Wolf pack rendezvous site selection in Greece is mainly affected by anthropogenic landscape features

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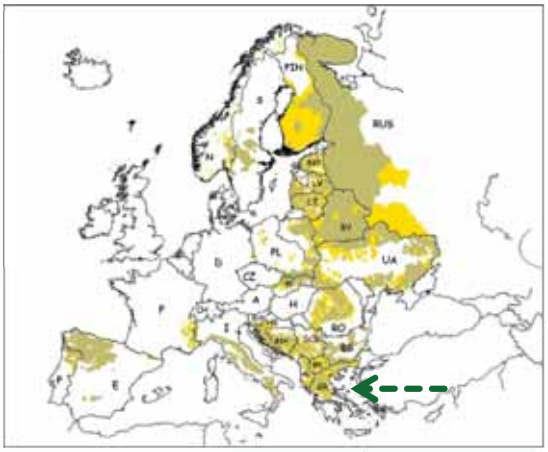
Wolf status and distribution in Greece.

- ✓Part of the "Dinaric" wolf
- ✓Population: 5000 ind.
(Salvatori & Linnell, 2008)



Map compilation from: (Salvatori & Linnell, 2008)

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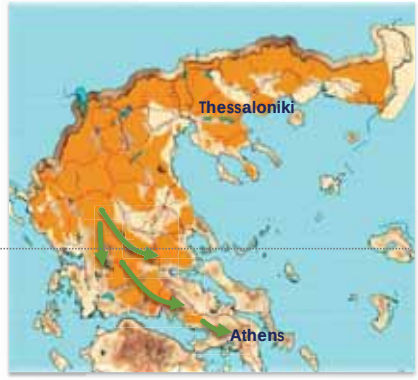
Wolf status and distribution in Greece.



- ✓ ~50.000km²
- ✓ Population size: ~100 wolf packs
(Iliopoulos et al., 1999,2000)
- ✓ Expanding since 80's
- ✓High dependence on livestock
- ✓High levels of conflict
- ✓Fully protected under 39o parallel (II, IV, 92/43)- rest in Annex V

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Rendezvous sites?

Rendezvous sites?

- ✓**Small areas, used after denning to gather & protect pups: (summer-autumn),** Packard et al 2003.
- ✓**Located a few hundred meters up to several kilometers from dens**
- ✓**Spend lot's of time there** (e.g Alfredeen, 2006)

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Why study /protect rendezvous sites?

Wolf population successful reproduction and recovery:

- **Resource availability** (e.g Fuller et al. 2003)
- **Human caused mortality** (e.g Liberg et al. 2011)
- **Wolf pack homesite location** (e.g Frame, 2008; Argue 2008, Nonaka, 2011)
- **Rendezvous sites**
- **Den sites**

Selection of RS is probably critical in "human dominated landscapes"

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Period of intense and repeatable R.S use, coincides with high human activity :

Free ranging livestock raising

Onset of wild boar hunting with "drive- hunts"

Encounter rates with shepherd dogs & humans increase

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Free ranging livestock raising activity:
Frequent killing of pups/young wolves by shepherd dogs
(Iliopoulos et al, 1998,1999,2000, Iliopoulos & Petridou 2012)

"Drive hunts": correspond to 42% of overall human-caused mortality
(Iliopoulos et al, 1998)

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Aims of the study:

✓ **1**. Test the hypothesis:

High mortality risk during RS occupancy, affect selection of RS's in a way to avoid human disturbance:

✓**2**. Identify the most important attributes:

- **Landscape,**
- **Resource availability**
- **Anthropogenic**

affecting rendezvous site selection at the :

a) **Regional scale**
b) **Home range scale** (Johnson , 1980)

✓**3. Create and test a "GIS-friendly" model to produce RS probability maps for monitoring & management purposes.**

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Study area

Surface:6.700km²

Altitudinal range : 100-2500m.

High diversity in land use types

Road density: 2.43 ± 0.63 km/km²

Livestock raising -Nomadic: May to October in higher altitudes

Average sheep/goat density : 67.21 head/ km²

Cattle :2.55/head/km²,

Free-ranging pigs: 2.9 heads/km².

