The role of memory in shaping migratory behavior

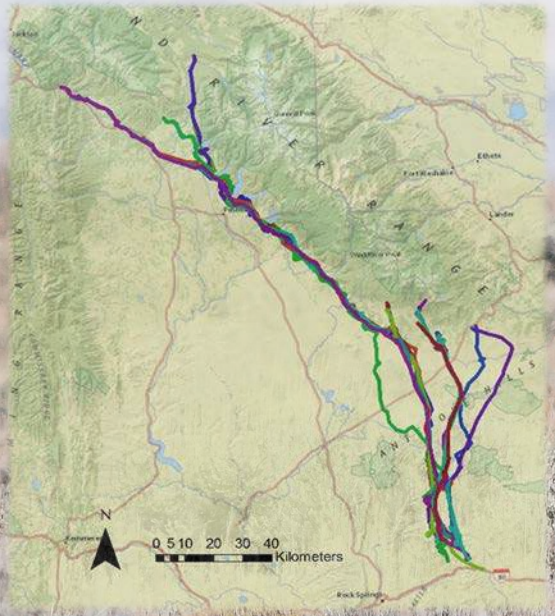
Jerod A. Merkle, Hall Sawyer, and Matt Kauffman

Wyoming Cooperative Fish and Wildlife

Research Unit, University of Wyoming

Western Ecosystems Technology, Inc.

U.S. Geological Survey

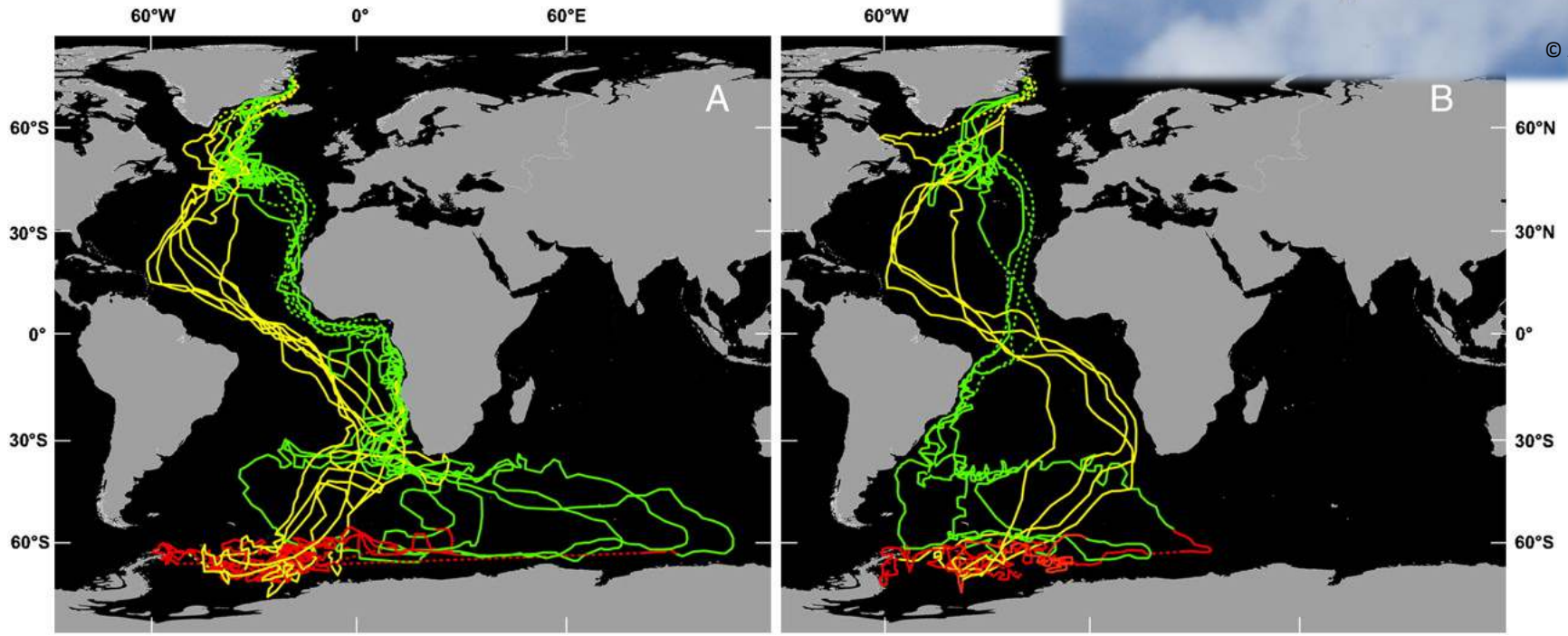


Why animals migrate

- Attraction to fitness enhancing locations
  - Increase energy intake
  - Mate finding
- Avoiding areas with unfavorable conditions
  - Energy expenditure (hot, cold, buggy places)
  - Competition
  - Predation

Avgar et al. 2013 (Review in *CJZ*)

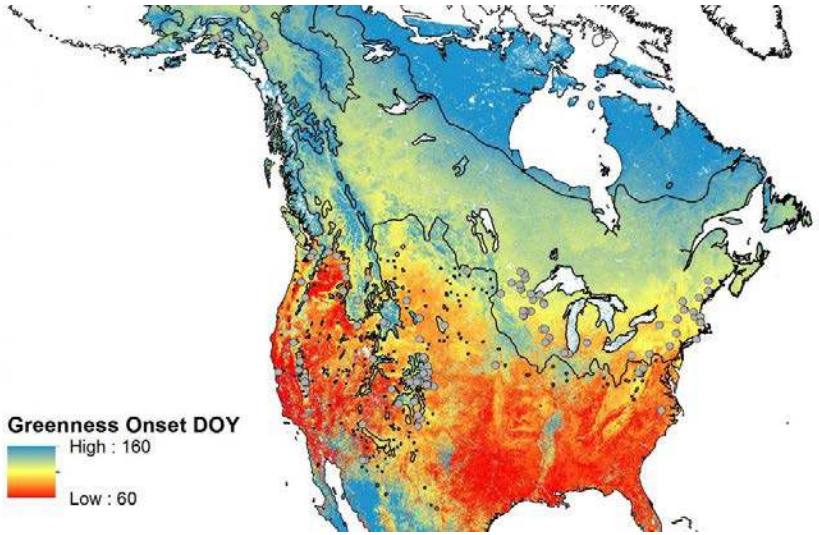
Migration can be spectacular



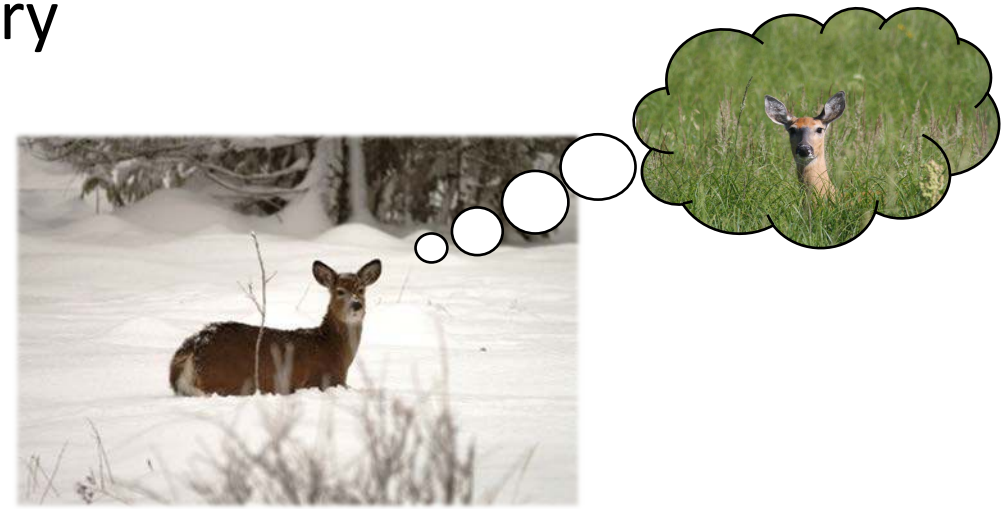
Egevang et al. 2009 (*PNAS*)

How do they migrate?

