Effects of Hunting Pressure on Canada Goose Movement Behavior

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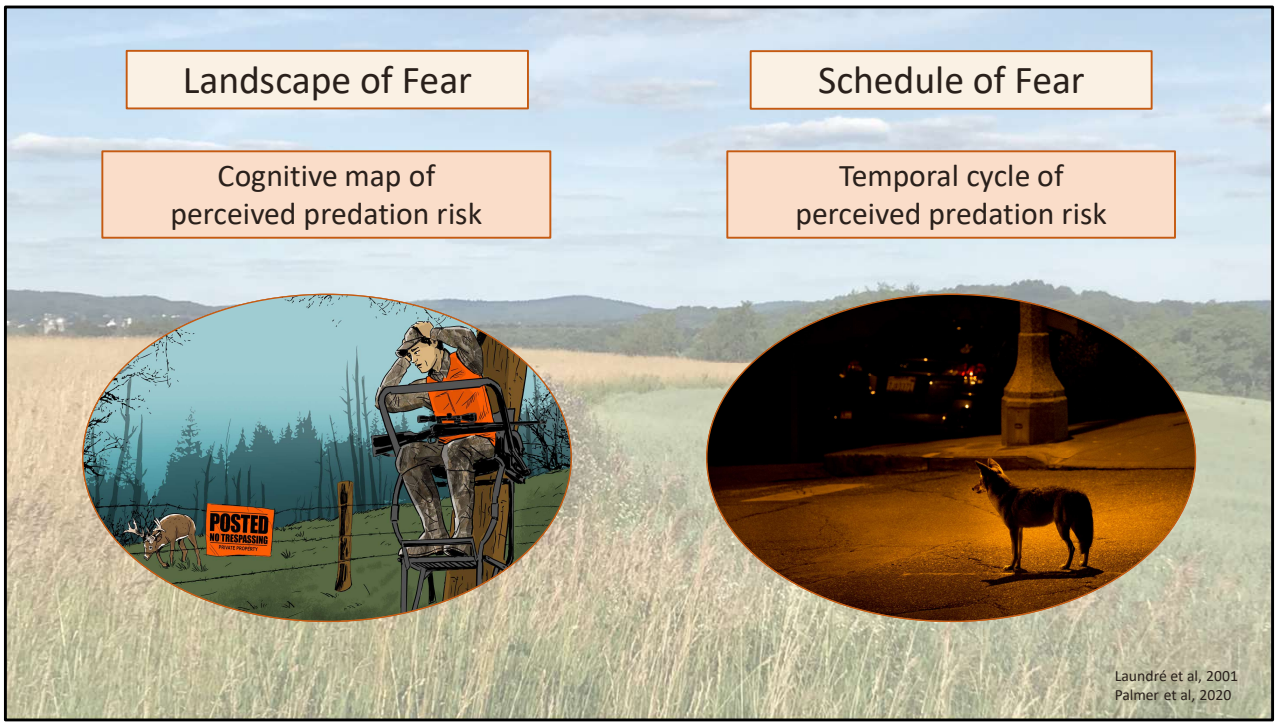
Hello everyone, my name is Karen Beatty and I recently completed my masters degree at Penn State advised by Dr. Franny Buderman
Today I'm going to speak about a portion of my research that was conducted in partnership with the Pennsylvania Game Commission,
studying how hunting pressure can influence Canada goose movement across the landscape



We believe that animals navigate their environment based on not only resources they're drawn *toward*, like food and mates, but also by something called the "Landscape of Fear"…

…which is a mental map of perceived risks across the landscape
One example of this is the phenomenon that hunters have suggested that claims deer know which areas are protected from hunting and they go there during hunting season to avoid being shot

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Similarly, animals might also maintain a "Schedule of Fear" and perceive risks within a daily or seasonal cycle.

An example of this is the trend of wildlife becoming more active during times when humans are less active

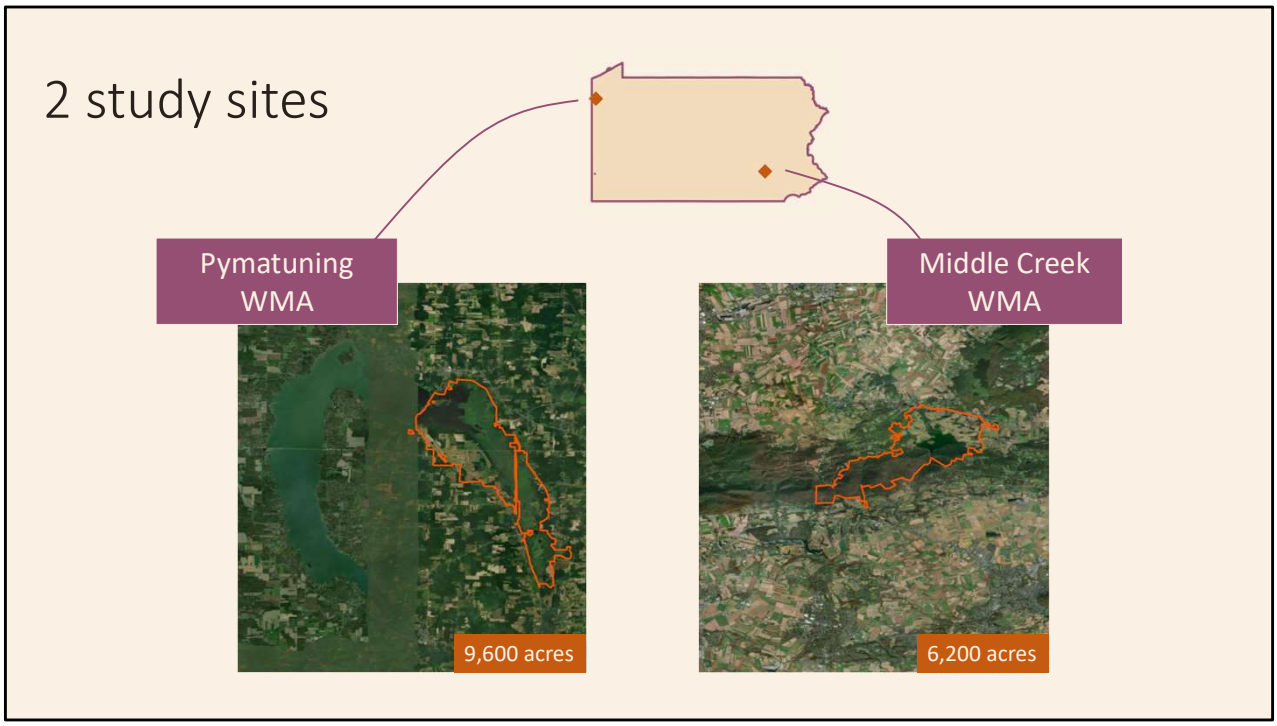
Which anti-predator behavior is used?

