WILD REINDEER

MAIN RESEARCH FINDINGS

FROM OUR WORK ON SPACE USE AND HUMAN/REINDEER COEXISTENCE

Manuela Panzacchi

3 Oct 2016, Trondheim

Kickoff meeting, NINA-Guelph collaboration

NINA
Norwegian Institute for Nature Research

HOW DO WE WORK:

Understand ***MECHANISMS*** of reindeer-human coexistence

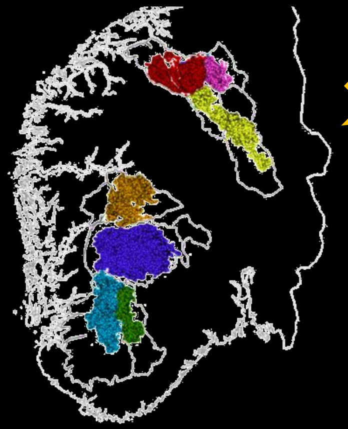
(data modelling – largely based on reindeer GPS data)

PREDICT reindeer behaviour in a scenario approach

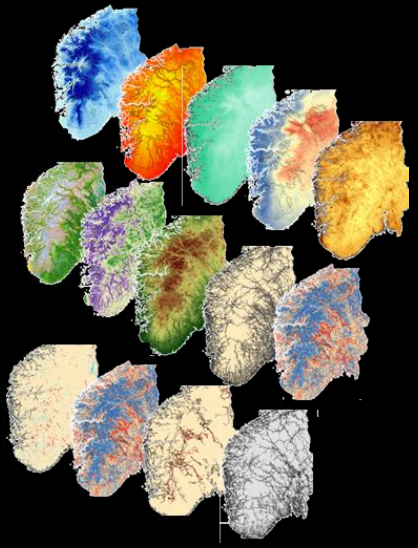
Develop tools to aid sustainable ***LAND-PLANNING, MITIGATIONS, OFF-SET….***

DATA MANAGEMENT TOOL: SAM – SPATIAL DATABASE FOR ANIMAL MOVEMENTS

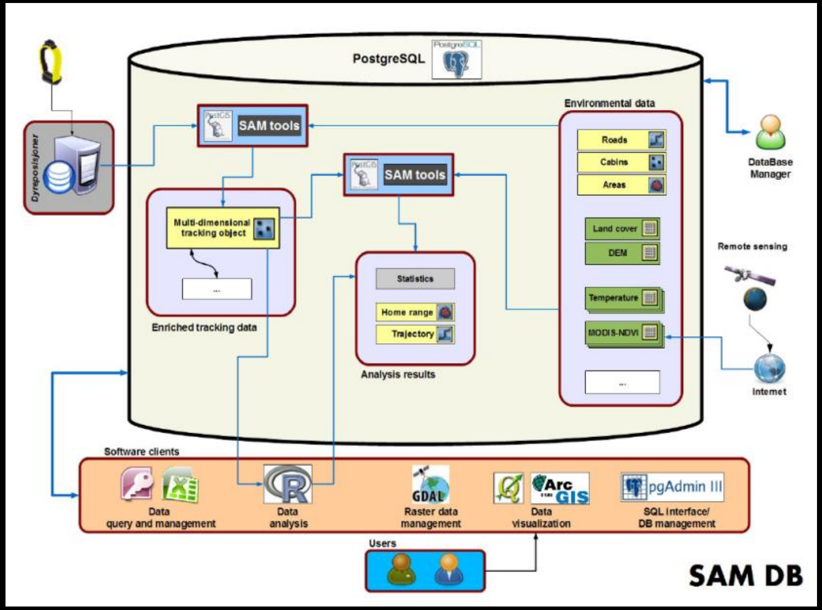
> 250 reindeer GPS data



Climate, Habitat, infrastructures..



Open source, free



NINA WIKI

Cagnacci & Urbano 2015

Output pane

Data Output | Explain | Messages | History

	animals_id integer	acquisition_time timestamp without time zone	longitude double precision	latitude double precision	the_geom geometry	x_utm32 integer	y_utm32 integer	reindeer_areas_id integer	sun_angle double precision	altitude_dem_25 integer	temperature_nve double precision	closest_cabin integer	lc_norut integer
1	43	2008-01-01 00:00:50	8.114352	60.19383	01010000	450891	6673327	3	-52.5105	1187	2547	854	14
2	43	2008-01-01 03:00:44	8.116049	60.195748	01010000	450988	6673540	3	-38.2023	1216	2546	821	14
3	43	2008-01-01 06:00:43	8.123135	60.196081	01010000	451381	6673571	3	-16.3138	1244	2546	1180	17
4	43	2008-01-01 09:00:41	8.12218	60.195436	01010000	451327	6673500	3	1.66246	1223	2546	1150	14
5	43	2008-01-01 12:00:44	8.126824	60.198916	01010000	451590	6673884	3	6.61718	1243	2546	1347	14
6	43	2008-01-01 15:00:41	8.129531	60.201478	01010000	451744	6674168	3	-3.60621	1234	2546	1417	14
7	43	2008-01-01 18:00:25	8.143045	60.20729	01010000	452501	6674805	3	-23.9792	1163	2546	429	17

WHAT HAVE WE LEARNED?

Research

Searching for the fundamental niche using individual-based habitat selection modelling across populations

Manuela Panzacchi[1,†], Bram Van Moorter[1,†], Olav Strand[1], Leif Egil Loe[2] and Egil Reimers[3]

Issue

ECOGRAPHY

Ecography

Volume 38, Issue 7

Journal of Animal Ecology

Special Feature: Stuck In Motion? Reconnecting Questions And Tools In Movement Ecology

Predicting the *continuum* between corridors and barriers to animal movements using Step Selection Functions and Randomized Shortest Paths

Manuela Panzacchi[1,*], Bram Van Moorter[1], Olav Strand[1], Marco Saerens[2], Ilkka Kivimäki[2], Colleen C. St. Clair[3], Ivar Herfindal[4] and Luigi Boitani[5]

Issue

Journal of Animal Ecology

Early View (Online Version

Record published before

Journal of Animal Ecology

British Ecological Society

Explore this journal >

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Special Feature Review: Stuck in Motion? Reconnecting Questions and Tools in Movement Ecology

REVIEW: Can habitat selection predict abundance?

Mark S. Boyce, Chris J. Johnson, Evelyn H. Merrill, Scott E. Nielsen, Erling J. Solberg, Bram van Moorter

Journal of Animal Ecolog

Special Feature: Stuck in Motion? Reconnecting Questions and Tools in Movemen Ecology

Movement is the glue connecting home ranges and habitat selection

Bram Van Moorter, Christer M. Rolandsen, Mathieu Basille, Jean-Michel Gaillard

Journal of Animal Ecology

Standard Paper

How many routes lead to migration? Comparison of methods to assess and characterise migratory movements

Francesca Cagnacci[1,2,*], Stefano Focardi[3], Anne Ghisla[4], Bram van Moorter[5], Evelyn Merrill[6], Eliezer Gurarie[7,8], Marco Heurich[9], Atle Mysterud[10], John Linnell[5], Manuela Panzacchi[5], Roel May[5], Torgeir Nygård[5], Christer Rolandsen[5] and Mark Hebblewhite

Issue

Journal of Animal Ecology

Accepted Article (Accepted, unedited articles published online and citable. The final edited and typeset version of

A road in the middle of one of the last wild reindeer migration routes in Norway: crossing behaviour and threats to conservation

Manuela Panzacchi[1], Bram Van Moorter[1] & Olav Strand[1]

Rangifer, 33, Special Issue No. 21, 2013: 15–26

Landscape Ecol

DOI 10.1007/s10980-012-9793-5

RESEARCH ARTICLE

Learning from the past to predict the future: using archaeological findings and GPS data to quantify reindeer sensitivity to anthropogenic disturbance in Norway

Manuela Panzacchi · Bram Van Moorter · Per Jordhøy · Olav Strand

PosTRACK

Home | Summer School

Summer School on Management and Analysis of Animal Tracking Data

Stuck in motion?