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Methods: Surveying and locating "Rendezvous sites"

✓**Data collected during: 1998-2010:**

✓**RS's located with the simulated howling method** (Harrington & Mech, 1982)

✓**July-September when packs are sedentary** (Packard, 2003) **& distinction of pup howls feasible.**

✓**To avoid false-absence records** (Boyce et al., 2002):

▪**We enforced the method only in areas occupied by wolf packs, identified with a preliminary field census.**

Methods: Surveying and locating "Rendezvous sites"

After eliciting a wolf /pack response:

An area was characterized as a Rendezvous Site:

✓**Wolf pup response heard** (at least twice), n=29

✓Only adult wolves heard but **pup presence verified** (capture, camera traps, dead pups) n = 6 cases

✓Neighboring RS **were distinguished by repeating protocol** the same night in both areas.

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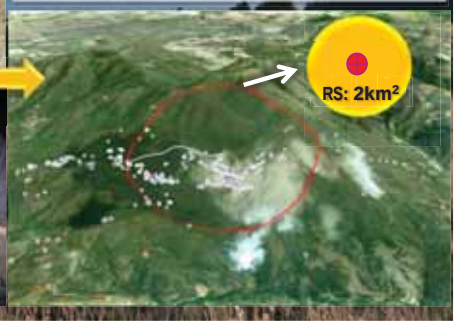
Methods: Surveying and locating "Rendezvous sites"

Rendezvous sites were considered circular surfaces of 2 km²

RS surface aver. = 2.2 ± 0.39 km²
(n=8 radio-collared wolves)



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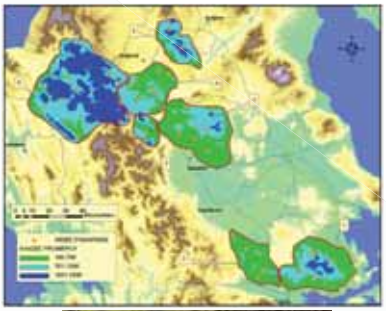
LANDSCAPE SCALE ANALYSIS: Explanatory Variables used



1.Altitude (3 classes):
(100-500) (501-800) (801-1200) (1201-2500) m Quantile classification

2.CORINE land use (6 classes):

✓ **Evergreen scrubland**
✓**Deciduous forests**
✓**Conifer forests**
✓**Transition scrubland to forest**
✓**Mixed agricultural-forest scrublands**
✓**Natural Grasslands**

3.Livestock density (3-classes)

A:(0-32 head /km²) B: (33-79 head/km²) C: (>80 head /km²), Quantile classification

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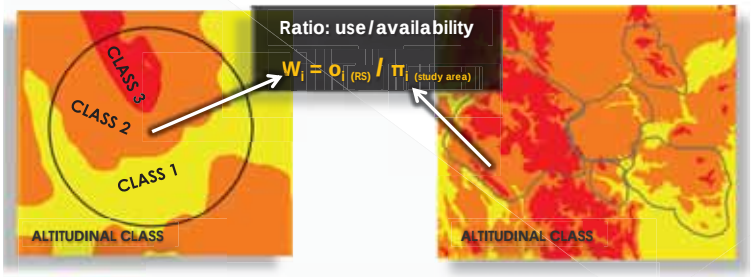
LANDSCAPE SCALE: Statistical analysis

For each variable class we compared use at RS vs. availability at the study area : Selection ratio W_i (Manly et al., 2002)



W_i >1 : preference W_i <1 : avoidance

o **Tested for significance with Bonferroni –corrected confidence intervals** (Manly et al., 2002; Rodgers and White, 2007)**:** $W_i \pm z_{\alpha/(2l)}\, SE\,(W_i)$

HOME RANGE -SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates

1. Human infrastructure group

- ✓Distance from center of site to **nearest village** (m):
CLASS 1 (1000-2120m), CLASS 2 (2121-2880m), CLASS 3 (>2880m),
- ✓**Forest road length** inside site (m)
- ✓**Distance** from center of site **to roads** (m)
- ✓**Distance from nearest active farms** (m)
- ✓**Distance from protected area** (m)