But it's difficult to entirely avoid all these threats, so a natural next question is How do the animals respond when they encounter a threat.

We see species that employ vigilance with a flight response, and cryptic species that employ vigilance with a freeze response…

…but these are scenarios where the threat is unpredictable and mobile.

Our study system was a bit different.



Our research focused on two study sites: Pymatuning Wildlife Management Area and Middle Creek Wildlife Management Area.
Both sites are managed by the Pennsylvania Game Commission for wildlife habitat and hunting opportunities.

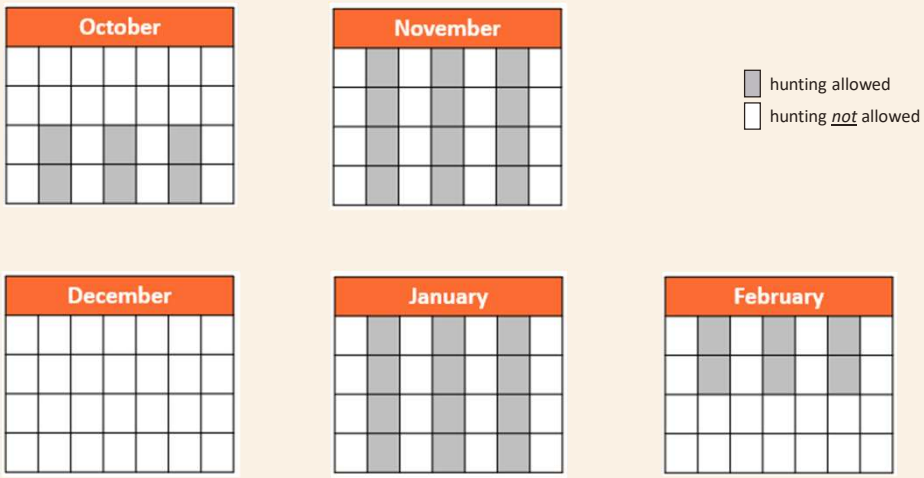
Specifically managed for waterfowl hunting – offer high-quality hunts and restricted access via lottery
→ Detailed hunting records for these sites

Hunting occurs from stationary blinds

Hunting occurs exclusively from stationary blinds, shown with yellow pins on the aerial image

So, the hunting threat in this study was originating from predictable locations.

Hunting days alternate within the season

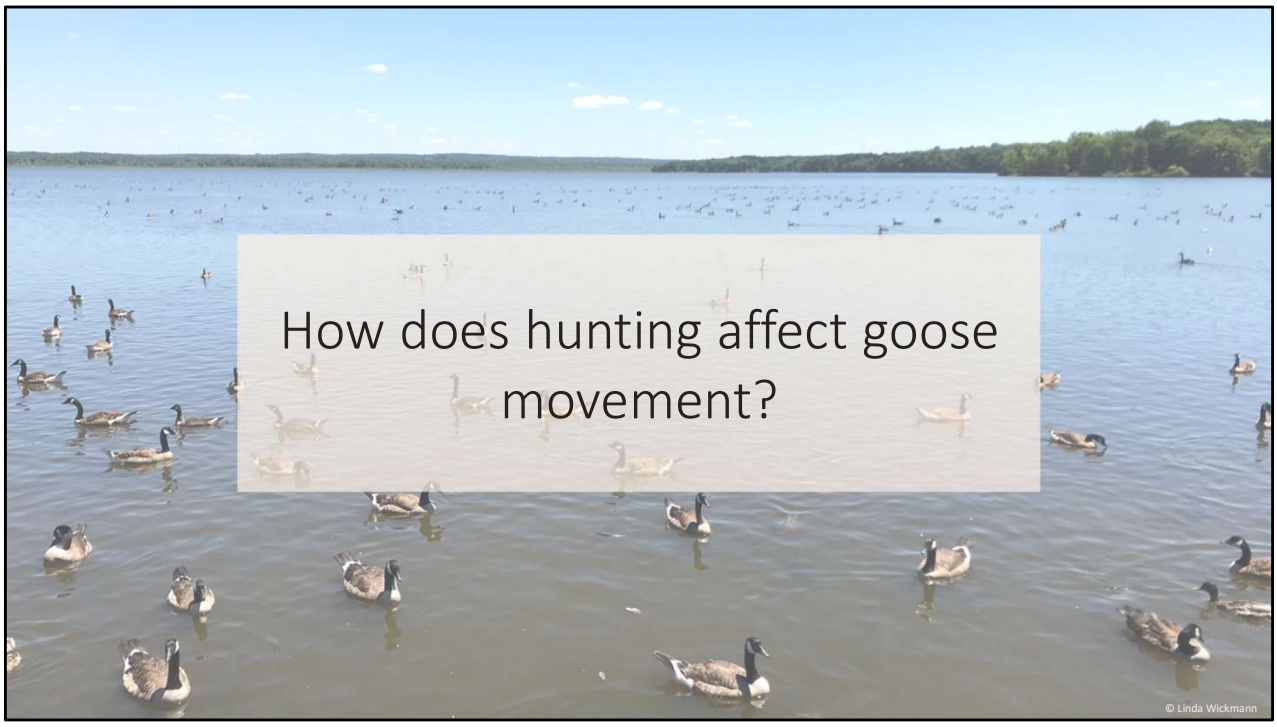


The Canada goose hunting season extends from about mid-Oct to mid-Feb
At these two WMAs, hunting is only allowed on certain days within the hunting season – grey vs white.