Reconnecting questions and tools in movement ecology

Download

- Presentations, data, scripts, DEMOS
- Pictures
- List of speakers
- List and contacts of participants
- Program_SummerSchool_Conference
- Welcome_Practicalities

Journal of Animal Ecology

British Ecological Society

Journal of Animal Ecology 2013 doi: 10.1111/1365-2656.12045

Understanding scales of movement: animals ride waves and ripples of environmental change

Bram van Moorter[1,2*], Nils Bunnefeld[3,4], Manuela Panzacchi[2], Christer M. Rolandsen[1], Erling J. Solberg[2] and Bernt-Erik Sæther[1]

Journal of Animal Ecology

British Ecological Society

Journal of Animal Ecology 2014 doi: 10.1111/1365-2656.12275

SPECIAL FEATURE: STUCK IN MOTION? RECONNECTING QUESTIONS AND TOOLS IN MOVEMENT ECOLOGY

'You shall not pass!': quantifying barrier permeability and proximity avoidance by animals

Hawthorne L. Beyer[1*], Eliezer Gurarie[2,3], Luca Börger[4], Manuela Panzacchi[5], Mathieu Basille[6], Ivar Herfindal[7], Bram Van Moorter[5], Subhash R. Lele[8] and Jason Matthiopoulos[9]

VERY short, very simplified version: **wild reindeer tend to avoid all sources of human disturbance**

However, the devil is in the details!! ***Their response depend on…***

1. TYPE OF DISTURBANCE

EFFECT OF ROADS

(10.635 km of roads within reindeer areas)

Roads shape reindeer distribution

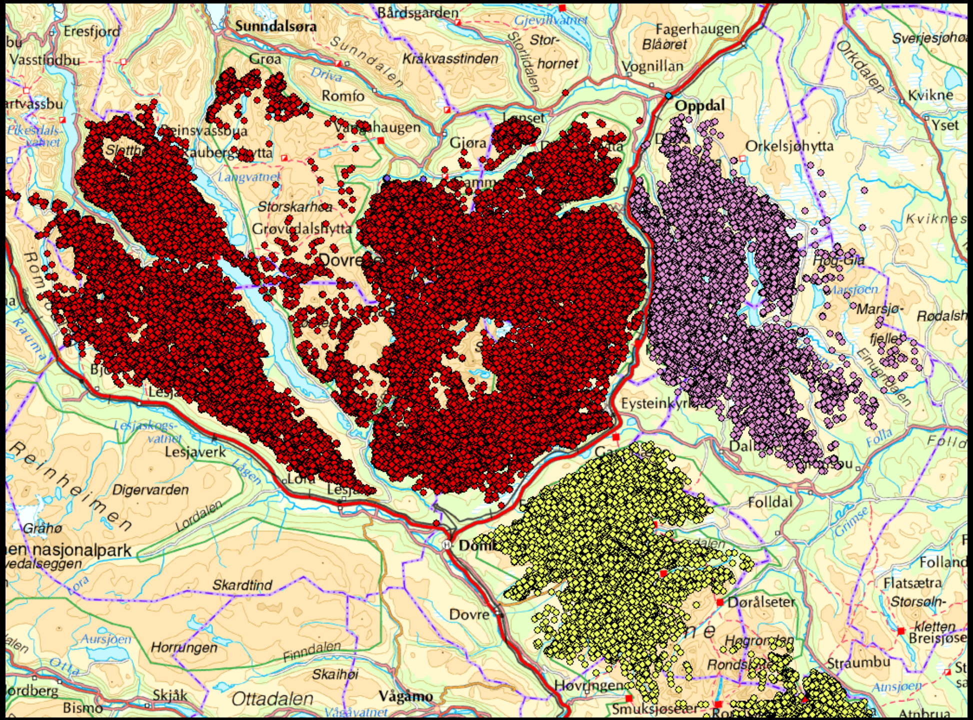
⇒ Strongly avoided in all seasons and areas, up to: ***[RSF - SSF]***

- 10-15 km - *public* roads
- 1 km (winter), 5 km (summer) – *private* roads

⇒ Reduce landscape permeability of 44-100% *[Movement Kernel]*

⇒ Hamper migration *[Net displacement]*

⇒ …



Variables	coef	se(coef)	z	Pr(>|z|)
poly(pca1, 2)1	341.955	20.507	16.675	< 0.001
poly(pca1, 2)2	-297.059	16.850	-17.630	< 0.001
poly(pca2, 2)1	-889.623	39.347	-22.609	< 0.001
poly(pca2, 2)2	-494.932	24.107	-20.531	< 0.001
poly(pca3, 2)1	-126.648	14.798	-8.558	< 0.001
poly(pca3, 2)2	-118.996	14.257	-8.347	< 0.001
poly(pca4, 2)1	4.090	11.998	0.341	0.733
poly(pca4, 2)2	24.017	9.647	2.490	0.013
CabinsPublic_10K	-0.157	0.023	-6.843	< 0.001
PowerLines_res15K	-0.305	0.025	-11.990	< 0.001
CabinsPrivate_15K	-0.226	0.035	-6.456	< 0.001
RoadsPrivate_res1K	-0.781	0.074	-10.544	< 0.001
RoadsPublic_15K	-0.684	0.058	-11.726	< 0.001
SkiTrails_res3K	0.089	0.017	5.420	< 0.001
NORUT_Mountain12	1.500	0.165	9.081	< 0.001
NORUT_Mountain13	3.057	0.155	19.745	< 0.001
NORUT_Mountain14	2.637	0.150	17.543	< 0.001
NORUT_Mountain15	2.871	0.169	17.026	< 0.001
NORUT_Mountain16	2.674	0.151	17.677	< 0.001
NORUT_Mountain17	2.483	0.146	16.981	< 0.001
NORUT_Mountain18	1.986	0.167	11.909	< 0.001
NORUT_Mountain19	2.501	0.155	16.106	< 0.001
NORUT_Mountain20	1.813	0.156	11.588	< 0.001
NORUT_Bog	1.184	0.199	5.934	< 0.001
NORUT_Water	1.114	0.181	6.169	< 0.001
NORUT_Other	-11.727	1.E+03	-0.011	< 0.001

Panzacchi-Van Moorter et al. Ecography, 2015

Panzacchi et al, J anim Ecol 2015

Panzacchi et al Rangifer 2013

Beyer et al J anim Ecol. 2016

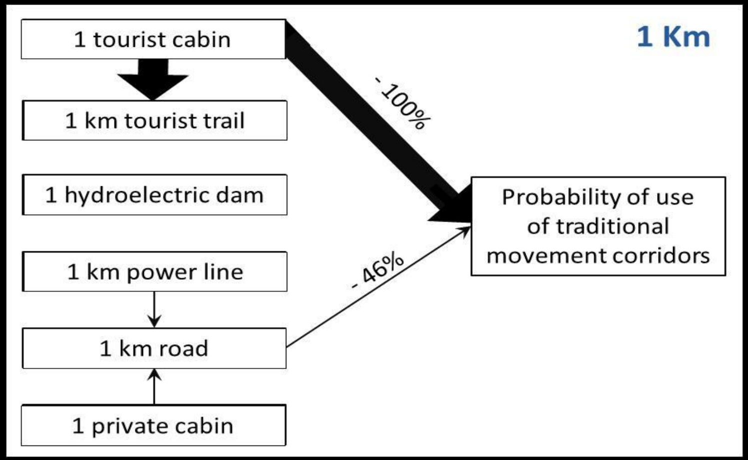
Beyer et al J anim Ecol. 2015

EFFECT OF TOURIST CABINS, HICKING TRAILS

CABINS *(299 DNT + 42.925 private cabins)*

⇒ Avoided in all areas (high d), especially in summer *[RSF - SSF]*

⇒ Large tourist cabins (DNT) built along traditional migration corridors can stop migrations: *[Path Analysis]*

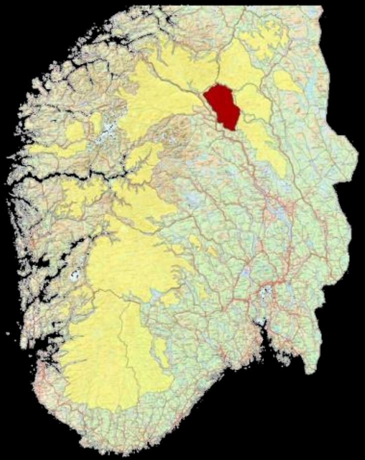


HIKING TRAILS *(7.850 km)*

⇒ Negative, significant, but highly variable effects *[RSF, SSF, Path Analysis]*

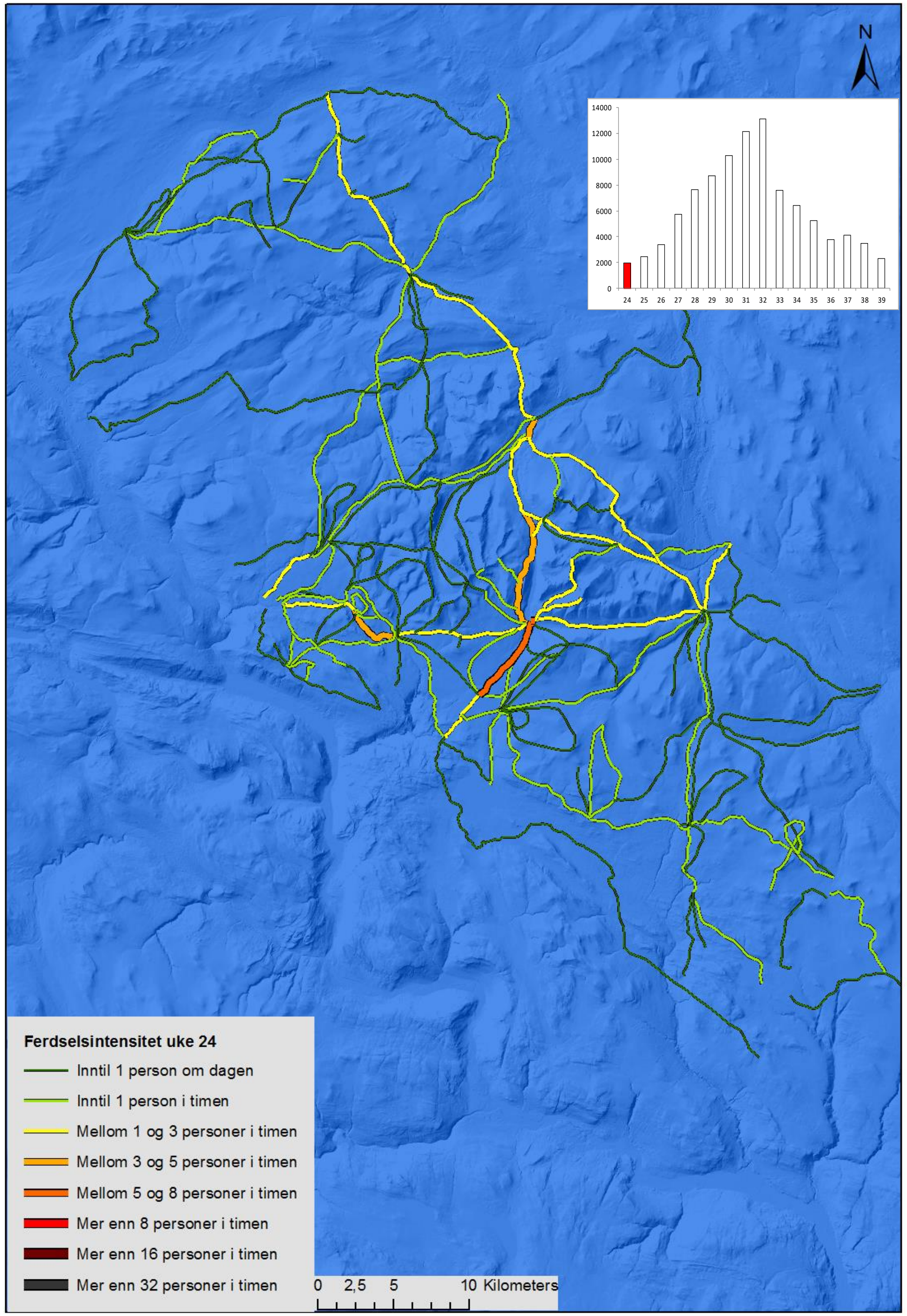
Panzacchi-Van Moorter et al. Ecography, 2015
Panzacchi et al, J anim Ecol 2015
Panzacchi et al, Land. Ecol, 2013

