**Research Questions:**

1. **What are the dates that swans leave their summer territory in the fall and return in the spring?**
   1. **“Leave” defined with a spatial threshold**
2. **How far are swans moving from summer territories during the non-breeding period?**
3. **How long are swans spending ‘overwintering’ in non-breeding areas**
   1. **Or simply over a certain distance away from the breeding area**
4. **How do migration patterns differ by latitude, longitude, and breeding status?**
5. **How does water condition (natural open lake/river/artificial open lake)?**
6. **What is the degree of annual individual and population variability in migration patterns?**

**Objective: Describe the spatio-temporal patterns of IP swan movement during the non-breeding season (i.e. annual movements but not focused on the breeding season).**

Methods Outline

1. **Migration Phenology**

* What are the **dates** that swans leave their breeding/summer territory in the fall, and arrive back in the spring?
  + No arrival/departure of overwintering area b/c that is not necessarily stable for the entire winter, instead, anchor to breeding site as a point of reference
  + Could consider stopover use dates, but stopover vs overwintering can be squishy with a short-distance migrant
  + Might want to use a different term than “migration” phenology if we’re talking about swans that may leave their annual territory but only make a very small movement away (e.g. Grass Lake swan in Bemidji)

Steps:

* 1. Define summer territory using some metric of home range during the summer
  2. Define a spatial threshold, over which swans are considered to have left their breeding territory **(possibly with the previous segmentation method from the colt paper?)**
  3. **(Q1)** Using this distance limit versus a centroid of the summer movement (assuming relative stationarity), write out the estimated ‘fall leave’ and ‘spring return’ dates.
  4. Explore using mcp with these dates as initial values and tight priors for the parameters (therefore bound the first and last changepoint, and potentially define stopover/winter using data-driven cross-validation?)
     1. **Depending on how well this works, the # of stopovers and/or wintering sites, as well as their distance from the breeding sites can be pulled from mcp model output, satisfying questions 1-3 at the same time.**

1. **Migration Extent and Duration (Extent-> Distance, Duration-> Time)**

Steps:

* 1. **(Q2)** Assuming mcp is **NOT** a great option for doing all this, use either ‘max distance’ and/or ‘furthest point south’ for a measure of how far swans traveled during the nonbreeding period
     1. ‘furthest point south’ would be biased toward N/S movements
     2. Either have in table or make visualization
        1. How to group for visualization?
  2. **(Q3)** Calculate the time spent away from breeding/summer territory using the phenology dates from the first section
     1. Consider checking if swans made multiple trips back to their territory during the winter (**e.g. Michigan swan did this**)
     2. Contain estimates in table
  3. **(Q1-3)** Make NSD plots for all swans to simultaneously describe time and distance throughout annual cycle
     1. For a descriptive plot, I could run all (or some) of the swans through NSD, then either plot them all with a high alpha for overlap (and skinny line width) or pick out a few examples (e.g. a total resident, a clear migrant, and one with several plateaus that hops around during the winter season) Likely things won’t fit super neatly into just a few categories though.
     2. Consider migrateR package to get canned results of migration? Might be worth a try at least.

1. **Variation in migration patterns due to breeding status and breeding lat/long**

* Consider tradeoff between survival and fecundity?)
* More migration=higher survival and harsher breeding conditions?, residency/shorter migration=higher fecundity and milder breeding conditions?

Steps:

* 1. **(Q4)** Simple boxplot for migration time and/or distance for cygnets/non-breeders/breeders?
     1. Too bad we haven’t followed up with breeding status in subsequent years
  2. **(Q4)** Plot of breeding latitude versus migration distance for trends in latitude
     1. Or to follow up from that, could lump into 3 categories based on breeding latitude and then show boxplots or violinplots of distance moved.
     2. The previous plot is to the furthest point south. Maybe we should just do the furthest point period? Or consider some kind of metric that provides more than a snapshot assessment?
  3. **(Q4)** GLM with log(‘max migration distance’)~’breeding status’ + ‘breeding lat’+ ‘Sex’
  4. **(Q5)** Pick 1 or several points during the winter, and assess the ‘water condition’ of where each swan is (possibly do this many times to compare with weather trends?)
     1. Try to make a visualization or snapshots of collared dots (by water status) and 1) a line that differentiates water status by open water vs artificial/river, and 2) a line that represents the ‘actual’ freeze line approximately E-W?
     2. Be careful to identify aerators, gravel plants, etc and maybe also potential feeding sites that can influence swan behavior
  5. **(Q6) TBD**