This temporal layout makes the hunting threat cyclical and potentially predictable.
To evaluate whether geese perceived the hunting cycle and recognized the predictability, we looked for daily patterns in goose behavior.

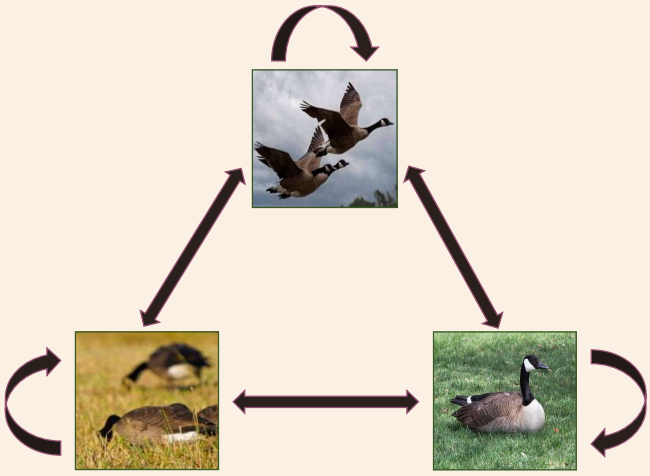
Which anti-predator behavior is used?

Returning to the question of How do the animals respond when they encounter a threat.
Unlike most natural settings, in our study system the hunting threat was predictable spatially and temporally,
and we weren't sure what type of anti-predator behavior the geese were employing:
Perhaps they were moving around more, moving around less, or leaving the area entirely.



Our objective was to evaluate whether the geese were maintaining a landscape of fear and a schedule of fear of this predictable threat,
and how they were adjusting their movement in response to it?

Infer goose behavioral states via indirect observation

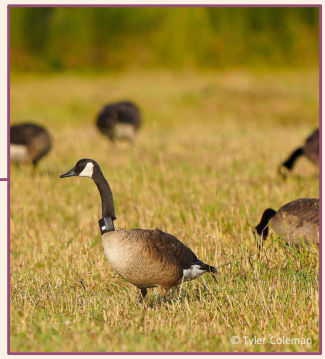


To understand how an individual's movement behavior was changing, we first had to determine what behavioral state it was displaying at any given time, and when it was switching between behavioral states.

We assumed that the geese were generally displaying three general types of behaviors: flying, resting, and feeding.

And because we weren't able to directly observe the birds, we used GPS tracking data to infer these behavioral states.

Fitted resident adult female geese with GPS collars to track their locations

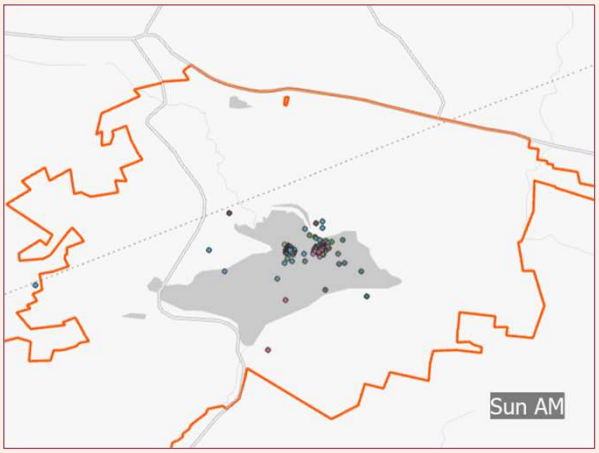


We captured geese via drive-trapping during their flightless summer molt and fitted adult females with Ornitela GPS-GSM receivers, which you can see in the photo

The population we studied were specifically resident population geese

On the right you can see an image of a collared goose in the wild

10-minute fix rate from 2021-2023



134
individuals
x
55,000
observations
per bird
=
7,400,000
data points

We captured geese in June 2021 and 2022 and tracked geese through March 2023, so we had two full seasons of data across two study sites
We marked bird locations every 10 minutes

The animation shows bird movement spanning 1-week during a hunting period. The grey area is a lake and each color represent a different bird
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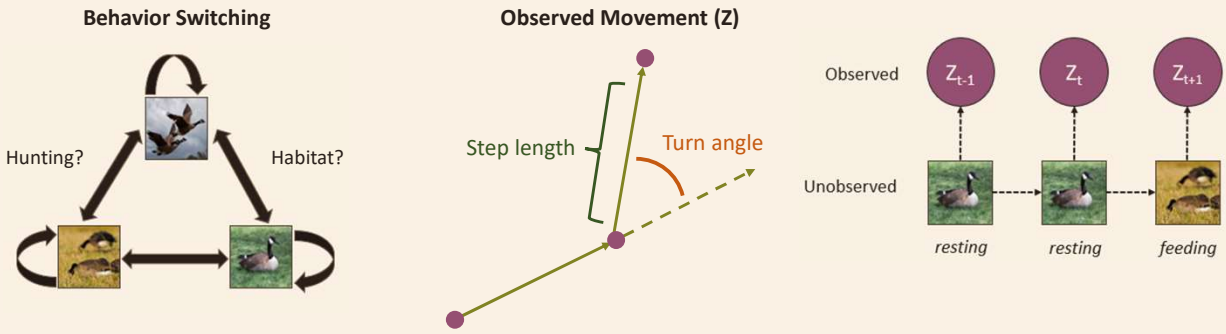
In total, over the two-year study period, we tracked 134 individuals and accumulated about 7.4 million data points.
For this analysis we only used about 300,000 data points across 80 birds because we eliminated observations that were outside our study area and outside hunting hours

Hidden Markov Model



To answer our question we need to know what behavior a goose was displaying at any given time,
the probability of switching to a different behavior,
and which factors affect that probability

We determined this by fitting a hidden Markov model.