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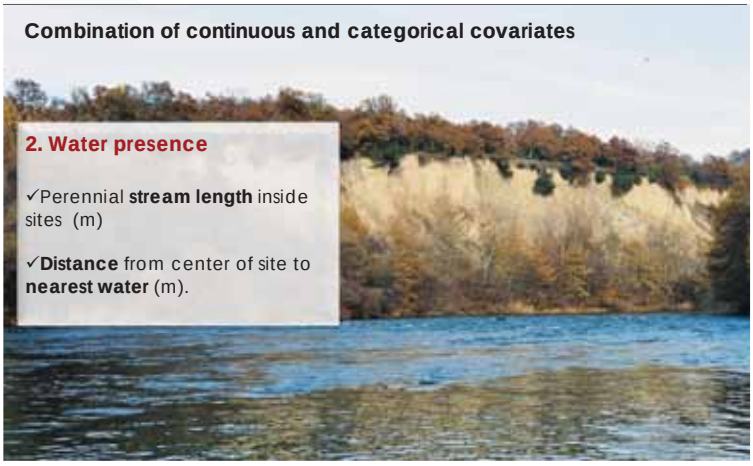
HOME RANGE SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates



2. Water presence

- ✓Perennial **stream length** inside sites (m)
- ✓**Distance** from center of site to **nearest water** (m).

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HOME RANGE SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates

3. Vegetation structure and form

- ✓% Forest cover
- ✓% high visibility forest-scrubland
- ✓% mature forest
- ✓% young scrubland – forest
- ✓% non forested area
- ✓% mixed forest
- ✓% deciduous forest
- ✓% evergreen forest
- ✓ Shannon diversity index for Corine landuse types.

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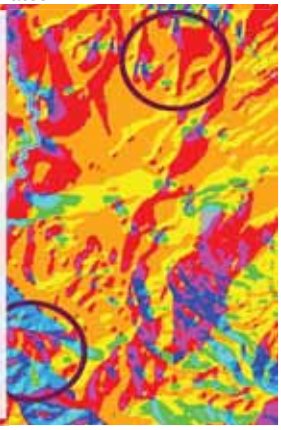
HOME RANGE SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates

4. Topographic characteristics

- ✓**Altitude**: range (m) & median (m)
- ✓% flat
- ✓% north
- ✓% east
- ✓% south
- ✓% west
- ✓**Aspect**: Shannon diversity index
- ✓**Slope** (degrees): average & SD
- ✓**Visibility** from site periphery - sum of values
- ✓**Cumulative solar radiation**
- ✓**Hillshade**: Average, SD & Sum of values
- ✓**Profile curvature**: Aver. SD & Sum of values



HOME RANGE SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates

5. Forest Fragmentation groups

- ✓**NUMP**- Number of forest fragments
- ✓**MPI** – Mean proximity index
- ✓**TE**, Total edge (m)
- ✓**ED**, Edge density
- ✓**AWMSI**- Area weighted mean patch fractal dimension
- ✓**TCA**- Total core area
- ✓**CAD**- Core area Density
- ✓**MCA**-Mean core area
- ✓**TCAI**- Total core area index

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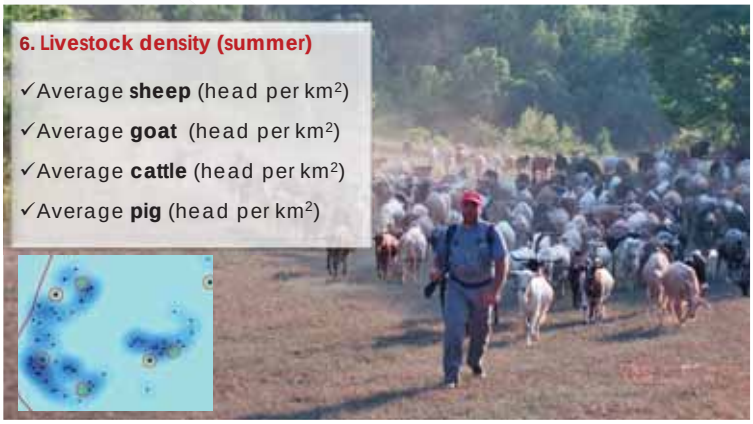
HOME RANGE SCALE ANALYSIS: Explanatory Variables used

Combination of continuous and categorical covariates

6. Livestock density (summer)

- ✓Average **sheep** (head per km^2)
- ✓Average **goat** (head per km^2)
- ✓Average **cattle** (head per km^2)
- ✓Average **pig** (head per km^2)



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HOME RANGE SCALE : Statistical analysis

Binary Logistic regression (Hosmer & Lemeshow, 2000,)

✓**Compare RS sites (used) with control sites (non-used) - (<5km from RS)**

✓**Each RS site was entered the analysis ONCE (even if re-used the following years)**

