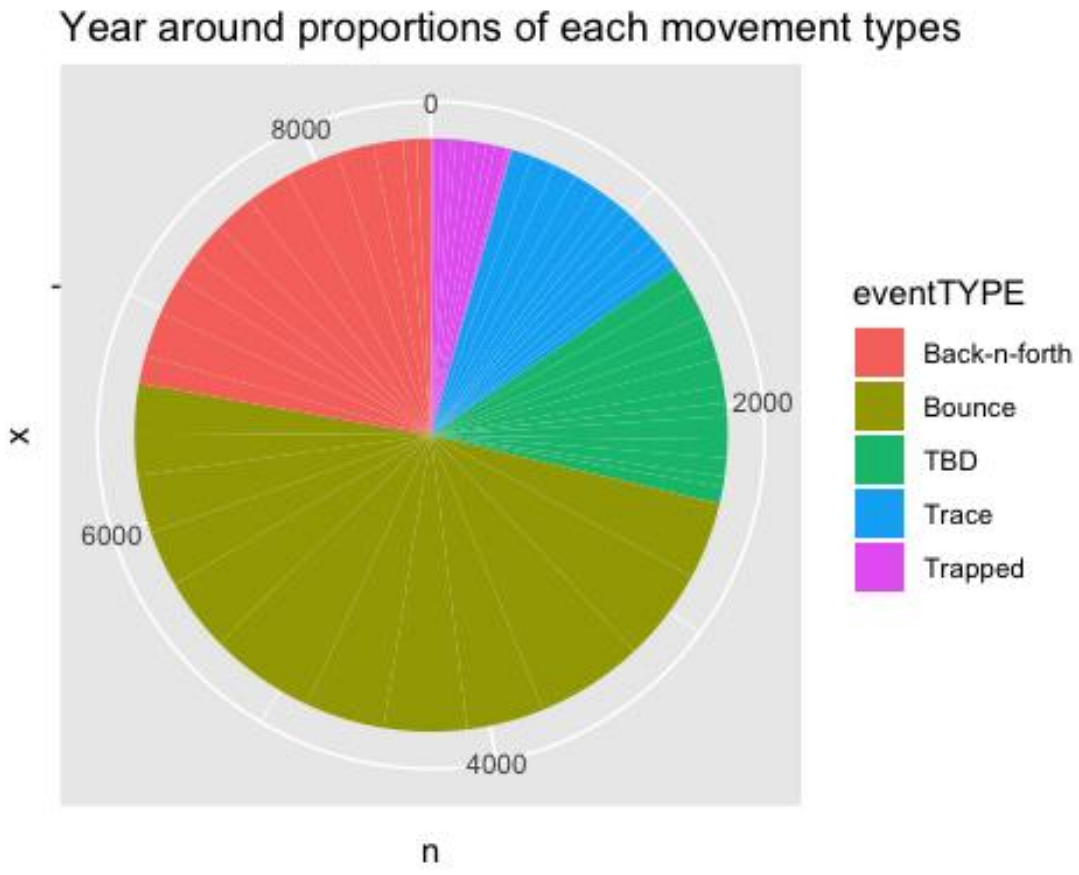


The result is pretty preliminary but there are a couple things that I notice:
1. There are in total 128 encounter events for animal POAPO79. We were able to classify 115 of them.
2. Most of the events are classified as bounce, then back-n-force and trace. Most envountering events are in the winter (Nov - Apr).
3. Most of the fence response behavior , especially *Bounce* happens more in winter/spring while *trap* is all in the summer/early fall.

I applied the method to all animals with 3 hour interval in pinedale and the data is vidualized at this link that I shared before.

The following are the same two summary plot for all individuals:


Movement types of fence encounter event by month
500
400
300
200
100
0
n
01
02
03
04
05
06
07
08
09
10
11
12
Month
eventTYPE
Back-n-forth
Bounce
TBD
Trace
Trapped