Using the GPS points (purple) I measured the step length and turn angle between each subsequent observation.

A step length is simply the Euclidean distance between two points, and the turn angle is the angular difference between a bird's trajectory from the previous point and the location of the next point.

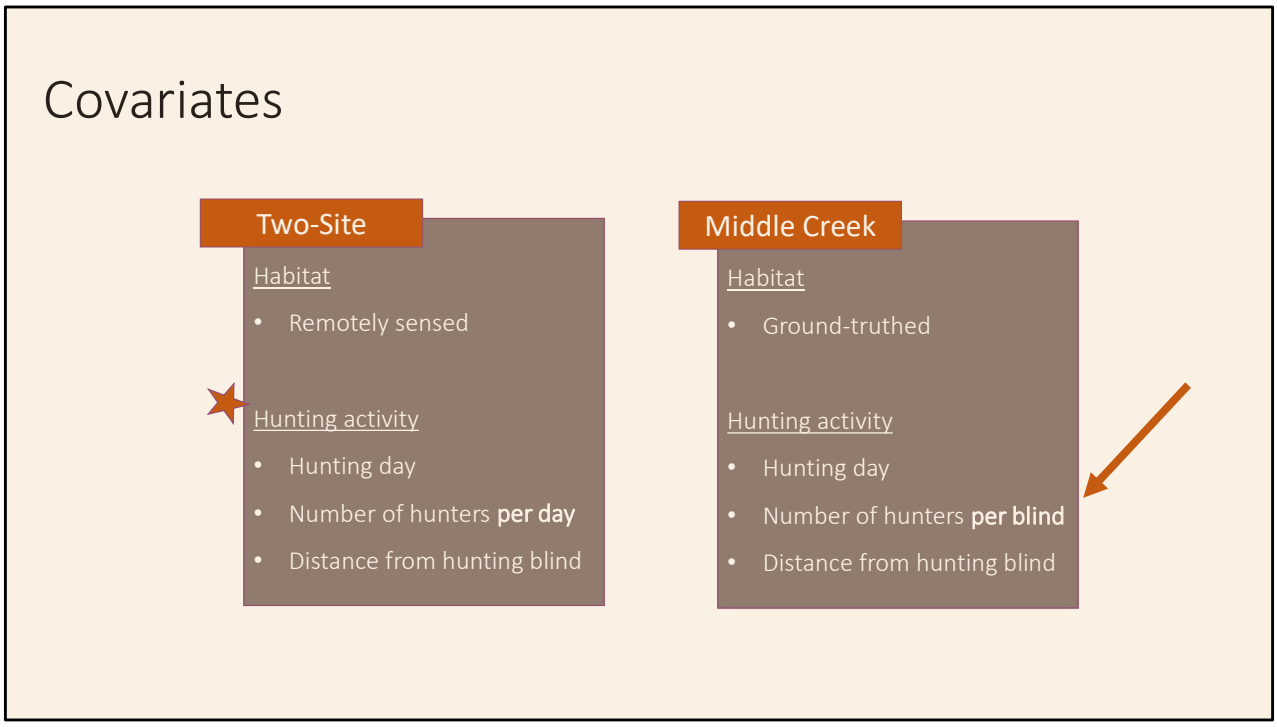
Based on these calculated step lengths and turn angles, the hidden Markov model estimates which 'movement group' the individual was in during each GPS observation.

As researchers and biologists, we match those movement groups to a reasonable

behavioral state
With the geese, we assumed their movement would fall into three categories: resting (short sl), feeding (intermediate sl and ta), and flying (longer sl, small ta)

We're also able to incorporate factors like hunting pressure to see which factors change the likelihood of a bird remaining in a behavioral state or switching to a different behavioral state.

Covariates

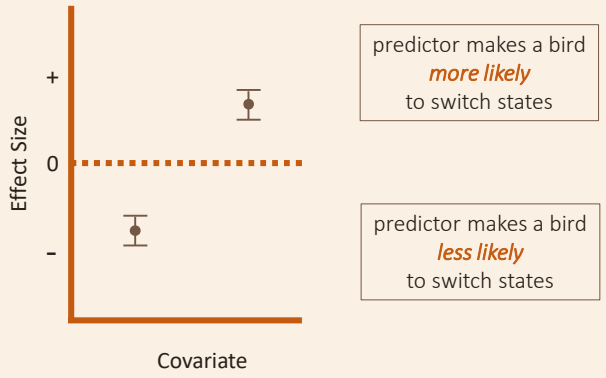


The factors or covariates we included were habitat (NLCD) and hunting activity represented by three different values.

Hunting pressure was captured by whether or not hunting occurred, the magnitude of hunting (number of hunters) and proximity to hunting (distance from blind).