2. INTENSITY OF DISTURBANCE

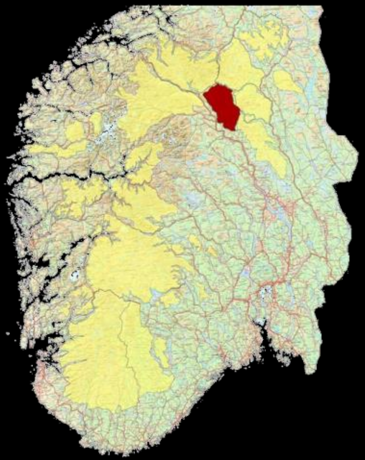


N PEOPLE WALKING ON TRAILS

RONDANE, SUMMER



V. Gundersen



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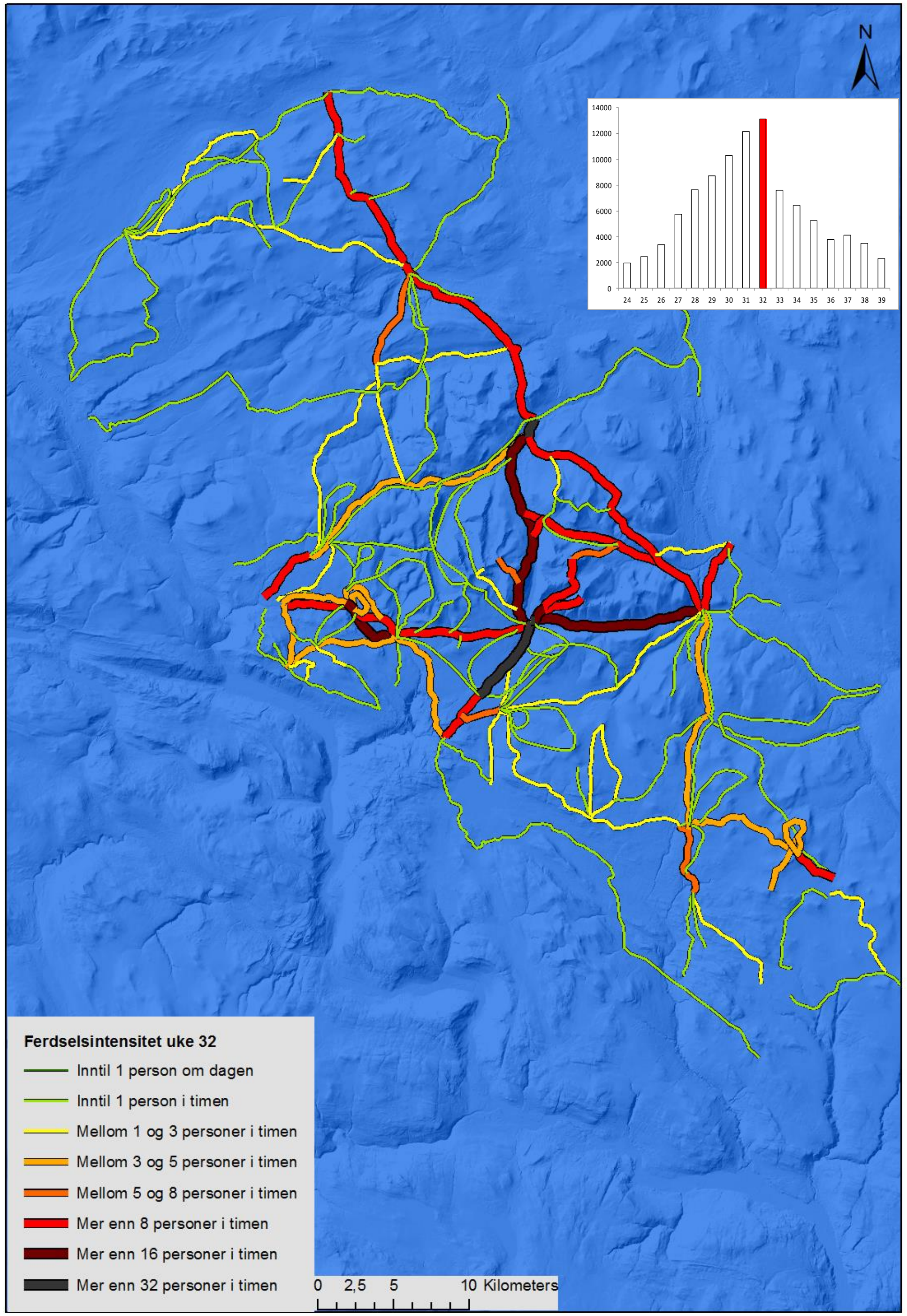

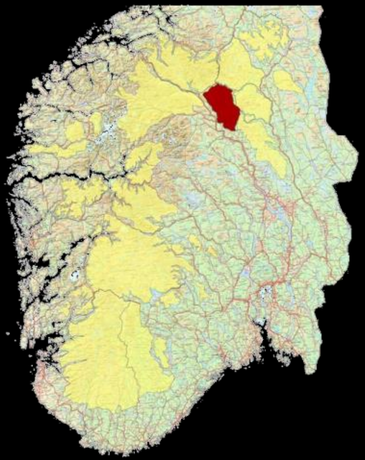

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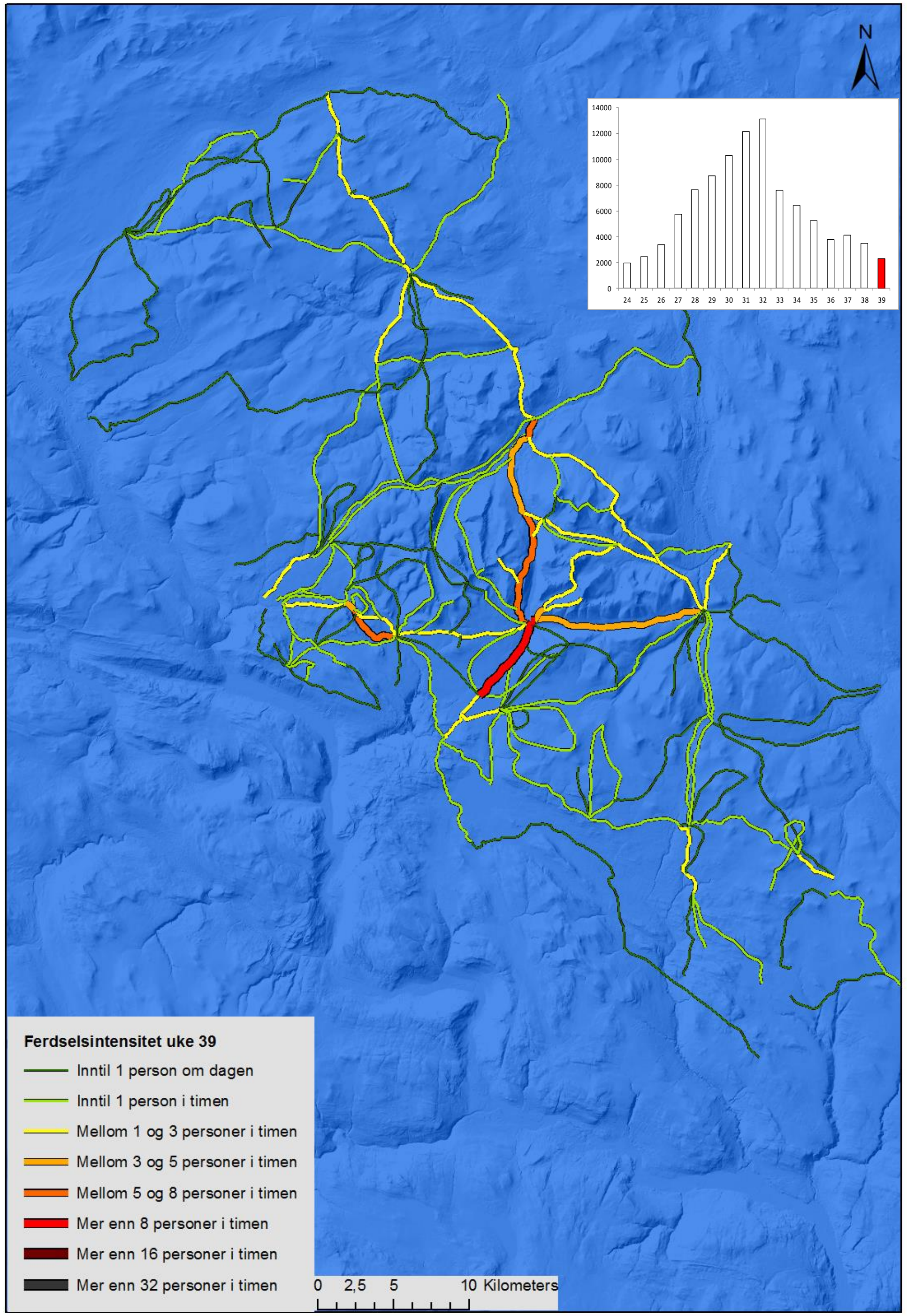


