Brainstorming Annual Mvmt Chapter

**Descriptive Component**

**Objective: Describe the patterns of annual movement in IP swans.**

**1) Migration Phenology**

- What are the dates of migration chronology (onset/stopovers/’overwintering’/etc)

- Must provide definitions of our terms

- (Caveat) If swans continue to move during the winter, when does migration really start/stop?

**2) Migration Duration** (in time and distance)

- How long are individual and overall average durations of fall and spring migration?

- (time) In number of days?

- (distance) In kilometers from summer territory?

- speed (will be affected by how we consider stopovers)

**3) Patterns of Variability**

- How much individual variability is there in:

- Timing

- Extent of migration (resident/long-distance migrant or a continuum of distances)

- How do breeding vs non-breeding swans compare?

- (Caveat) We don’t know subsequent years breeding status

- Relationship between latitude (as correlate for env conditions) and descriptive migration patterns

- Bring in direct environmental data? Or save that for other manuscript?

- How does fall and spring migration compare:

- Start dates, end dates, duration of time, distance, stopover use, etc

Methodological details:

-Define migration as continuum of movement from breeding/summer sites?

-Define start/stop of migration

1) Use mcp package method (w/ NSD) with visual checking

2) Use Wyoming Migration Mapper (a hands-on interactive tool using NSD)

3) Use spatial/temporal thresholds (e.g. less than xx km in xx time)

**To Consider:**

* How much do we care about **spatially-explicit** maps of collared swans?
  + Could use a Brownian Bridge to highlight migration corridors
  + Could ‘define’ stopover/wintering sites using decision rules (arbitrary?)
* It did seem that at least some swans arrive on the breeding grounds at least a week or two before ice-out, maybe to defend territory from other arriving swans? (Is there an energetic cost to this that is balanced by the gains in breeding potential?)

**Predictions:**

- Swans will use a stepwise migration in the **spring** to follow the line/front of ice-out that allows for forage availability. This lets them accumulate energy stores that they’ll need for breeding and use highly nutritious early forage SAV. Spring migration onset dates will be fairly consistent across years (and may correlate with winter severity index), but arrival on breeding grounds will vary somewhat based on ice conditions and forage potential (NDVI or GDD).

- In the **autumn**, swans will migrate either with or just before conditions ice up (except for a portion that move to rivers and artificial open water). There is a window of time where swans may delay long flight based on adverse winds or take advantage of favorable winds to reduce the energetic cost of migration. Fall migration onset dates will be very variable across years and strongly correlate with ice-on dates. Fall migration will be shorter, because most swans will just fly south until their conditions are met (open water and forage). Strong cold fronts will push waves of swans south during winter to get below the ice front latitude.

**Biological/Theory-Driven**

**At any point during migration, how do the local conditions affect each swan?**

-What are limiting conditions (that may prompt swans to leave)?

-What are beneficial conditions (that swans may seek out)?

Breeding strategy-focused:

**I assume TRUS are capital breeders**

**-Energetic resources (when and where)**

-Income vs Capital breeding strategies

-**Capital breeders** use endogenous resources (typically lipids) to finance reproduction (ie. Store up resources before reproduction begins)

-snow geese are a typical example (feed heavily on crops, then fly to arctic)

-**Income breeders**, breed after certain levels, which do not change, of increase in condition are reached, and who use energy gained **during** breeding to finance reproduction.

**Spring**:

-Are swans limited by forage availability and/or open water before they move north in the spring?

**Autumn:**

**-**How important are forage availability/open water as a means of resource acquisition versus the thermoregulatory costs of colder weather conditions? Are we able to parse these apart?

**Do we have the right data to answer this kind of question?**

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-**Competition vs resources tradeoff**

-Cost-benefit tradeoffs between time and energy in the spring:

    - Minimize time (**if competition for territories is great)**:

-benefit: get to nest sites first (establish/defend)

-benefit: higher potential for re-nesting (important for TRUS?)

- cost: less time to deposit fat in areas less “wintery”

- cost: less stored energetic resources to use for nesting

- Maximize energy (**if competition low and/or breeding sites less productive)**:

    - benefit: more fat to use for nesting->higher chance of nesting, higher clutch size

    - benefit: more accumulated fat -> increased survival?

    - cost: arrive later -> could miss out on good sites

- cost: on breeding grounds for less time -> more pressure to breed/molt/raise young in a shorter timeframe

**Arrival Time hypothesis**: Individuals that establish territories in the spring (typically adult males) are less likely to migrate as far as individuals who do not establish territories because a shorter migration distance ensures a more rapid return to the breeding grounds and thereby first access to the best territories.(Ketterson and Nolan, 1976)

**Dominance hypothesis**: Sub-dominant individuals migrate at the end of the breeding season and dominant individuals do not. Subordinate individuals are poor competitors relative to dominant individuals and are most likely to accept the costs associated with migration to avoid competition with dominant individuals when food becomes scarce on or near the breeding grounds. (Gauthreaux 1978).