At one site we knew how many hunters were at each blind as opposed to on the site in total, so we also fit a model to only the data from that site

Effect of covariate on probability of switching between states



The hidden Markov model estimates many values, but for our purposes today I'm going to streamline the results
and share the effect of a covariate on the probability of switching between behavioral states

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You'll see a plot with the covariate on the x axis, the behavioral state transition listed at the top

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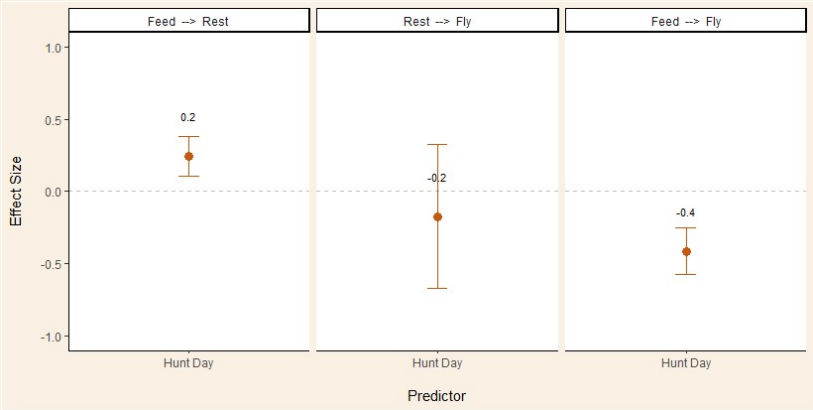
The point is the effect size
Values less than 0 mean that covariate makes a bird *less* likely to switch from state A to B,
whereas a positive value means the covariate makes a bird *more* likely to switch from state A to B.
I'm only going to show a few of the most meaningful estimated effect sizes.

Effect of **Hunting Day** on State Transition Probability



On hunting days
geese deferred feeding for rest…

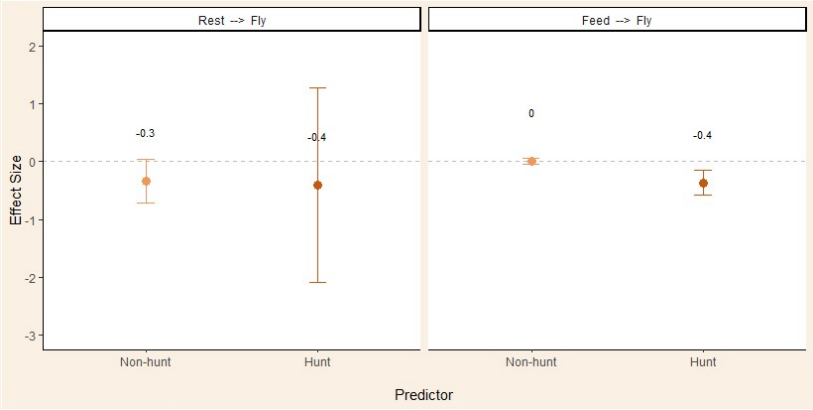
and were less likely to take flight

First we evaluated the effect of it being a hunting day versus a non-hunting day.

We found an increased probability of switching from feeding to resting on hunting days, indicating that geese were more likely to stay put instead of distractedly feed.

We also found that geese were less likely to take flight. Specifically, the effect of hunting on the probability of switching from feeding to flying was negative.
This indicates that geese were less apt to move around the WMA on hunting days.
Perhaps a proactive strategy to avoid hunters.

Effect of **Increasing Distance from Blind** on State Transition Probability



On hunting days, geese were more likely to take flight when closer to a blind…

When we consider the effect of a goose's distance from a hunting blind,
we can again compare what's happening on a hunting day versus a non-hunting day.

Starting with non-hunting days, whether a goose was farther from or closer to a blind they were no less likely or somewhat less likely to take flight

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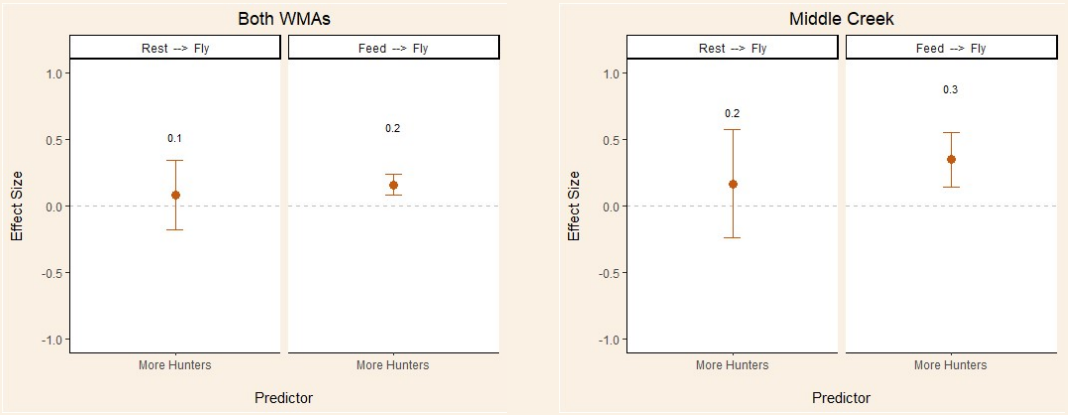
But on hunting days, we see a change. If a goose was feeding, it was less likely to take flight when farther from a blind.
Or, we can think of this as a feeding goose was much more likely to take flight if it was closer to a blind than farther.

So essentially, if geese were farther from the hunting threat, perhaps in what they perceived to be a 'safe zone', they were less likely to start flying around.