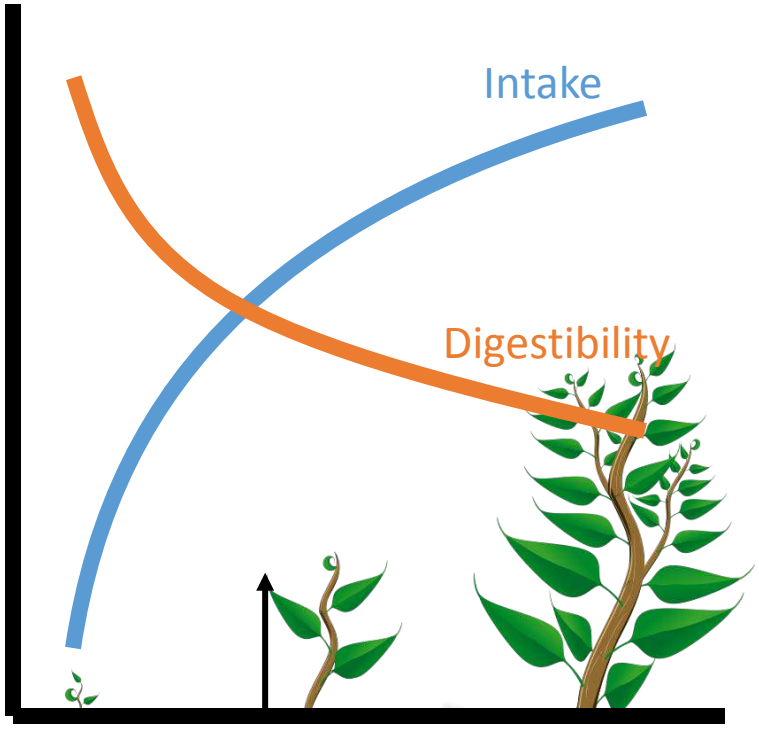
1. Tracking resource and environmental gradients

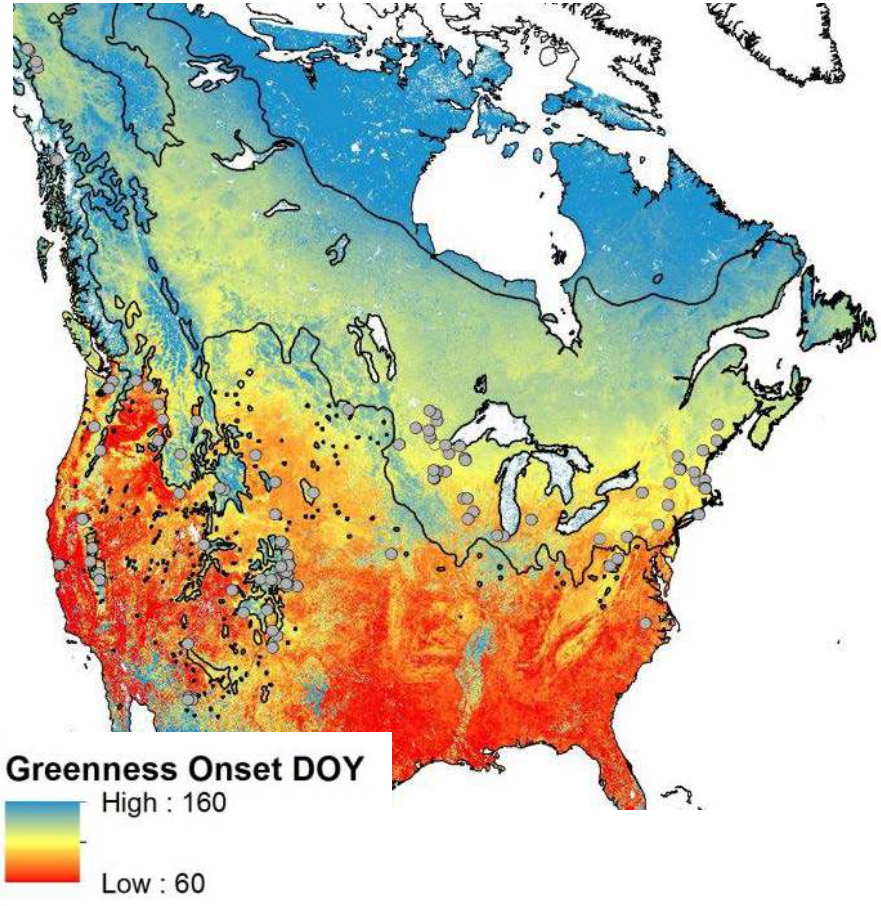


2. Employing memory capabilities



Forage Maturation and Green-Wave Hypotheses





(Fryxell 1991 *Am Nat*; Hebblewhite et al. 2008, *Ecol Monogr*)

Spatial and attribute memory

- Jays and Caching
  - Can remember location, content, and time of caching

Clayton et al. 2001 (*Phil Trans Royal Soc*)

Predictions/Expectations

Variable	Tracking	Memory

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Green-wave surfing	Yes	Perhaps

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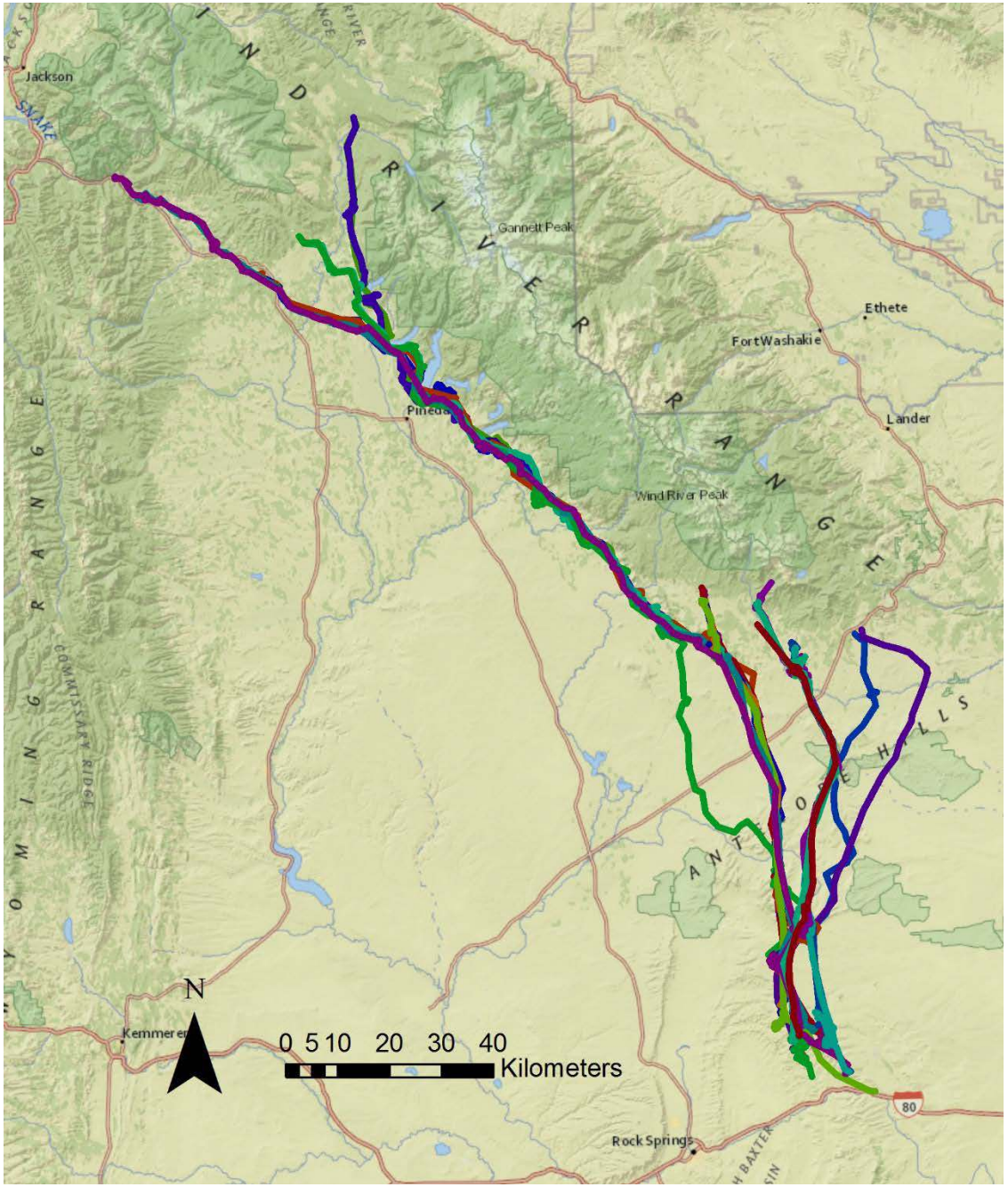
Movement bias towards previous year's route	No	Yes
Migratory route changes over time	Yes	No