V. Gundersen

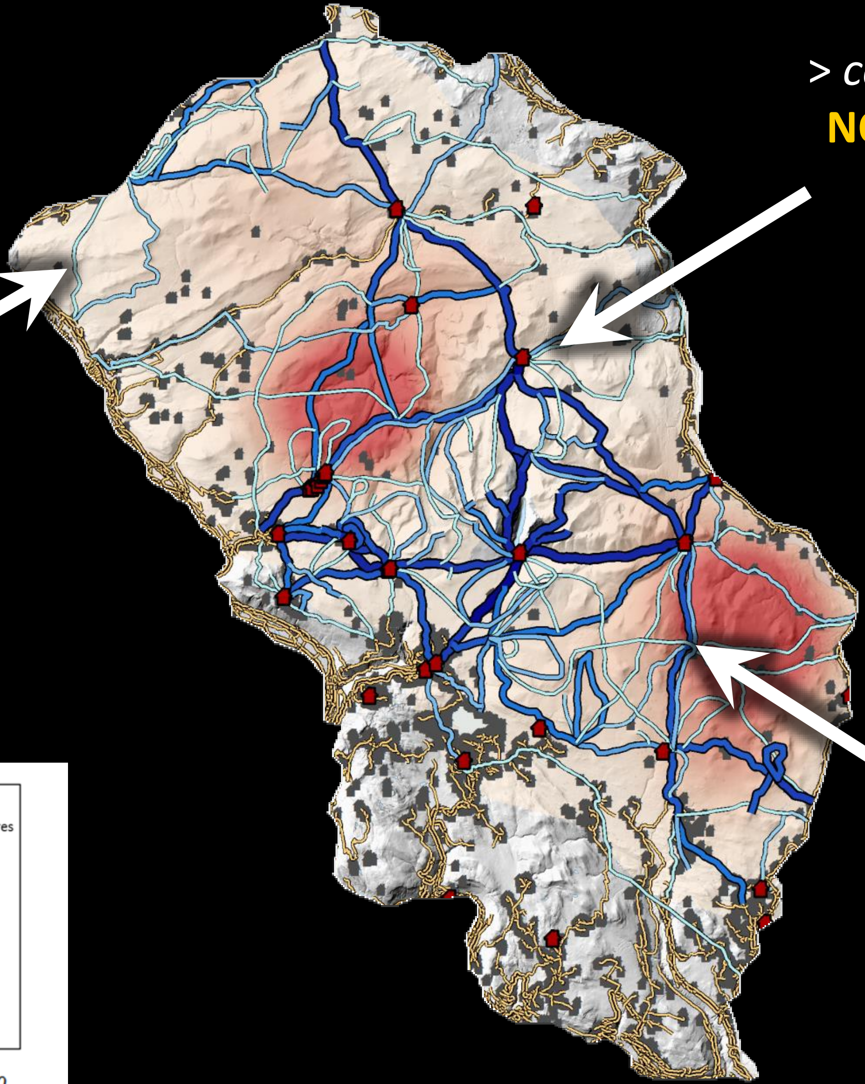
EFFECT OF TOURIST VOLUME ON REINDEER SPACE USE

> *ca.* 100 people/day*

NON-TRAVERSABLE BARRIER

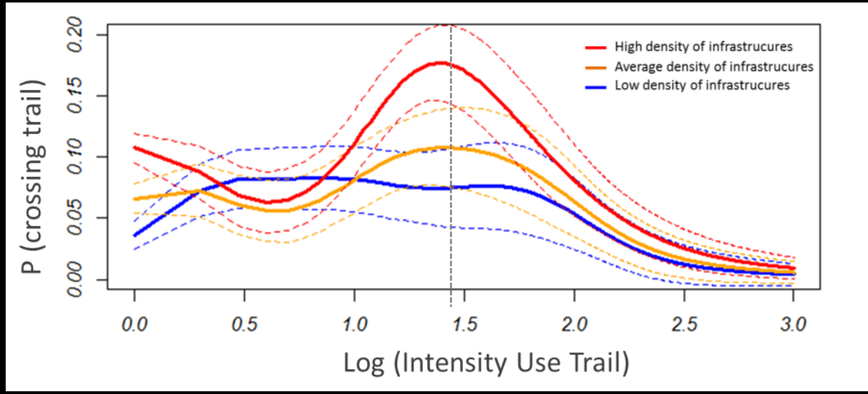
< *ca.* 2 people/day*

.. It's «OK-ish»



> *ca.* 15 people/day*

Becomes difficult for reindeer to traverse the trail



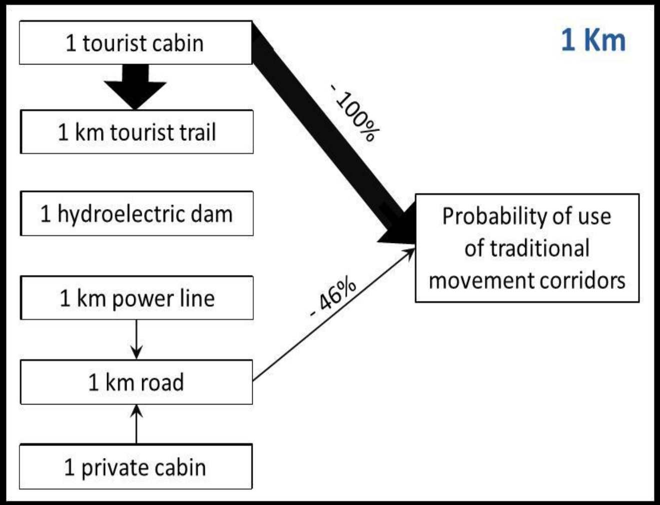
* Numbers refer to Trail Use Index, which roughly represents twice the number of people walking along a trail

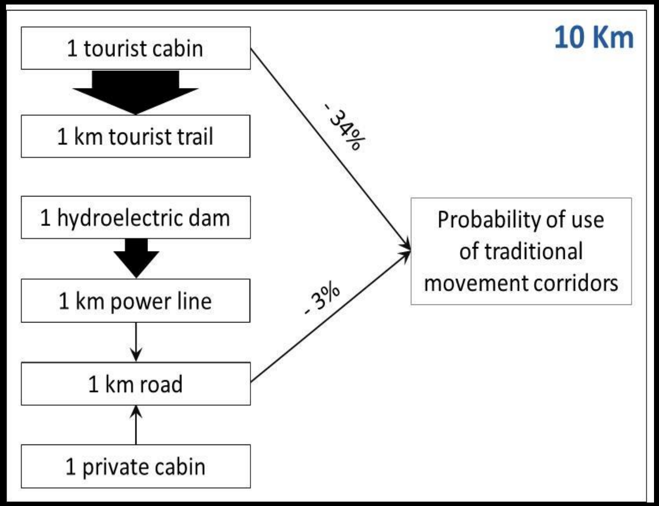
Panzacchi et al in prep

CUMULATIVE EFFECTS

Effect of spatial correlation among infrastructures

DIRECT, INDIRECT, CUMULATIVE EFFECTS





Path analysis,
Meyer et al 2006

DIRECT EFFECTS: - road: -46%
(e.g. 1 km) - DNT cabin: -100%

} **CUMULATIVE (ADDITIVE) EFF. e.g:**
(e.g. 10 km)
- 1 km road: -3%
- 10 km road: - 25%
- 10 km road + DNT cabin : - 51%

INDIRECT EFFECTS: - power line
- private cabin
- Reservoir

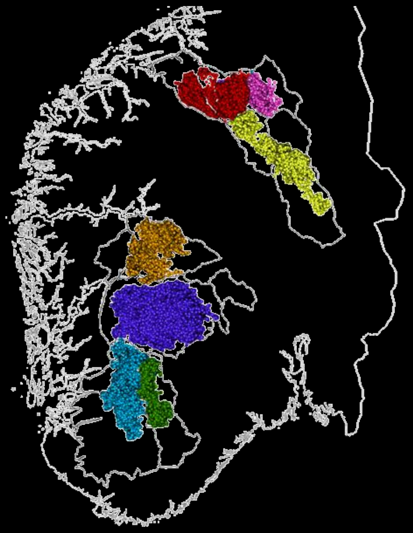
Panzacchi et al 2013, Land. Ecol.