**Body size hypothesis**: Smaller individuals migration and larger individuals do not. This is because individuals of larger body sizes are able to withstand colder temperatures and better endure food shortages than smaller individuals, thus they are less likely to migrate. (Belthoff and Gauthreaux 1991).

**Do we have the right data to answer this kind of question?**

We’ve got body mass for almost all swans, but that might not be the beset measure as it doesn’t necessarily correlate with age and/or dominance (correct?). We’ve got tarsus and head length, but I’m not sure I really trust that all the various people that took those measurements did it the same way. Same for sexing, I’d guess that we’re artificially high on females because people didn’t invert the cloaca properly. We don’t have a way to know the relative amounts of swan density and/or social competition on the landscape or for any particular individual. We might be able to infer nesting in subsequent years, but can probably only confirm with swans that had cygnets reported.

**-Genetic**

**Migratory threshold model**: “Posits that the inheritance of migratory behavior is based on a polygenic threshold model and that migration is a dichotomous trait (migrant or resident) in which an individual’s migratory phenotype results from the inheritance of enough migration-associated genes to exceed a threshold. (Pulido et al. 1996). More recently, Pulido (2011) built on the original threshold model to incorporate facultative migration as an intermediate phenotype between obligate migration and obligate residency. In the environmental threshold model of migration, Pulido (2011) describes the relationship between migration propensity, amount of migratory activity expressed, and sensitivity of such expression within a population to environmental variation. By allowing for individual and population variability in internal (i.e. genetic) and external influences, the environmental threshold model beings to account for the myriad of variables that underlie what has been historically treated as a dichotomous trait.” (from Fudickar et al. 2021)

**Do we have the right data to answer this kind of question?**

We don’t have social dominance. We have environmental data such as weather, food availability (inferred by snow and ice information), and migration information from the GPS data.

**Data/Analysis-related**

**Response variables:**

**-**arrival/departure date

**Environmental Covariates:**

**-**Julian date

**-**Daylength (geosphere::daylength function)

**-**Presence of ice (NSIDC IMS or Weller et al. method)

-Presence of snow (and amount) (NOAA NARR)

-Temperature (NOAA NARR) (mean daily surface air temp at 2m above ground)

-NDVI (MODIS)

-Crop data (USDA Cropscape for U.S., Annual Crop Inventory for Canada)

-Landcover (NLCD 2019)

-Wetland coverage and size (NWI for U.S., DU Canadian Wetland Inventory for Canada)

-or for water in general, JRC Global Surface Water layer

-Wind support (Env-data and NOAA NARR) (we can calculate both headwind and tailwind, although it is a PITA)

-Difference in pressure (NOAA NARR) (a correlate for cold front bringing stronger wind support)

**Derived Covariates:**

**-**time spent/selection coefficient for cropland and/or other landcover types

-Lag effects (e.g. movement 2 days after high winds, cold temp, cold front)

- Winter Severity Index, WSI (combination of temperature/snow/etc)

- frost days (consecutive days of mean temp <0 C)

- snow days (consecutive days of snow depth >2.5cm)

- Degree Days, GDD (growing) or CDD (cooling)

* DD=MeanTemp-BaseTemp where BaseTemp is 5.5 celsius, the lowest temp and which forage plants generally grow.
* GDDs which accumulate throughout the season can be used as a proxy for forage plant phenology in spring and autumn
* But maybe not as appropriate for submerged aquatic vegetation?

**To Consider:**

* Weller et al 2022 assess ice cover as the assumed presence of ice >1cm thick on shallow water bodies. They base the calculation on empirical formulae that reported thin ice growth of 1cm per 3.3 freezing degree days and melting of 1m per 1.3 thawing degree days. At a given location, tracking of ice thickness was triggered after 2 calendar days of mean temp <0 C, and reset to zero if thickness was estimated to drop below 1cm.
* We’ve got very detailed plant spp. data for certain lakes in MN, probably not for the rest of the study area.
* There is citizen monitoring data for ice-in and ice-out dates for some lakes. Most lakes swan are on wouldn’t have this data. Also, the data is really messy. What we really need is at least a rough sense of where the three zones of 1) total ice <-> 2) transition <-> 3) open water.

**Important life-history aspects:**

-food

-territory acquisition

-pair formation

-territory defense

-timing of egg-laying, raising young

-timing of molt