Mule deer - Red Desert to Hoback migration

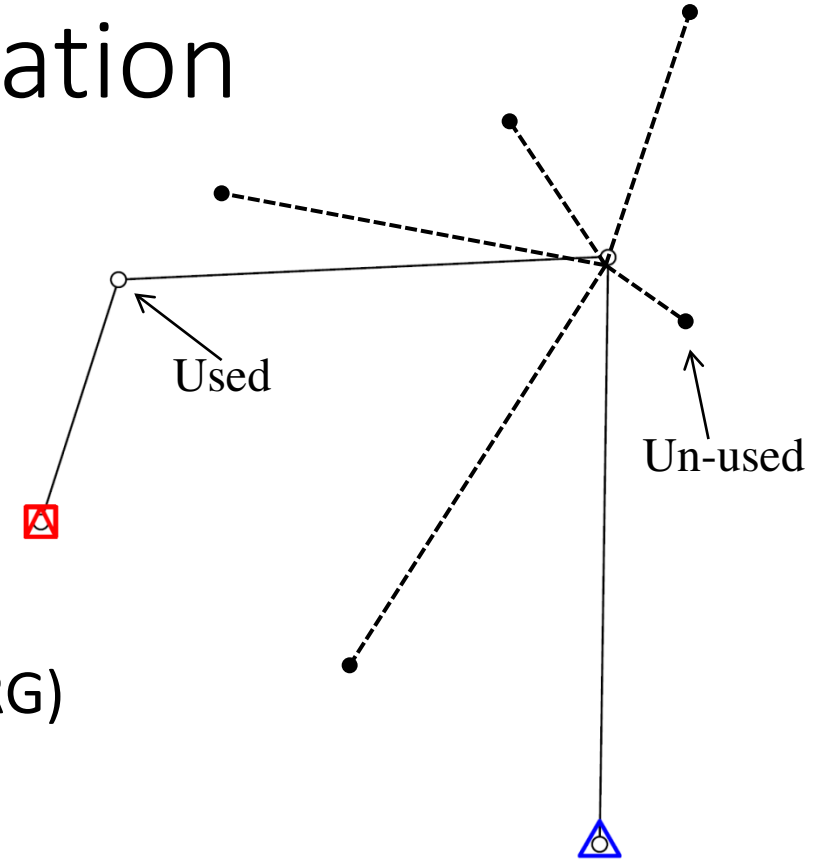
n = 13 animal-years

Up to approx.
240 km migration



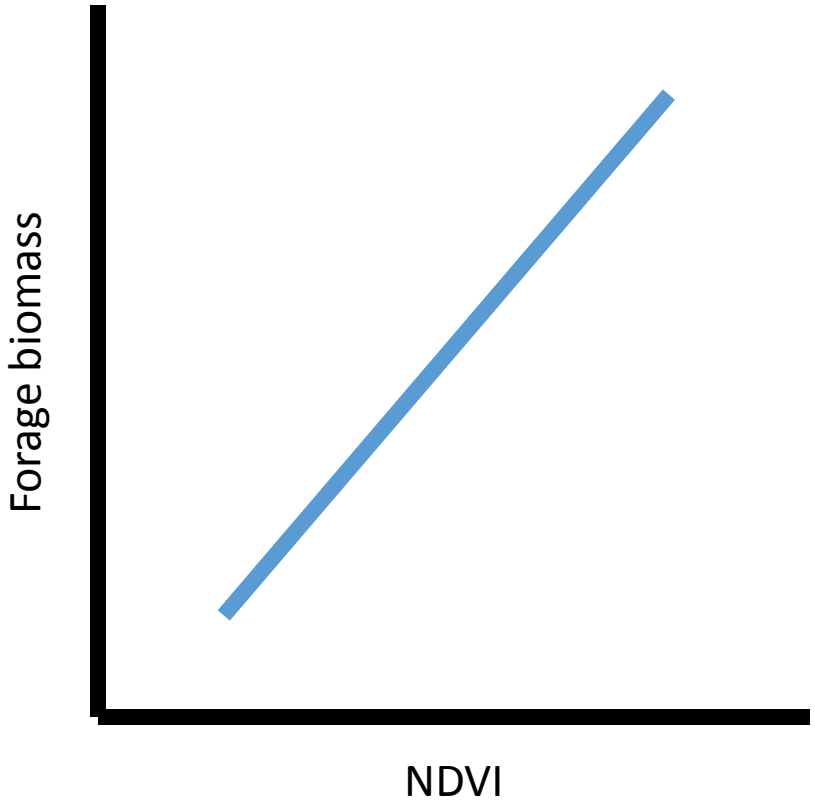
Step Selection Function during migration

- Base model:
  - Elevation, slope, aspect, % cover, distance to road, terrain position index, integrated NDVI
- Tracking hypothesis
  - Instantaneous rate of green-up (IRG)
- Memory hypothesis:
  - Bias towards previous summer range
  - Bias towards previous migration route

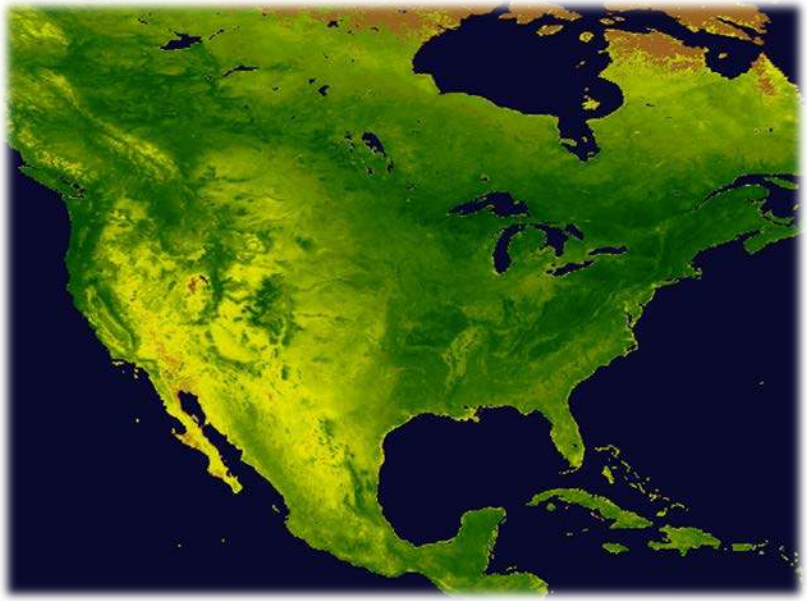


(Hird and McDermid 2009, Beck et al. 2006, Fortin et al. 2005)

Normalized Difference Vegetation Index (NDVI)