OPTIMAL VS. SUBOPTIMAL HABITATS

(HOW TO IDENTIFY THEM?)

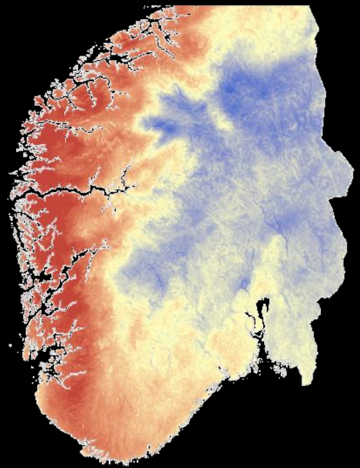
TRADITIONAL HABITAT SELECTION APPROACH

GPS data

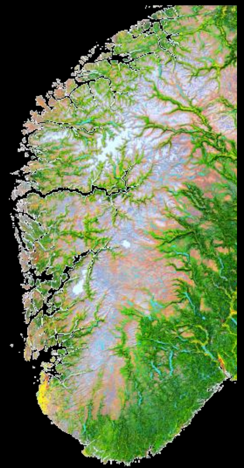


Compare used to available habitat
(within each population) using RSF

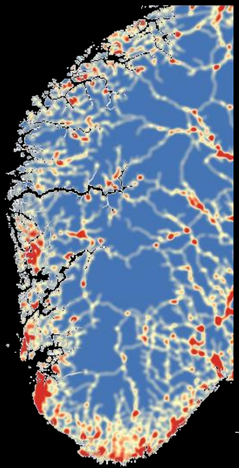
Climate



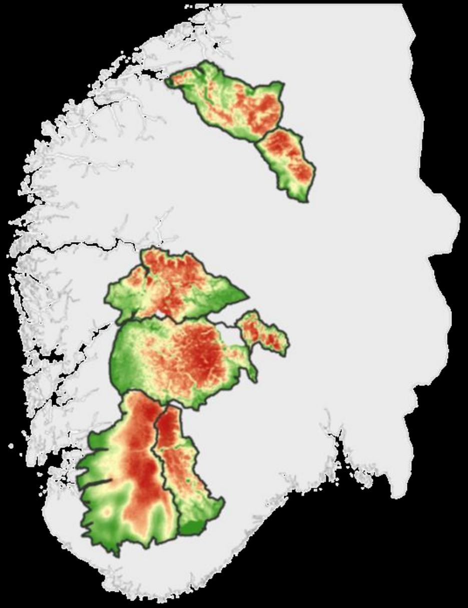
Habitat



Disturbance



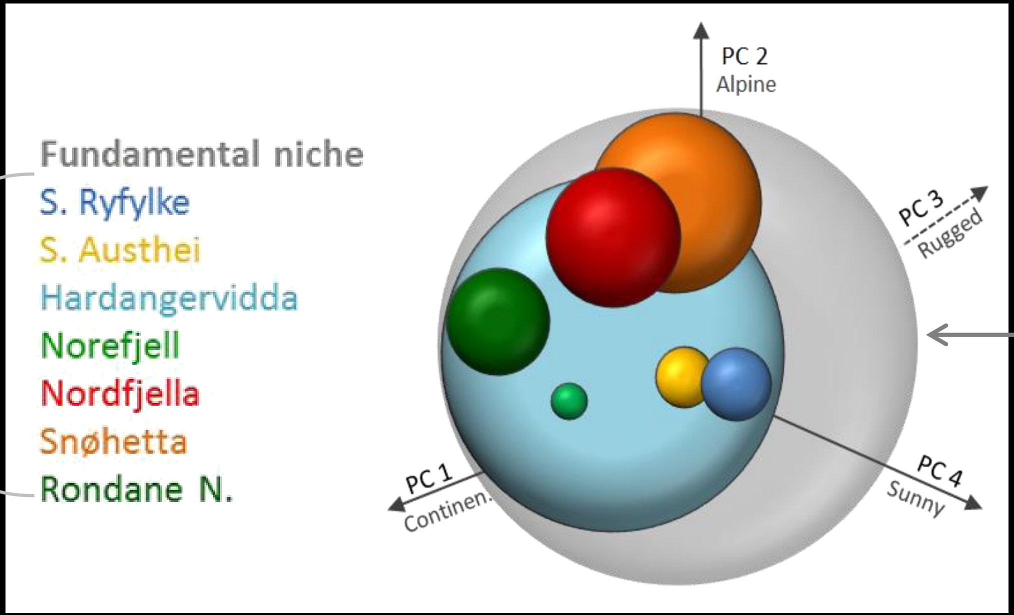
7 independent, Habitat Preference Maps



LIMIT: Mosaic of *Realized Niches*
$\Rightarrow$ can’t compare preference among pop.
due to different availability

SCALING UP HAB MODELLING ACROSS POP TO APPROXIMATE THE FUNDAMENTAL NICHE

Realized niches



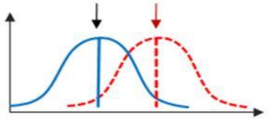
Fundamental niche

Fund. Niche can be viewed as a *generalization* of all Realized Niches of the species' populations, and may thus be *approximated by* the combination of all measurable niches

(Whittaker et al. 1973)

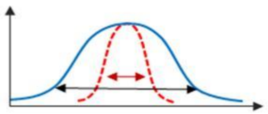
- CLR with log-link function. Used points conditioned to available points within available area
- Relevant variables modeled using a Gaussian curve to estimate ***NICHE OPTIMUM*** (curve mean) and ***NICE BREADTH*** (variance)

$$\text{Use}/\text{Available} \sim \alpha + \beta_0 \begin{bmatrix}\text{Human disturbance}_i \\ \text{(different scales)}\end{bmatrix} + \beta_1 \begin{bmatrix}\text{Environmental} \\ \text{variable}_j\end{bmatrix} + \beta_2 \begin{bmatrix}\text{Environmental} \\ \text{variable}_j\end{bmatrix}^2 + \ldots + \varepsilon$$



Niche Optimum $= \beta_1 \sigma^2$

Niche Breadth $= -1/(2\,\beta_2)$

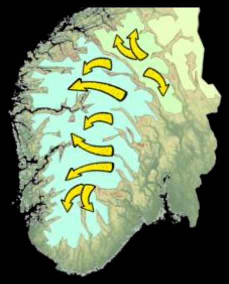


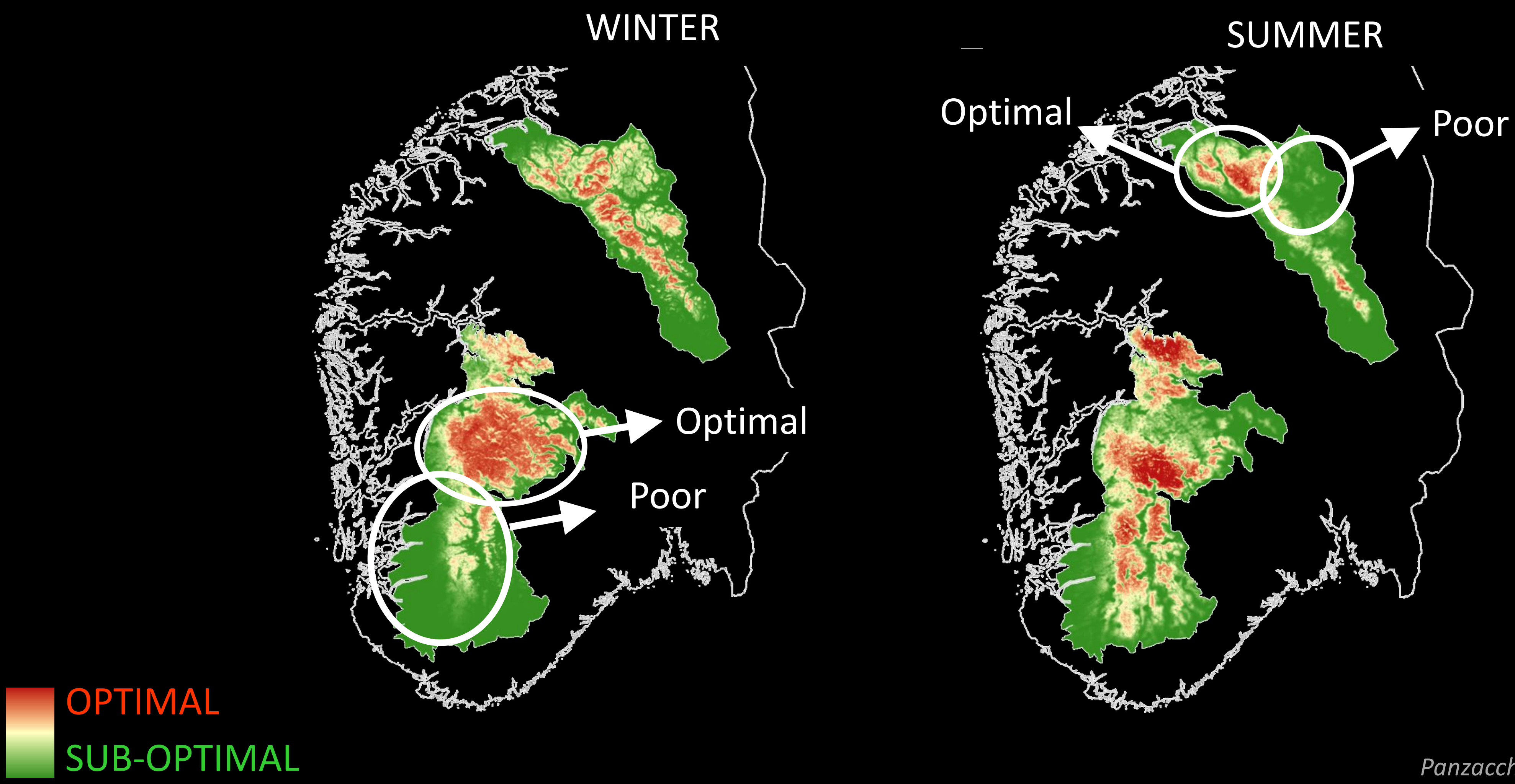
Panzacchi-Van Moorter et al. Ecography, 2015