Effect of **Increasing Number of Hunters** on State Transition Probability



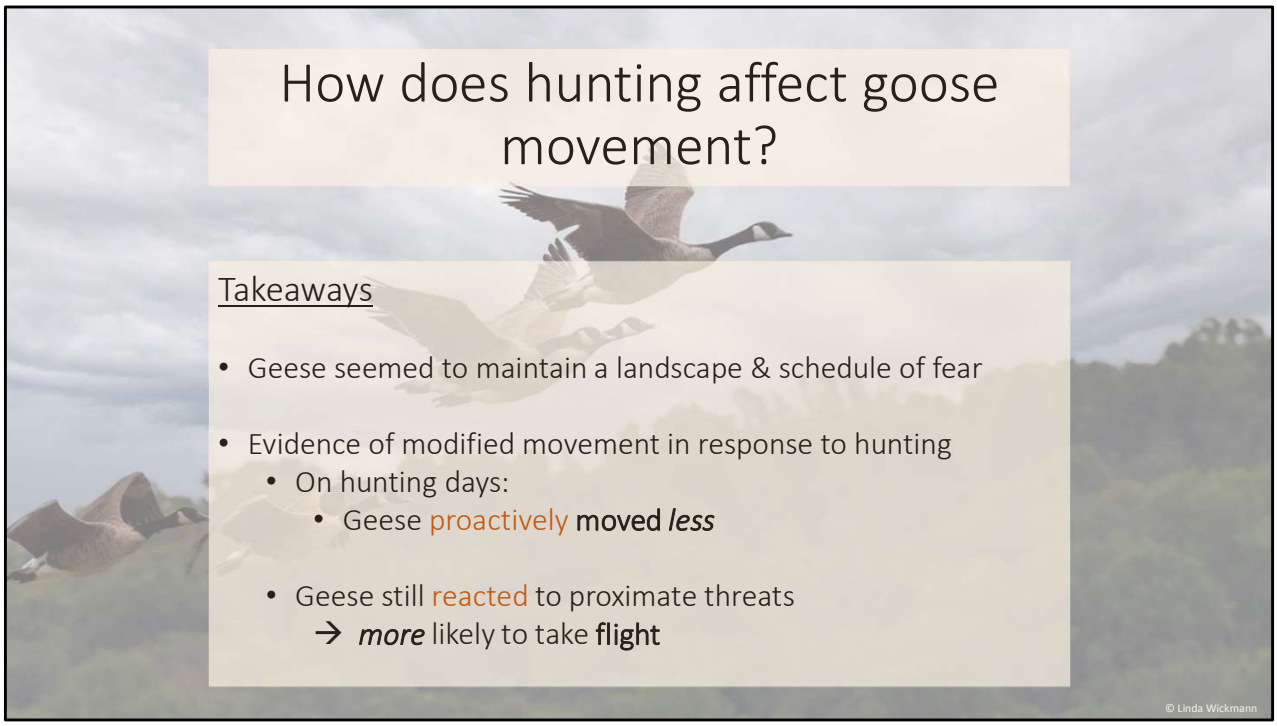
As the number of hunters increased, geese were more likely to take flight

Lastly we considered the effect of an increasing number of hunters.

And we found that as the number of hunters increased, resting geese were somewhat unaffected, but feeding geese were more likely to take flight.

This was based on the total number of hunters on the WMA
But at one site, we knew the number of hunters at each blind.

And we found the same pattern of effects on the probability of switching from resting or feeding to flying.



Circling back to our research question of 'how hunting affects goose movement'…

Geese seemed to recognize the predictable predation threat because we saw adjusted movement patterns on hunting days

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We did see evidence of modified movement in response to hunting.
On hunting days they proactively moved less

But they still reacted to proximate threats and were more likely to take flight when closer to hunting and when there were more hunters

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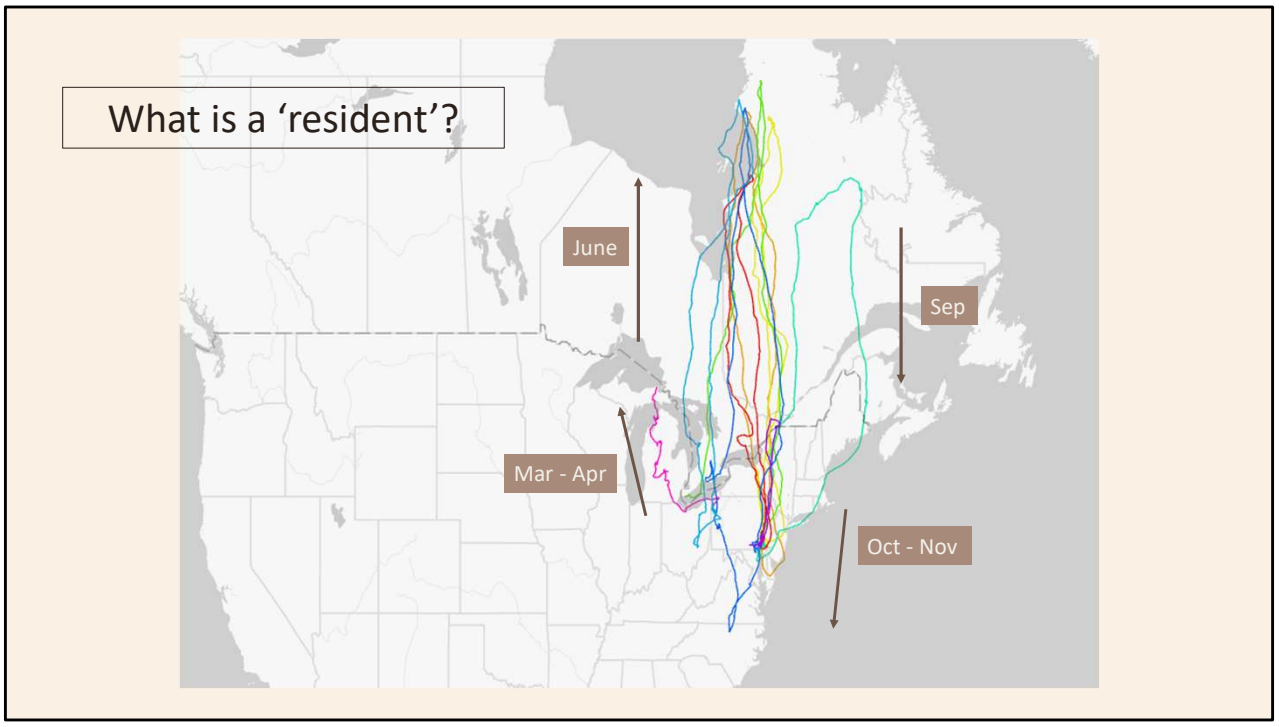
But those effects were more pronounced if a goose had been feeding as opposed to resting.
One important note here is that we don't know if a 'resting' bird was resting and not paying attention (truly resting),
or if it was being still and vigilant.