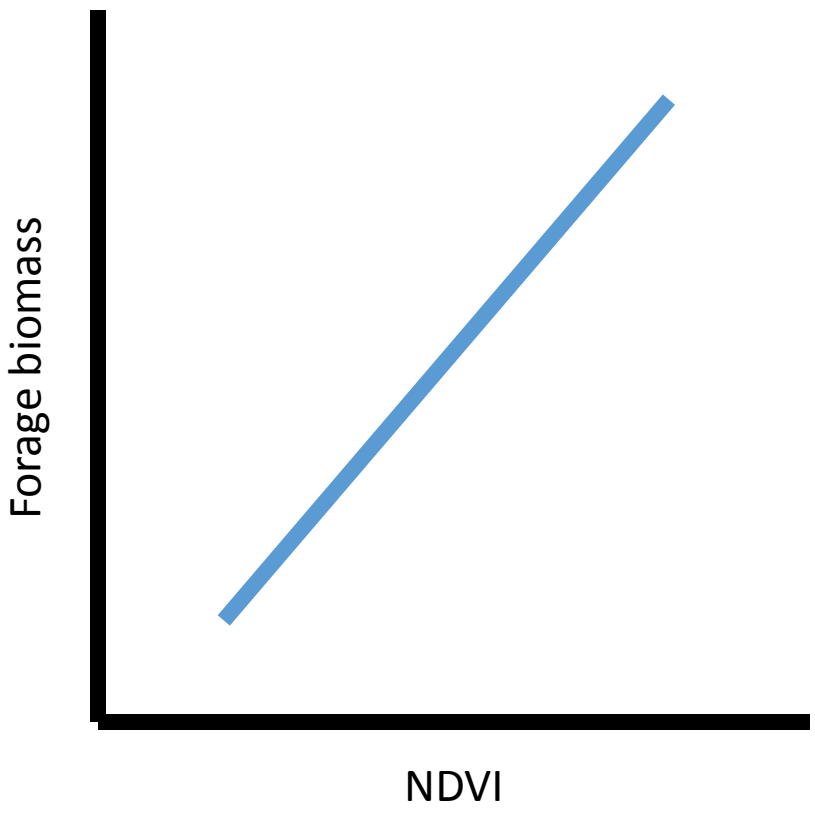


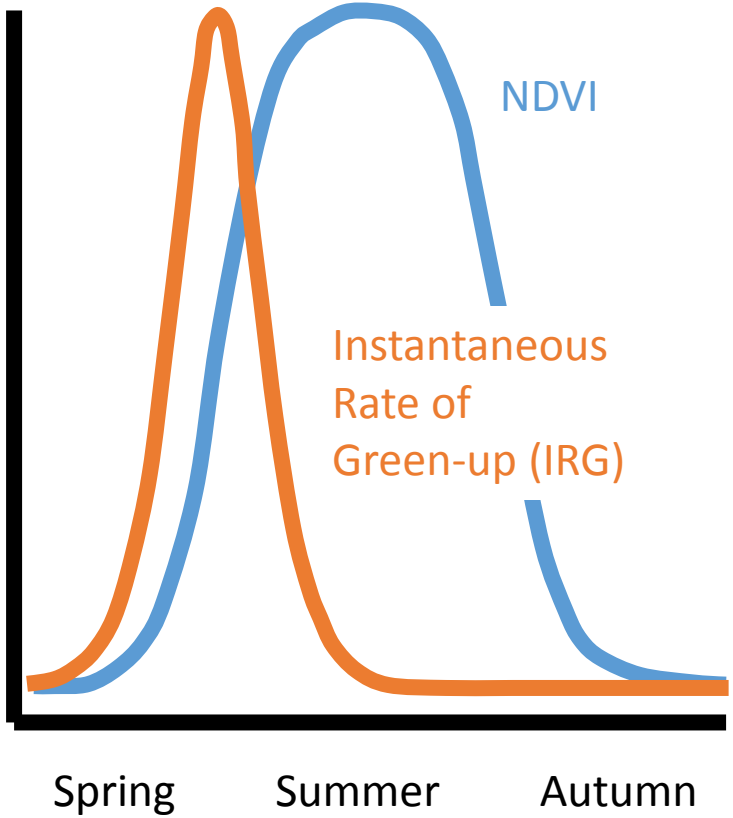
- Spatial and temporal measure of greeness



(Pettorelli et al. 2005, *TREE*; Bischof et al. 2012, *Am Nat*)

IRG as intermediate forage biomass





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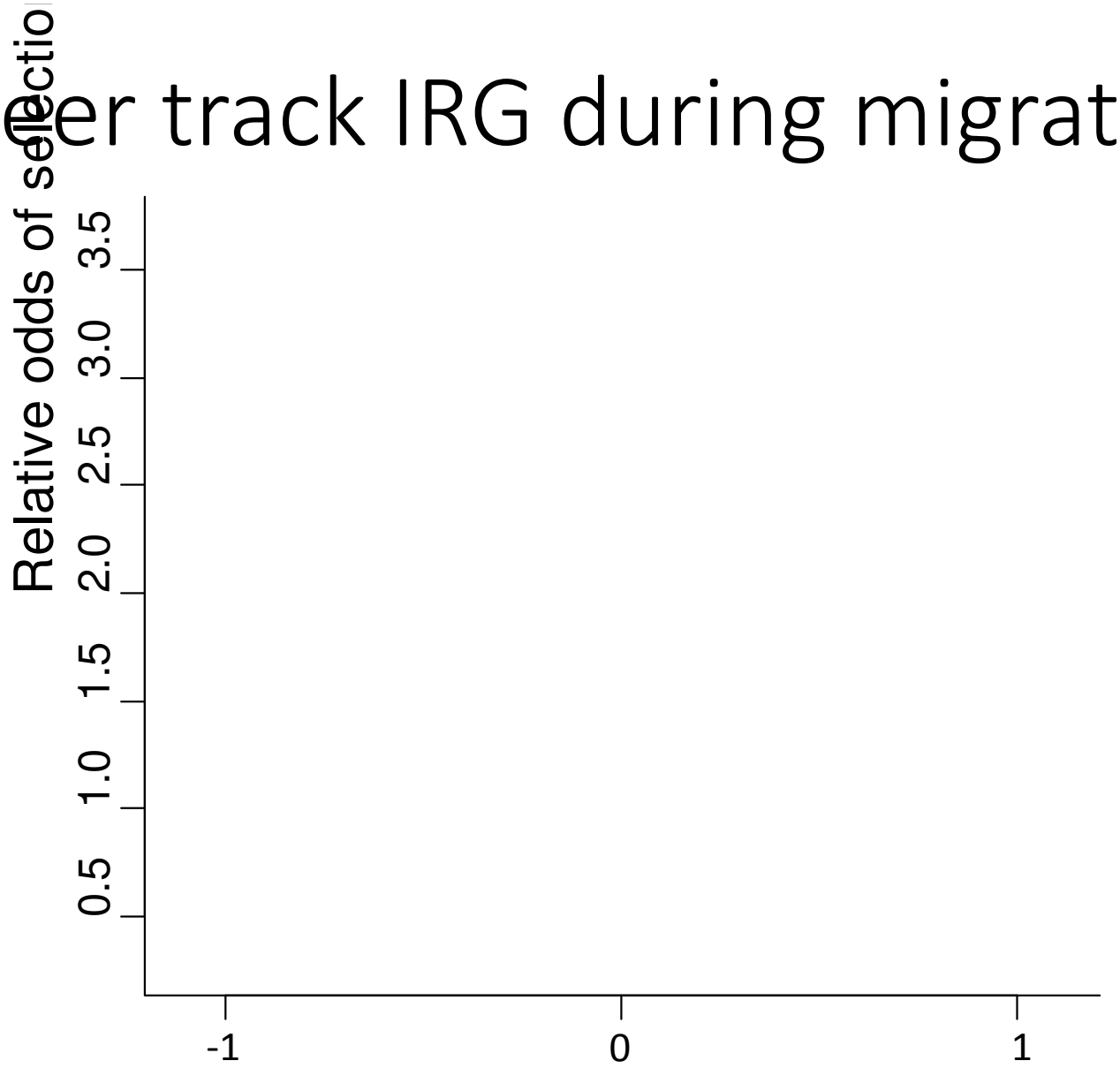
Deer track IRG during migration