APPROXIMATION OF THE FUNDAMENTAL NICHE OF WILD REINDEER IN NORWAY

≅ "Optimal habitat", i.e. hab. reindeer would choose if they could move freely (no barriers)

=> Allows to identify ***gradients in habitat quality across the distribution range***





Panzacchi-Van Moorter et al. Ecography, 2015

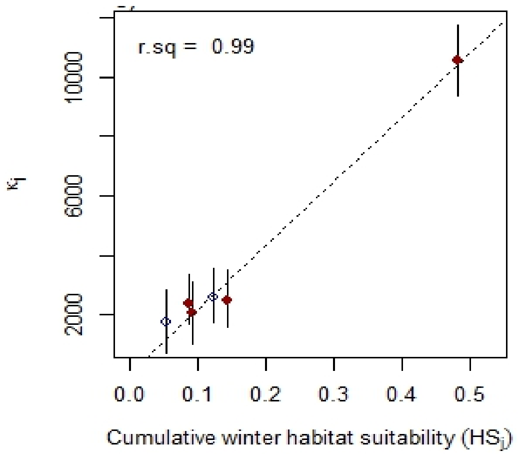
DOES THE «APPROXIMATION OF FUNDAMENTAL NICHE» REFLECT FITNESS? IT SEEMS SO!

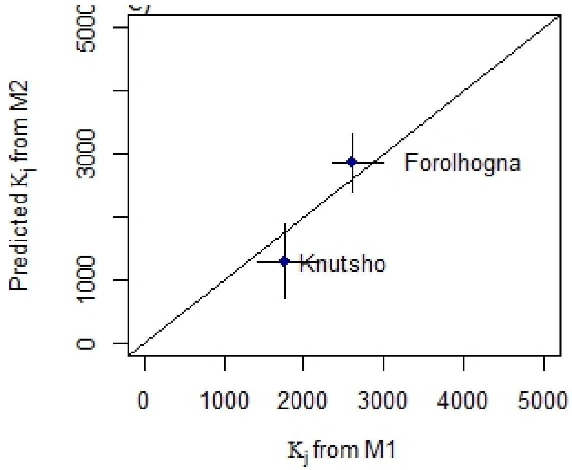
(Nilsen et al. *in prep)*:

1) Identify Population-specific Carrying Capacity $\boldsymbol{\kappa}$

- Data: Minimum Counts (aerial transects), harvest data (6 pop, 1960-)
- Approach: Cross-population Theta-Logistic State Space models:
  - Observation model - accounts for environmental stochasticity & measurement errors
  - Population dynamic model

2) Set of models explaining κ using population effects, total available area, winter/summer range, «fundamental niche models»..





winter fundamental niche is the best predictor of cross-population differences in carrying capacity

(PRELIMINARY RESULTS!)

NINA
Norwegian Institute for Nature Research

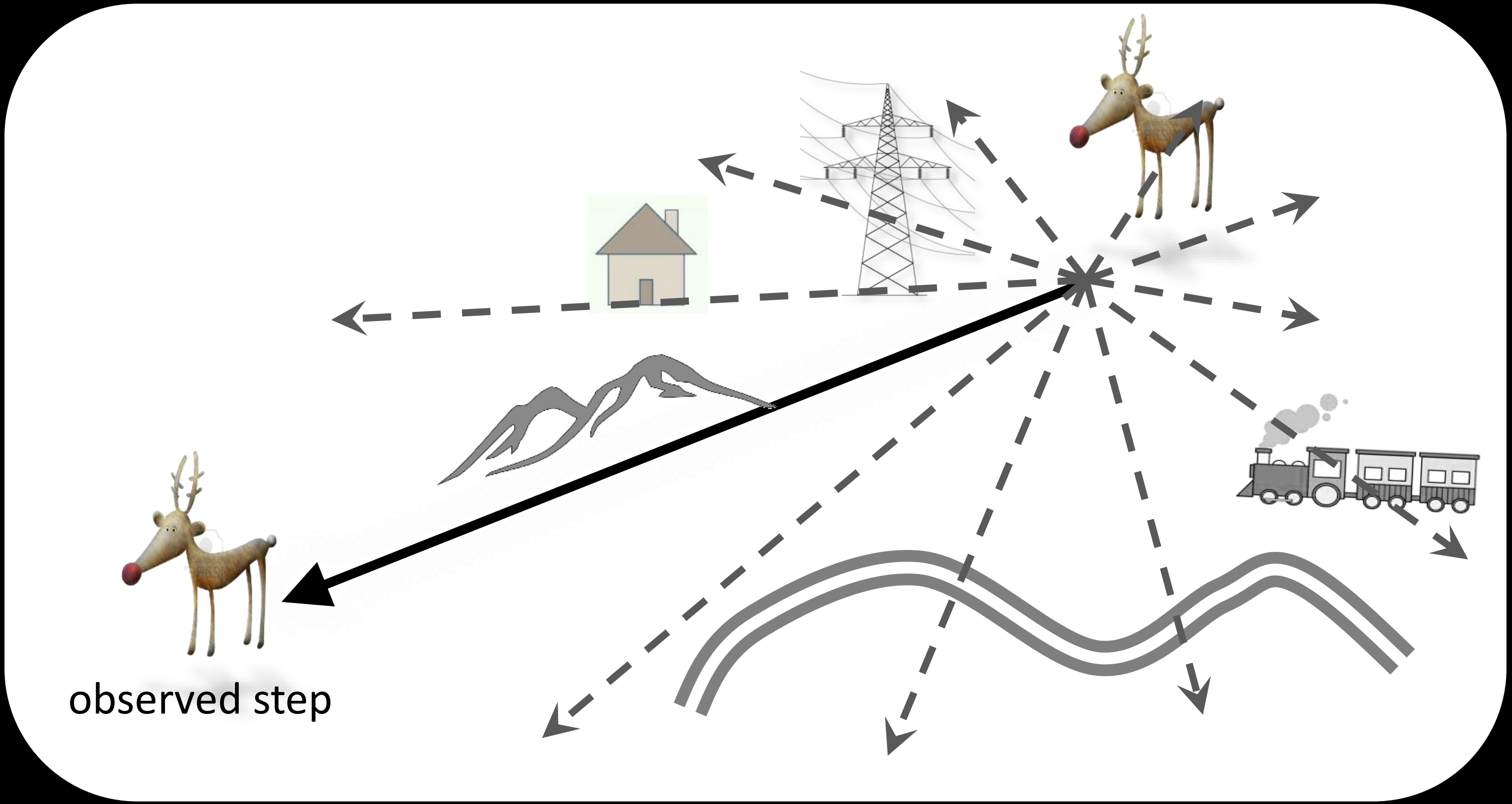
 

HOW TO IDENTIFY MOVEMENT CORRIDORS?

HOW TO IDENTIFY MOVEMENT CORRIDORS: STEP 1 – QUANTIFY LANDSCAPE FRICTION TO STEPS

To which degree each landscape feature can be traversed by a “step”?