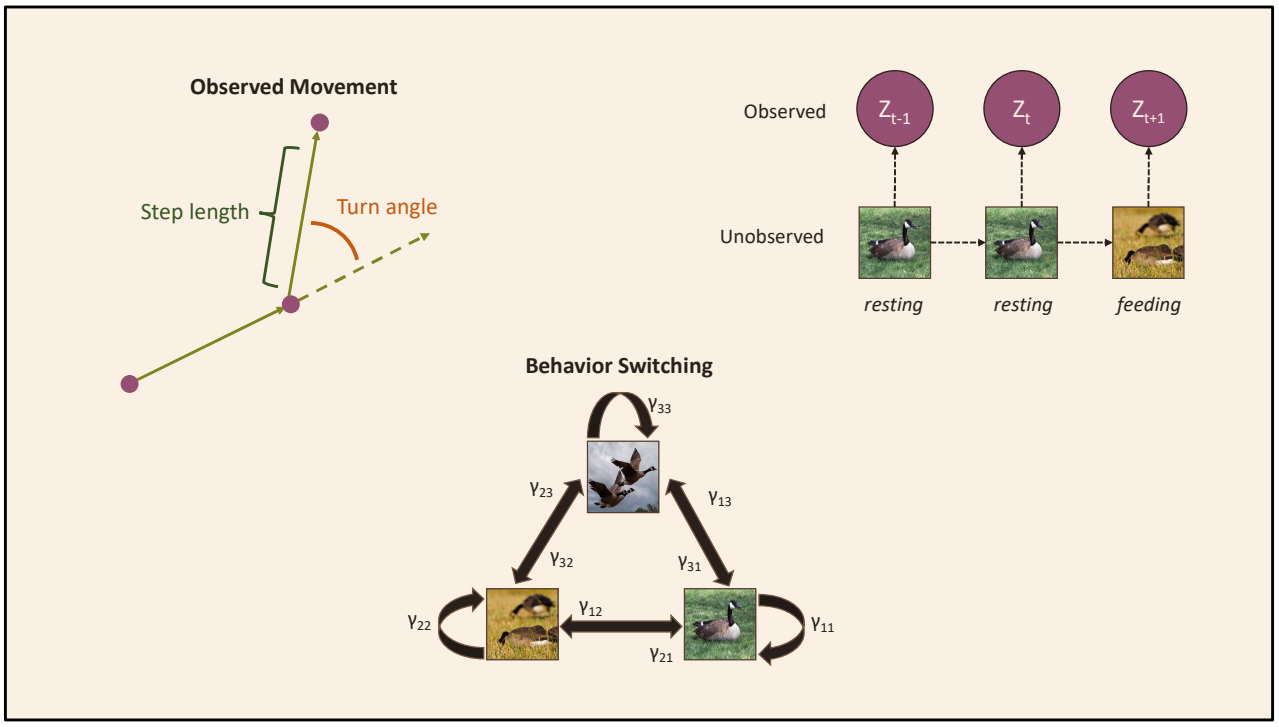
From a management perspective this nuance might not matter (either a bird is moving and available to hunt or not),

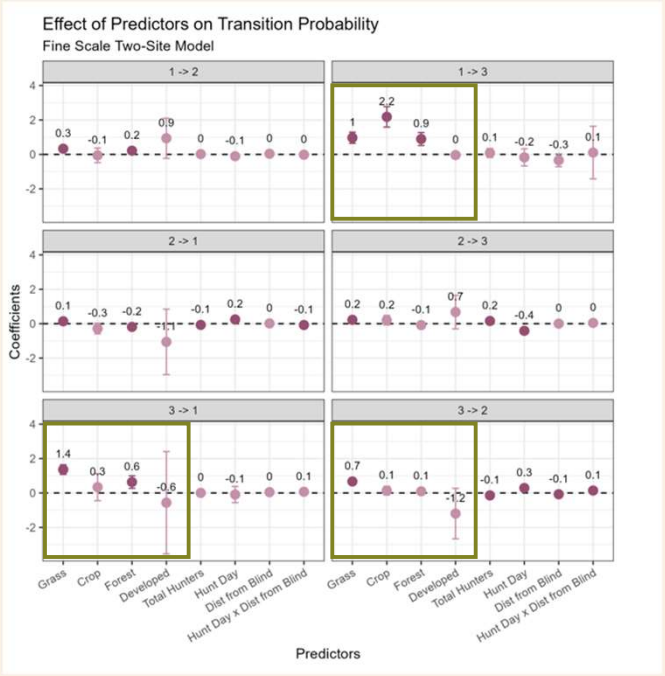
But from an ecological perspective this is an important distinction in anti-predator behavior.
So as a next step I'll be trying to incorporate accelerometer data to parse out that difference. And if you have any advice about that I'd love to chat later.

I'd like to thank the PGC for funding this project, and providing data and expertise.
You can learn more about this research, or take a closer look at this presentation, by scanning the QR code.
And I'm happy to take questions if there's time.