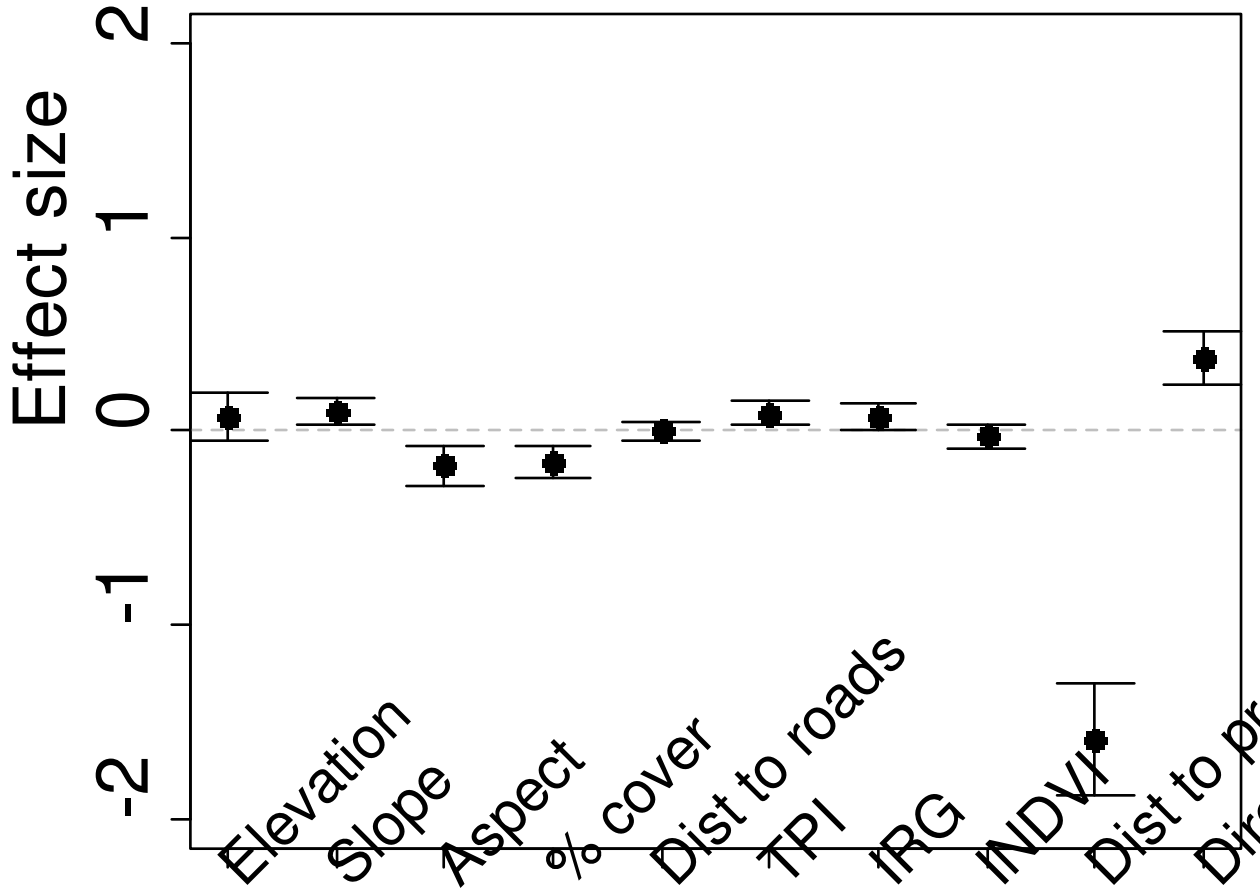


ΔQIC = 11.6

Predictions/Expectations

Variable	Tracking	Memory
Green-wave surfing	Yes	Perhaps
Movement bias towards previous year's summer range	No	Yes
Movement bias towards previous year's route	No	Yes
Migratory route changes over time	Yes	No

Effect size
2
1
0
-1
-2
Elevation
Slope
Aspect
% cover
Dist to roads
TPI
iRG
Direction t



Strong selection for the previous year's route and summer range

ΔQIC > 267.7

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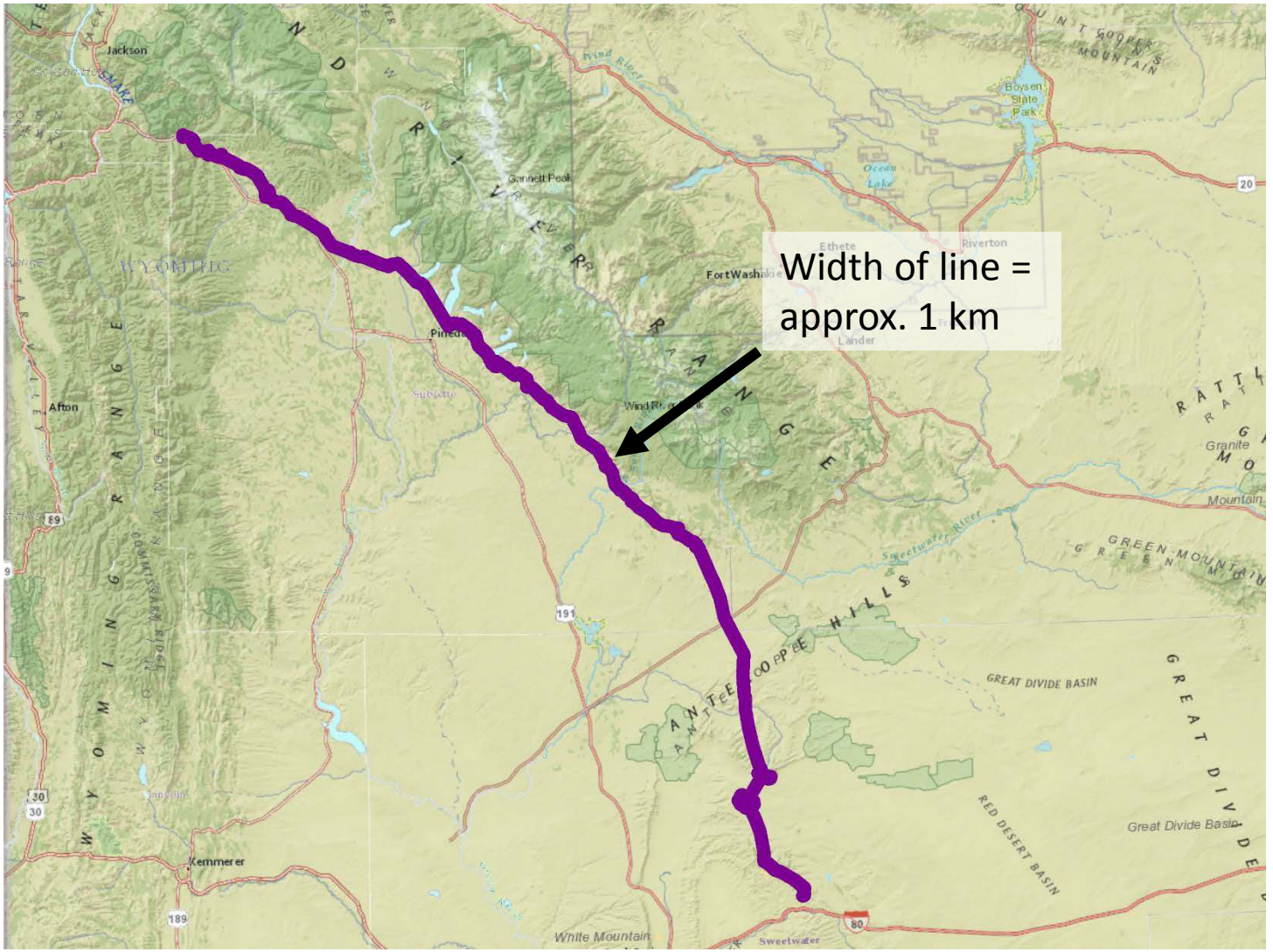
Does the route change over time?