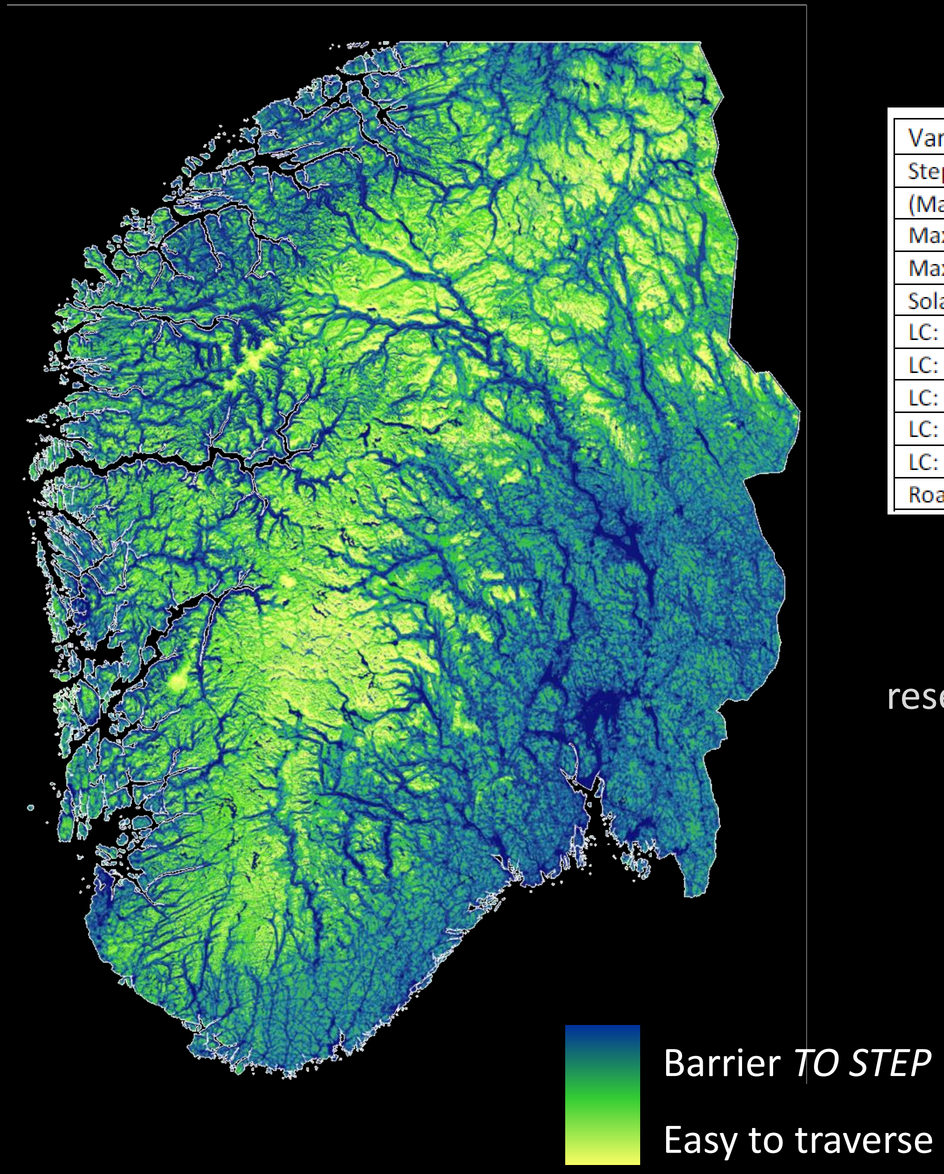
Step Selection Function - CLR



Panzacchi et al, J. Anim. Ecol. 2015

HOW TO IDENTIFY MOVEMENT CORRIDORS: STEP 1 – LANDSCAPE FRICTION MAP

Spring migration (April-May)



Variables	coef	se(coef)	z	p
Step length (corrected)	-1.142e-03	1.171e-05	-97.500	***
(Max slope)^2	-1.165e-03	3.559e-05	-32.732	***
Max trail density	-1.538e-01	2.338e-02	-6.581	***
Max road density	-5.324e-01	1.006e-01	-5.295	***
Solar radiation	3.978e-01	1.051e-02	37.832	***
LC: bog	-5.510e-01	1.570e-01	-3.509	***
LC: mountain not edible veg.	1.516e-01	6.908e-02	2.195	*
LC: mountain edible veg.	5.996e-01	6.096e-02	9.835	***
LC: non dammed lakes	-1.431e+00	1.268e-01	-11.288	***
LC: dammed lakes	-3.936e+00	4.645e-01	-8.473	***
Road crossing	-3.099e-01	1.264e-01	-2.451	*

P (crossing) natural lakes (24%) >> P (crossing) reservoirs (2%): (frozen) lakes can be traversed, while reservoirs are an almost impermeable barrier

Panzacchi et al, J. Anim. Ecol. 2015

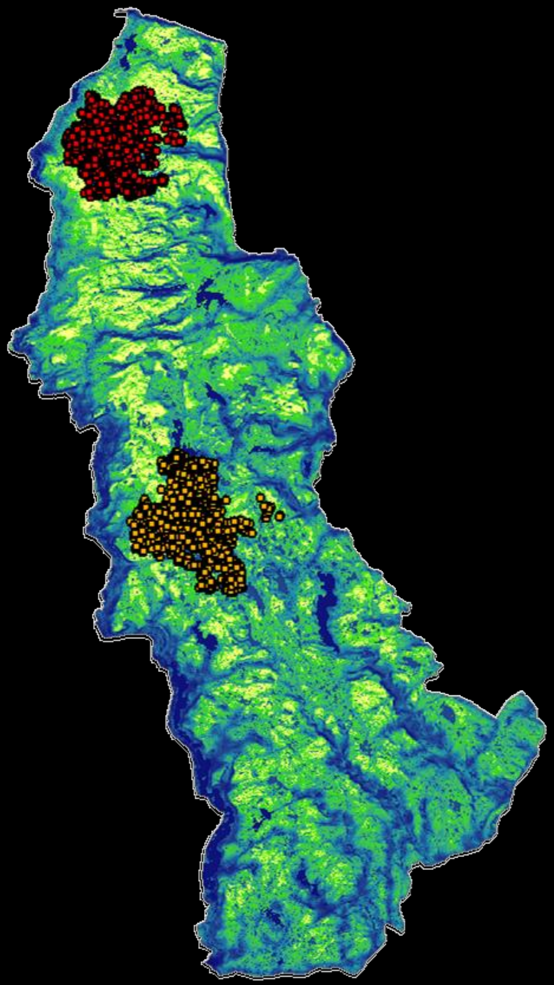
HOW TO IDENTIFY MOVEMENT CORRIDORS: STEP 2 – RANDOMIZED SHORTEST PATH

We know where migration starts and ends & how permeable is the landscape in between

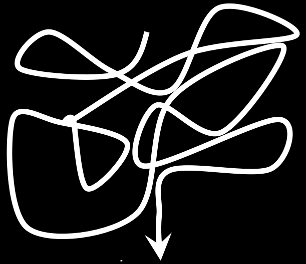
… but which way do reindeer walk?

OPTIMAL MOVEMENTS
«as the fox runs»

e.g. Least Cost Path,
Network-flow Models



RANDOM WALK
«the drunkard's walk»



e.g. Current Models, Diffusion
Models, Agent Based Models

EXAMPLE: Setesdal Austhei area

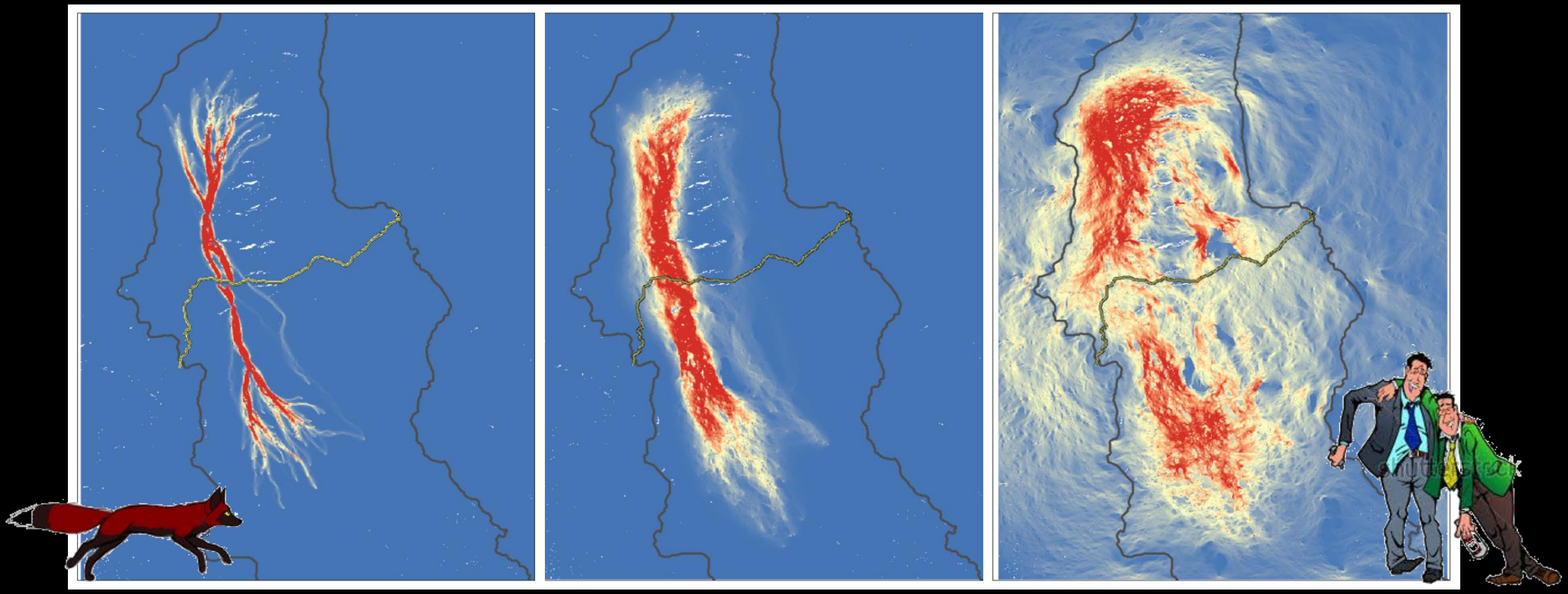
Panzacchi et al, J. Anim. Ecol. 2015

HOW TO IDENTIFY MOVEMENT CORRIDORS: STEP 2 – RANDOMIZED SHORTEST PATH

RSP bridges the gap between LCP and random-walk based approaches.