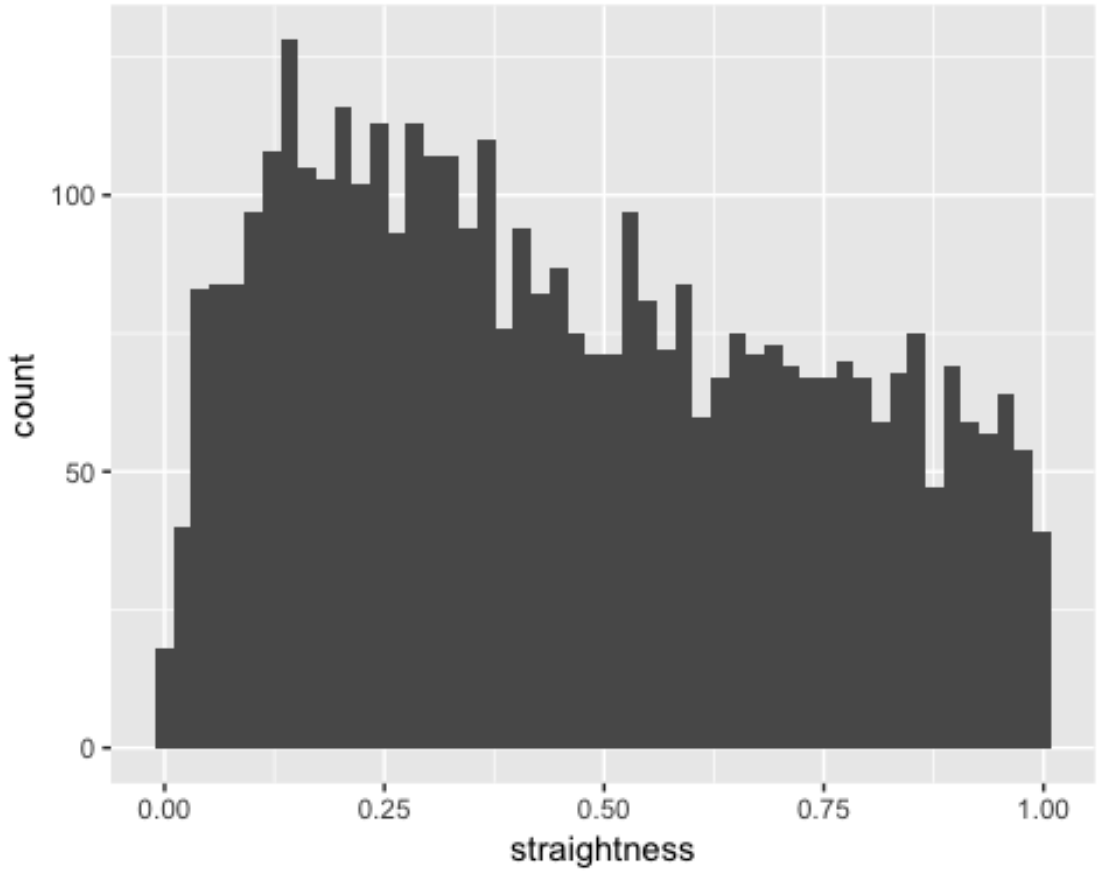
1. There are in total 8542 encounter events for 62 animal-year. We were able to classify 7408 of them.

2. Same as the individual result, most of the events are classified as bounce, then back-n-force and trace.But now summer shows the most encountering event, following by late spring.

3. Both *Bounce* and *Back-n-forth* show 2 peaks one in spring on in summer, while *Trace* and *Trap* is relative stable.

Feedback needed

1. What to do with the intermediate classes *TBD*? Visual interpretation shows they are indeed something in the middle of "*trace*" and "*back-n-forth*". The following histogram shows the straightness calculation for Back-n-forn, TBD, and Trace. There is no clear cut-offs really.



A potential solution is to treat "trace" and "back-n-forth" as a continuous behavior. So we only keep *bounce* and *trace*, with *trace* characterized with a straightness index. Any thoughts?

2. Ecological interpretations of "bouncing", "tracing" and "back-n-force"? This question is related to my next question -

3. How to quantify the level of *problematic* of fences? Or really, we are trying to find the fence that is worthwhile to modify.
   - accumulative time animals spent near it?
   - (maybe a better tone) fence lines where animal more often conduct *back-n-force* behavior. *Trace* may mean the fence is paralell to the general direction the animal wants to go but *back-n-forth* may mean they are seeking for an exist.
4. We do not know whether this method is sensitive to different fix intervals or not. I would assume a higher temporal frequency will yield better classification results. I might conduct a sensitivity analysis using high frequency animal data resampled down to multiple different invervals.

Implications of the method

The next step is then to use the classification results to **1)** identify the most problematic fences, **2)** idenfity time of year when animals are the most vulnerable to fences, **3)** examine external factors which may affect how animals respond to fences (e.g. landscape features, time of year, human activities…), **4)** examine intra- and inter-species differences in animals behaviral responses to fences. But for this document, it is main to discuss the method itself.

1), **2)**, and maybe **3)** can reveal more practical answers for the managers in WY and maybe can be included in one paper. I am very interested in **4)** and I might be able to test this on Mongolian gazelle and wildebeast (both of them are proven to be heavily restricted by fences). As a comparison, we could apply to one species that is not as susceptible to fences, such as mule deer?