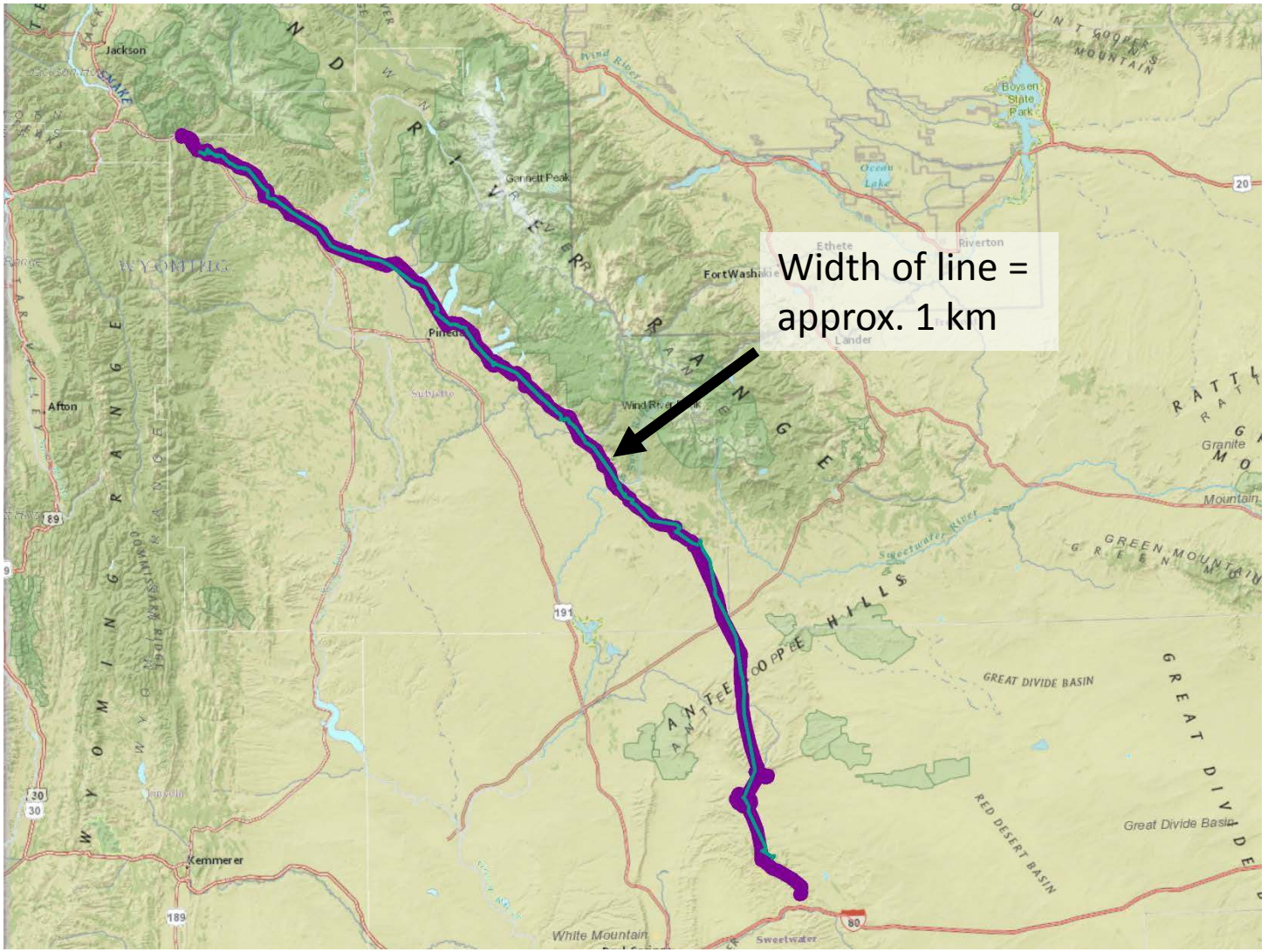
AID 17
2011



~ 240 km migration

High fidelity to previous route

AID 17
2011
2012



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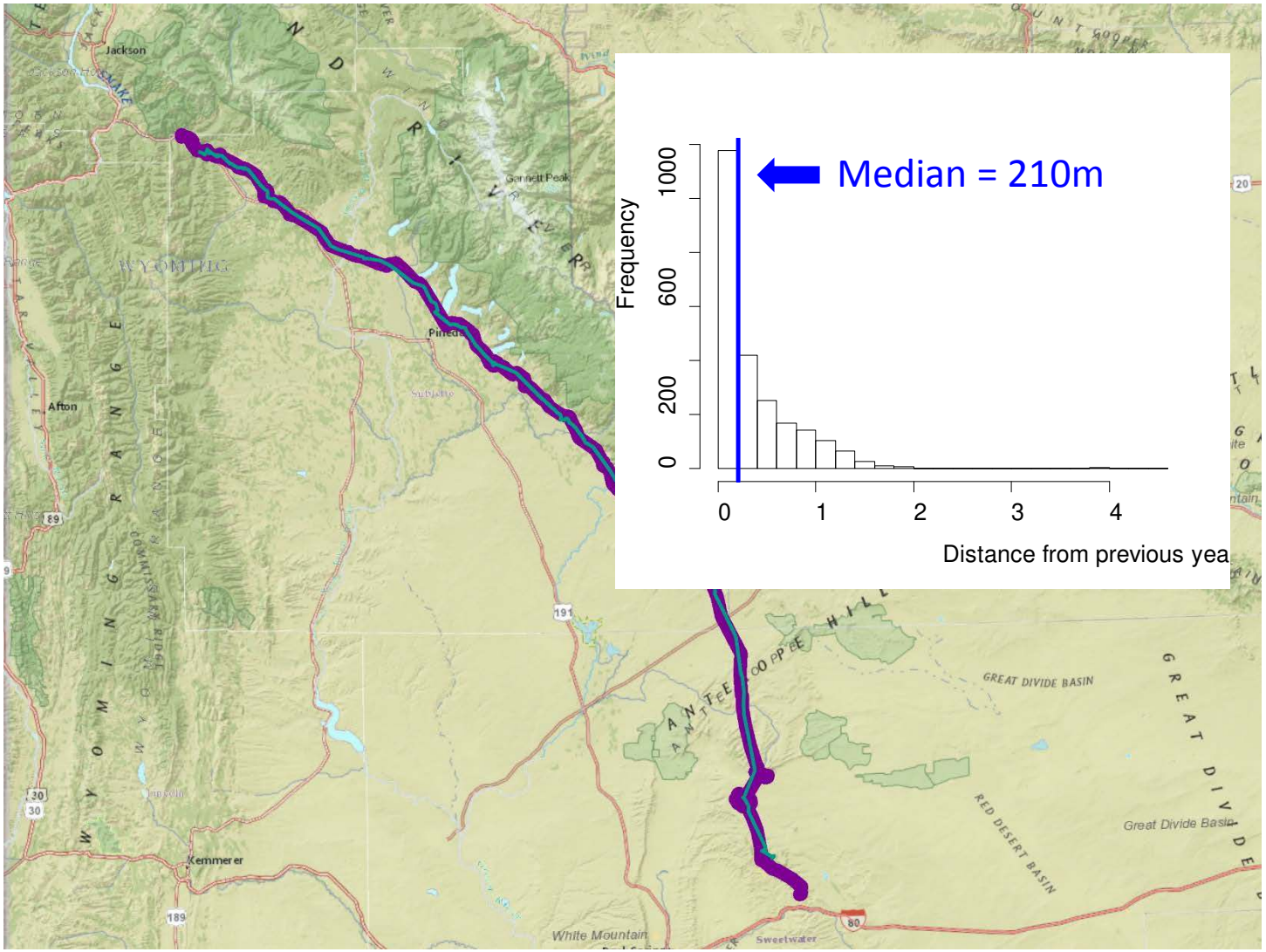