It identifies paths based on a *given degree of randomness* in animal movements (controlled by the parameter Θ):

Θ = 20 (Least Cost Path) Θ = 0 (Random Walk)



Sensitivity analysis to find Θ values that best match the observed reindeer movement pattern

Panzacchi et al, J. Anim. Ecol. 2015

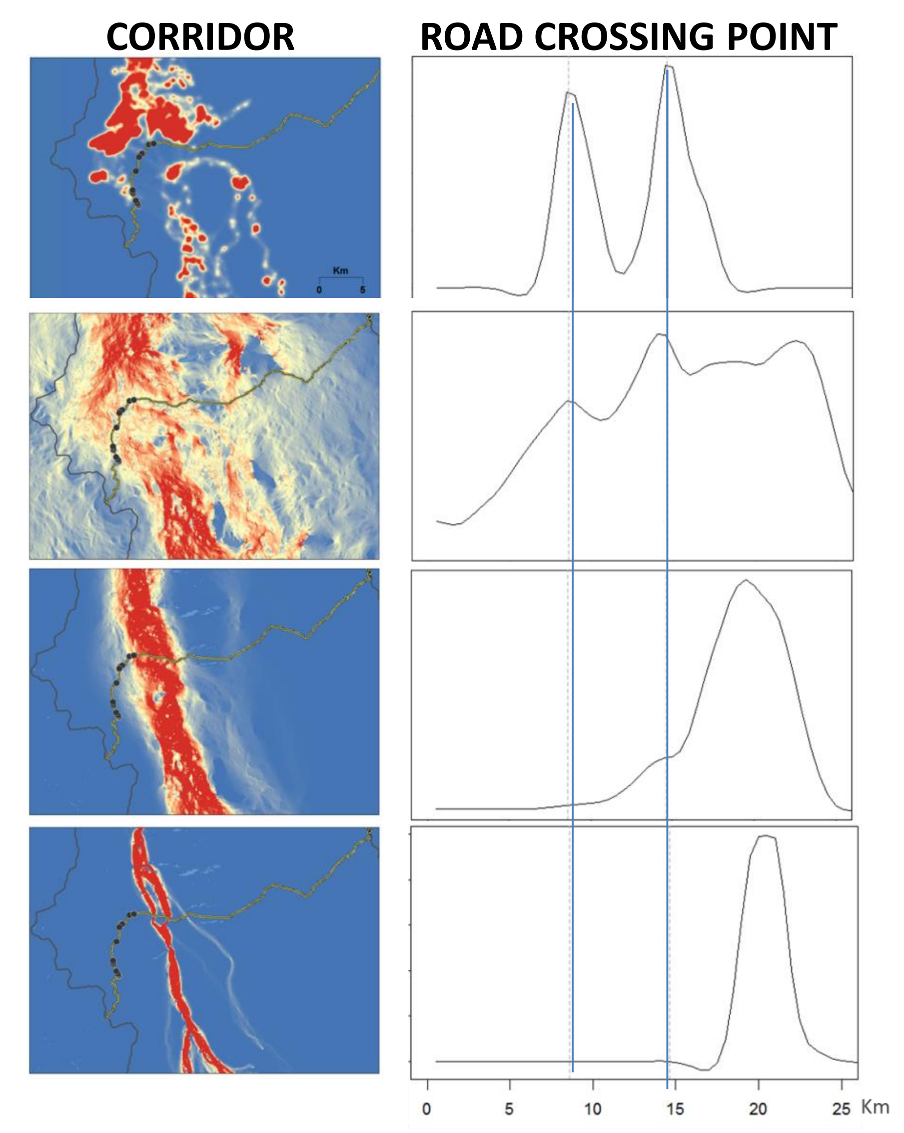
STEP 3: RSP SENSITIVITY ANALYSIS & VALIDATION

During migration reindeer move neither optimally nor at random - intermediate behaviour

Observed movement area
(Brownian Bridge)

Best prediction
Intermediate Θ

Worst prediction - LCP



Observed crossing point

Best prediction:
km 9-14

Worst pred.:
km 22

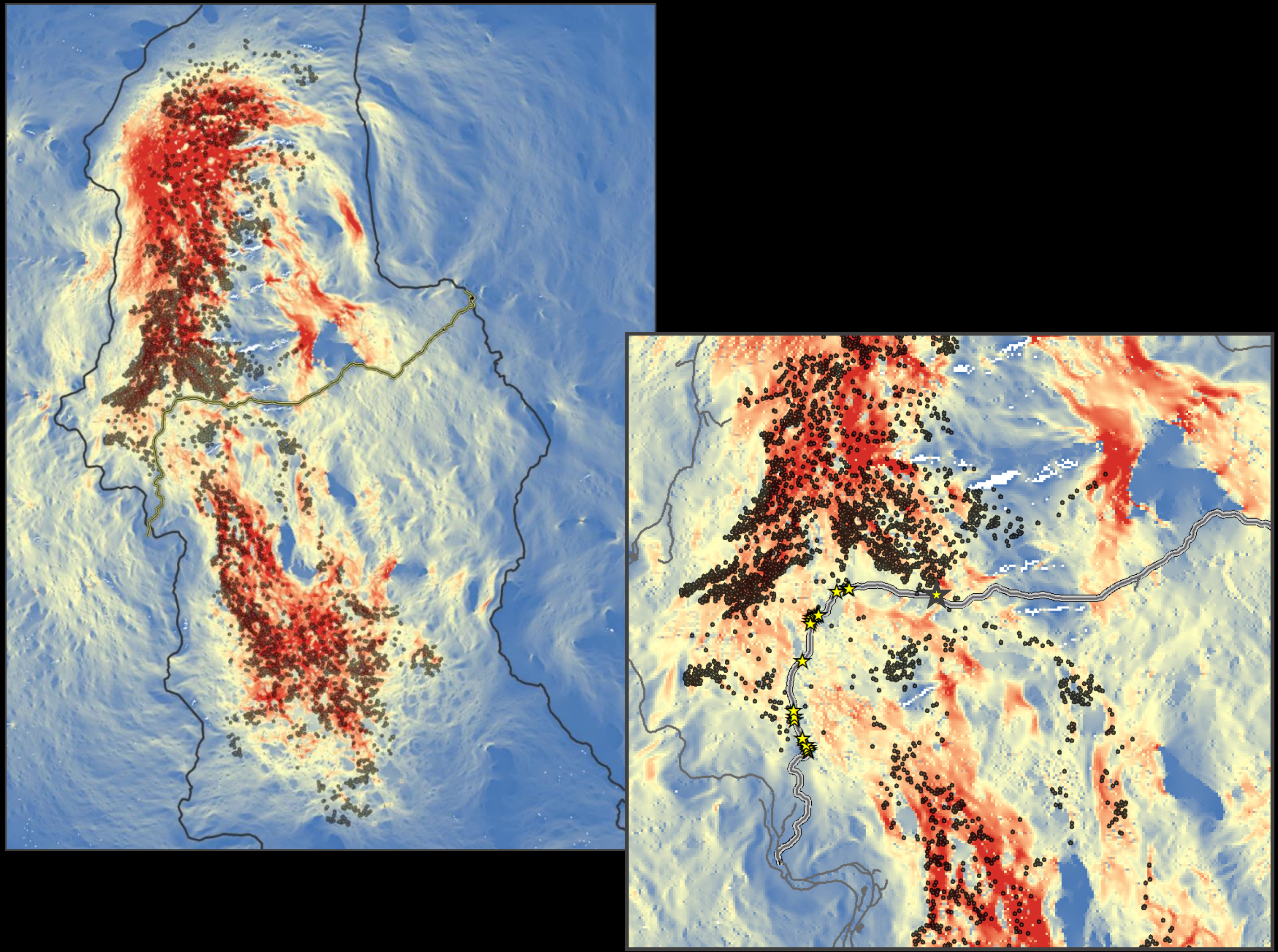
Panzacchi et al, J. Anim. Ecol. 2015

WE CAN PREDICT THE CORRIDOR-BARRIER *CONTINUUM* DURING MIGRATION

Highest probability of flow: **CORRIDOR**

0 *P*(flow): **BARRIER**

GPS locations



APPLICATIONS:

- Support sustainable land planning: forecast changes in movement routes following changes in infrastructure network
- Identify cost-efficient mitigation /defragmentation measures

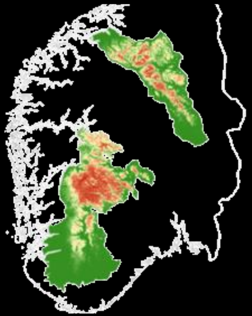
Panzacchi et al, J. Anim. Ecol. 2015

HOW CAN OUR PREDICTIONS BE USEFUL?

IN CONCLUSION, WE CAN PREDICT:

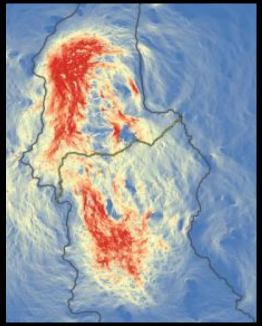
Effect of different types of disturbance

Where is optimal habitat



Where is it more difficult to move

Where are migration corridors



WE CAN PREDICT THE EFFECT ON REINDEER OF:

- CHANGES IN THE NETWORK INFRASTRUCTURES
- CHANGES IN LAND USE, CLIMATE
- MITIGATION- OFF-SET –MEASURES

⇒ **WE CAN ASSIST SUSTAINABLE LAND PLANNING,**

to allow reindeer and human to coexist in the future