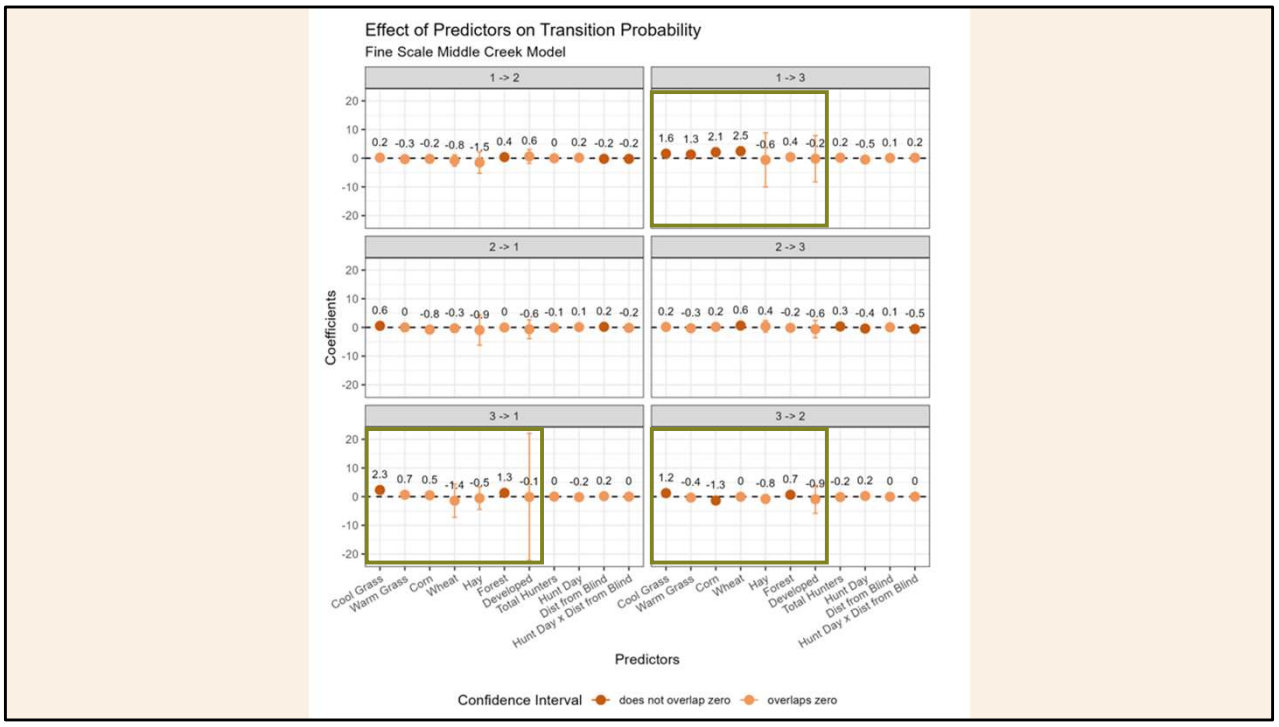


As a bonus, I want to share this image from our GPS data. We tracked ‘resident’ Canada geese, but many of them migrated at least once during the study.
Mostly they flew to the migratory CAGO breeding grounds in northern Canada, but they also went elsewhere in the mid-Atlantic and Great Lakes states, sometimes going south.
I offer this image because I think it’s fun to see where all the geese went, but also because often when we conduct research our results prompt new questions, like “Is ‘resident’ a misnomer?”
So, I’ll leave you with that food for thought.

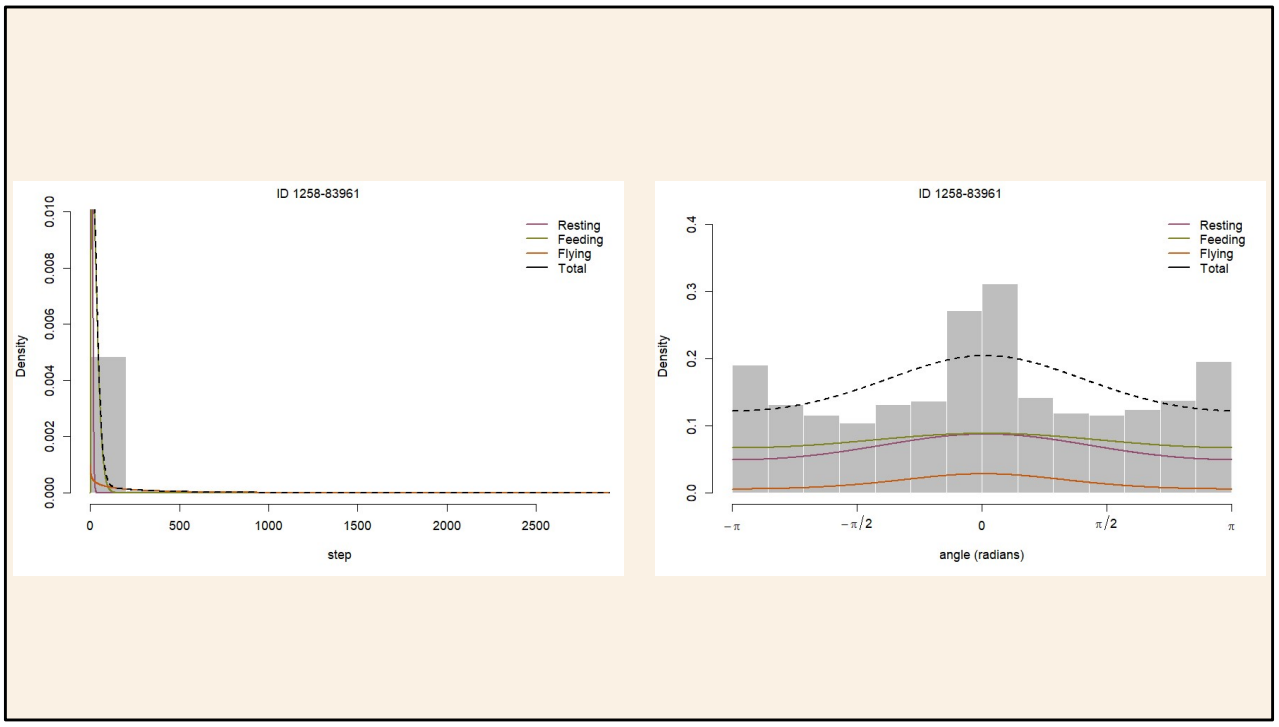

Observed Movement
Step length
Turn angle
Observed
Unobserved
Z_{t-1}
Z_t
Z_{t+1}
resting
resting
feeding
Behavior Switching
γ_{33}
γ_{23}
γ_{13}
γ_{32}
γ_{31}
γ_{22}
γ_{12}
γ_{11}
γ_{21}



Full results from two-site model



Full results from Middle Creek model



Example step length (left) and turn angle (right) distributions for one individual