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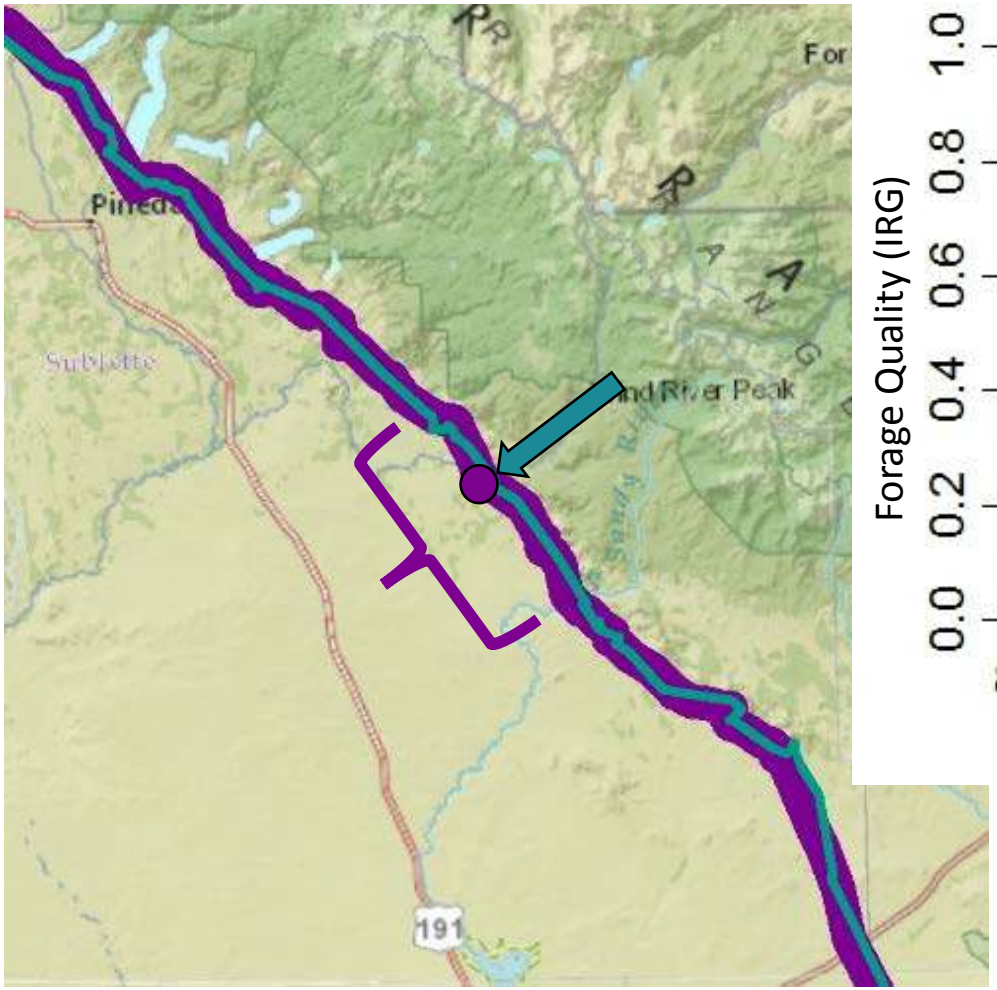
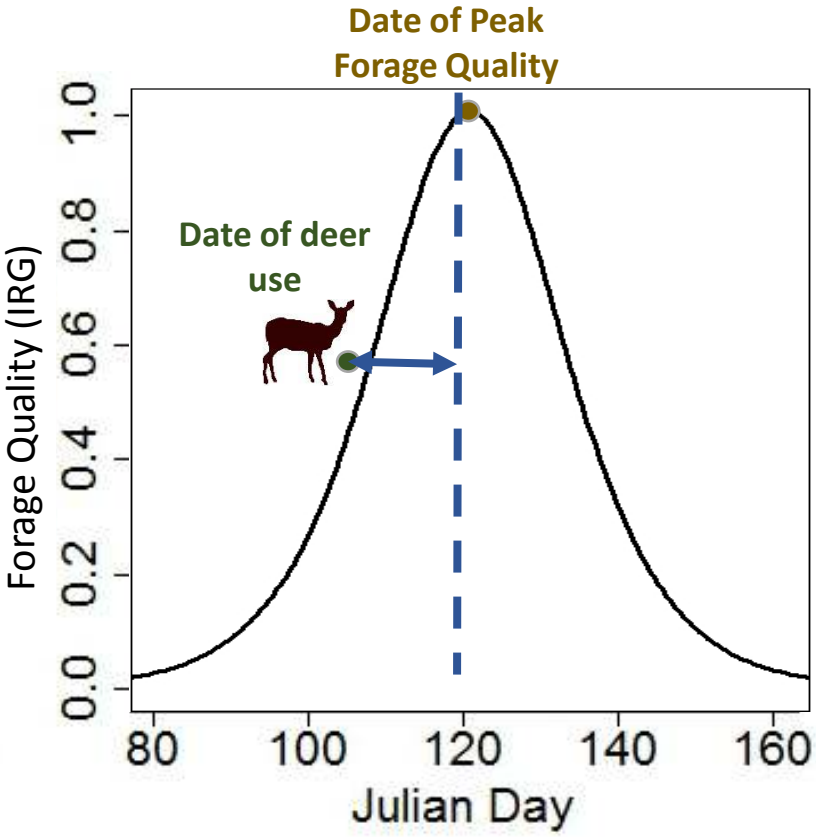
The use of attribute memory

- Is the use of memory stronger when past experience was good?
  - Expectation: Selection of previous route strengthens with better surfing the previous year

Previous year's surfing score based on 3-day running mean

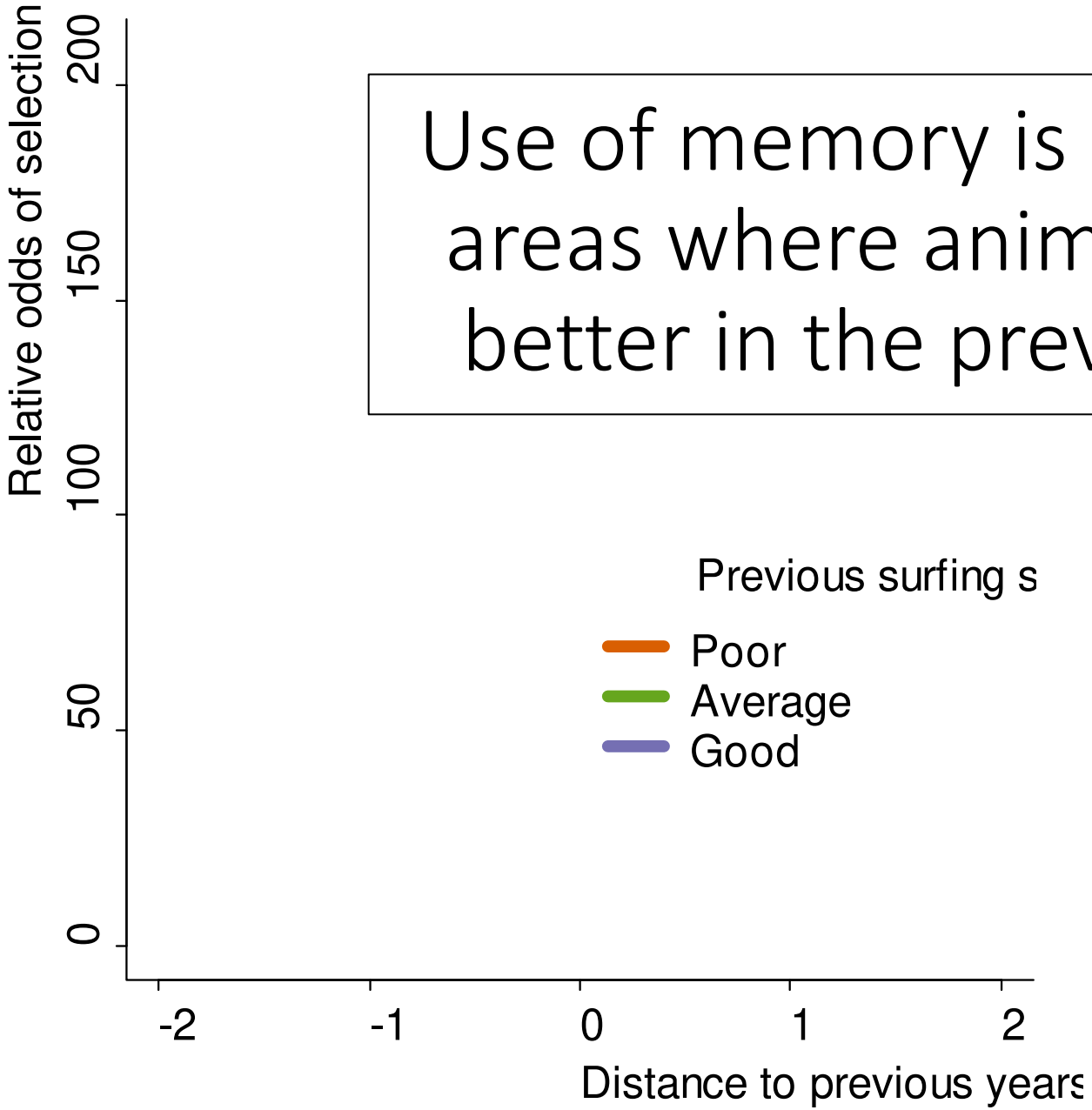
AID 17
2011
2012





Days from peak IRG
0 = surfing

Use of memory is stronger in areas where animals surfed better in the previous year



ΔQIC = 8.6

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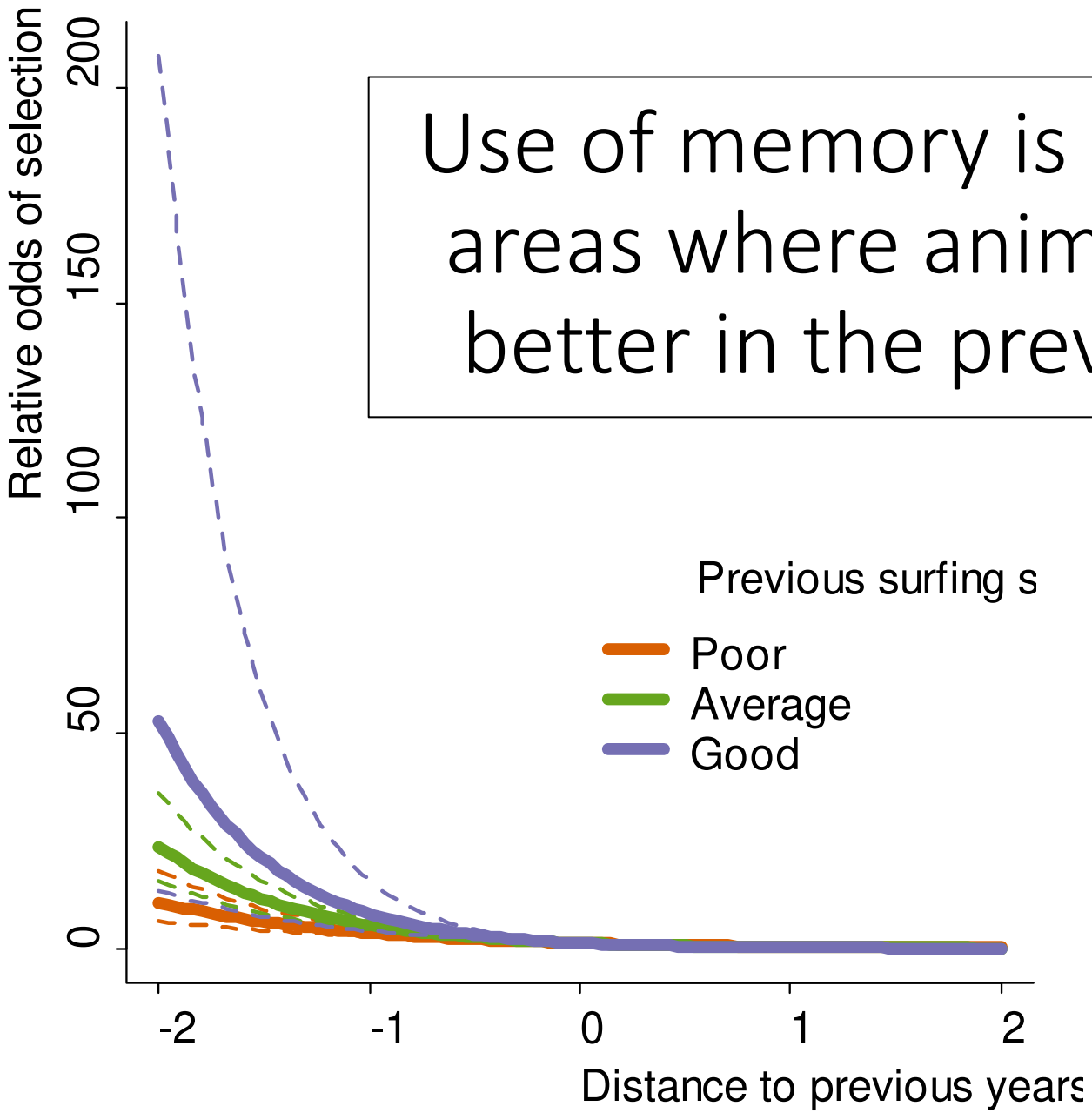
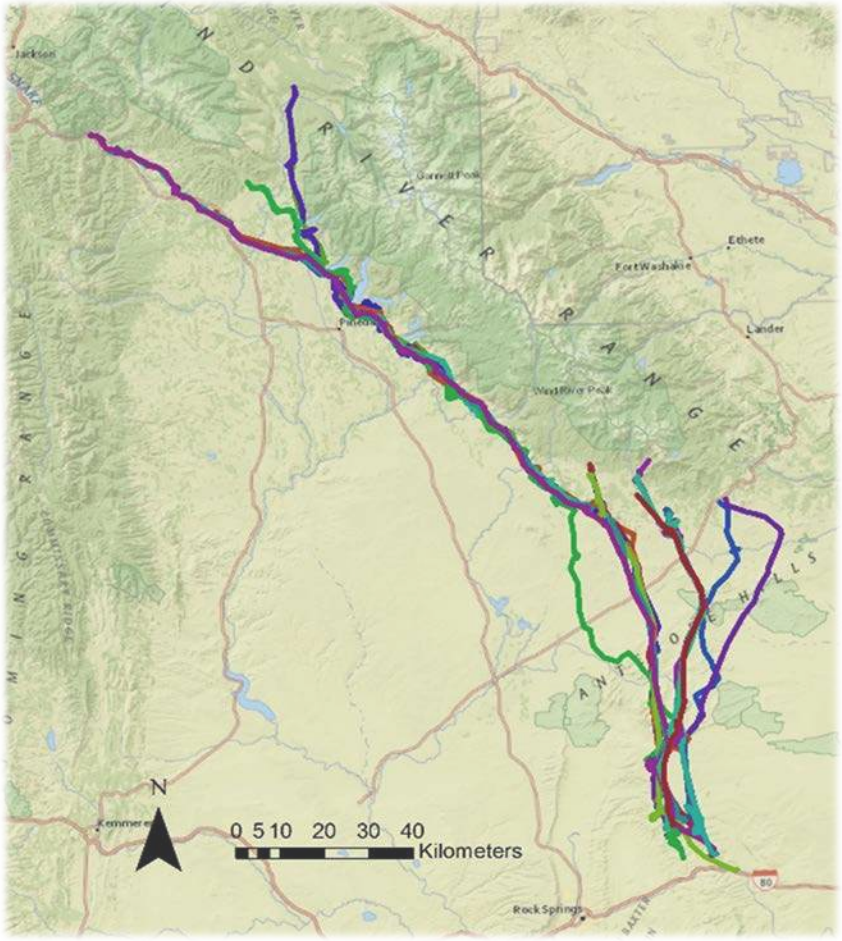


ΔQIC = 8.6

Take home messages

- Deer have excellent spatial memory
- Memory is the driver of migratory behavior, green-wave surfing is secondary
- Adjustable memory use may result in adaptation to change



Habitat is…

environment ✖ animal's knowledge

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UNIVERSITY OF WYOMING

New Thinking

jmerkle@uwyo.edu


Thank you!