✓**Robustness evaluation: Field test in an "out of sample area" under same field protocol.**

✓***Covariate selection: remove gradually covariates with lowest b/SE ratio until no further improving of model performance*** *(Arnold et al, 2010).*
✓***Reduce multicollinearity effects: Pearson's r between covariates < |0.5|***
✓***Model selection: most parsimonious, highest overall % prediction power, largest diagnostic R^2***
✓**Performance evaluation: Estimation of AUC (area under curve)**

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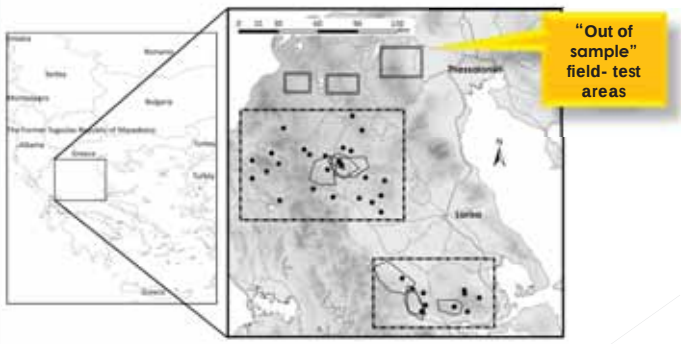
Results: Rendezvous sites located and packs involved



✓**Located: 40 RS (33 packs):**
✓ **Analysis: 35 RS**
✓ **30 wolf packs (~30% total Greek population)**

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Results- Landcape scale

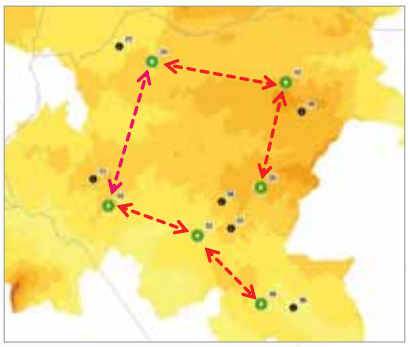
Spacing of RS

Average nearest inter-rendezvous site distance:

✓ D_{st} = **12.9 ± 1.7 (SD) km** (11.4 – 16.6), (n=12 neighboring pairs located the same summer)

✓**Low variation**

✓ **Not differed between sub portions of the study area (n = 4)** (Kruskal Wallis test, H= 2.68. d.f = 3, exact P = 0.509)



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Results- Selection of RS at the landscape scale

				Bonferroni CCI		
		W_i	SE (W_i)	Lower	Upper	Sign.
	Habitat type					
Non significant Preference	Evergreen scrubland	1.38	0.31	0.63	2.13	ns
	Deciduous forest	1.27	0.31	0.52	2.03	ns
	Conifers	1.22	0.36	0.36	2.07	ns
	Transitional scrubland	0.79	0.22	0.27	1.31	ns
Significant Avoidance	Natural grassland	0.57	0.17	0.15	0.99	<1
Significant Avoidance	Agricultural/forest-mix	0.52	0.16	0.14	0.90	<1
	Altitudinal zone					
	0-500 m	0.86	0.20	0.41	1.31	ns
Non significant Preference	501-800 m	1.37	0.23	0.87	1.88	ns
	801-1200 m	1.26	0.28	0.63	1.88	ns
Significant Avoidance	>1201 m	0.20	0.32	-0.51	0.92	<1
	Summer livestock density zone					
	0-32 head/km²	0.95	0.21	0.49	1.40	ns
	33-79 head/km²	1.09	0.22	0.63	1.55	ns
	>80 head/km²	0.96	0.24	0.47	1.47	ns

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Results- Selection of RS at the homerange scale

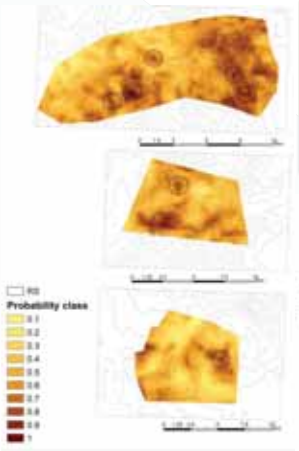
Logistic regression results:

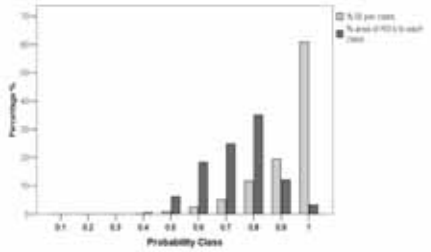
						95.0% CI	
Covariates	Coeff. b	SE	R	p	Odds ratio	lower	Upper
Distance from forest roads (m)	0.004	0.001	0.232	0.007	1.004	1.001	1.006
Distance from water (m)	-0.002	0.001	-0.209	0.012	0.998	0.997	1.000
Total core area index (TCAI)	0.060	0.027	0.172	0.040	1.062	1.007	1.121
Distance from nearest village (CLASS 3: >2880M	1.372	0.668	0.151	0.019	3.945	1.066	1.601
Constant	-4.829	2.057	0.190	0.008			

Model χ^2 (Hosmer and Lemeshow test) = 2.758, df=8, p=0.949;
R^2 (Nagerkelke) = 0.405]

✓**AUC: (0.818, SE = 0.051): "useful application"** (see Boyce et al., 2002)
✓**Predicted 80% of RS sites**

Results- Selection of RS at the homerange scale> model robustness





✓ **7 new RS located in the "out of sample" areas in 2011.**

✓**Average suitability of RS : 0.736 ± 0.096 (SD), range = 0.6-0.86)**

✓**Predominant class of RS : 0.8 probability class**

Results- Selection of RS at the homerange scale

Reuse of Rendezvous sites

✓ **Reuse patterns of 10 RS sites was monitored from 2 to 6 years** (not consecutively in all cases)

✓ **Reuse was observed in 80% of cases checked**

✓**Long term reuse stopped after breeder loss**

✓**Reuse was recorded even after long periods (e.g form 4 to 12 years)**

Discussion > Selection at the landcape scale > resources

✓ **Wolves avoided high livestock availability zone (>1200m) & selected lower altitudes.**

✓**Although proximity to resources is beneficial for pup survival,**
✓**no direct links with RS location and food abundance** (e.g. Heard and Williams 1992; Heard et al. 1996; Frame et al. 2008)

✓**Preference for areas that offer greater stability of resources year round (e.g 500-800 zone)** (Ciucci & Mech, 1992).

Discussion> Selection In the landcape scale> spacing

✓ **Wolf packs established RS spaced in relatively large distances with low variability** (also in Capitani et al., 2006)

✓**Appropriate spacing reduces inter-pack aggression &**

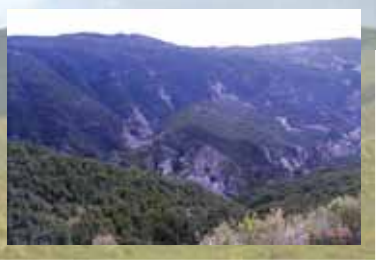
✓**Combines well with optimum distance to scattered food resources**
(Mech et al. 1998; Mech and Harper 2002)

Discussion> Selection at the landcape scale> habitat

✓ **Avoided open areas or semi opened areas -even when latter predominate** (e.g Cortes 2001)

✓**No specific habitat selection (widespread species) but some preference on thick evergreen scrublands when available:**

✓**excellent hiding cover** (like young forests selected in Finland, Kaartinen et al., 2010)



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Discussion> Selection at the home range scale > human disturbance

✓ **Forest road proximity to RS emerged as the most influential covariate (negative effect)**
(also in Italy, Poland e.g Ciucci et al. 1997; Capitani et al. 2006, Theuerkauf et al. 2003)

✓**Forest roads are directly linked to human disturbance**

✓**Although experimentally disturbed wolves and pups at homesites often abandon them** (e.g Frame et al. 2007; Argue 2008; Habib and Kumar 2008; Nonaka, 2011)

✓**They usually re-used them** (Frame et al. 2007; Argue et al. 2008, Person and Russel 2009).

✓**In Greece forest roads are directly linked not only to disturbance but to direct killing of wolves with drive- hunts:** (Iliopoulos, 1998, or at Poland Jedrzejewska, 1996,):

✓**Greatly facilitated by forest roads** (scouting for wolves, access, organize)

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Discussion> Selection at the home range scale > human disturbance

✓ **Wolves selected positively for RS at the most distant VILLAGE- class** (like in Italy, Poland) e.g Capitani et al. 2006, Theuerkauf et al. 2003

✓**Less important covariate as wolves seek food close to villages (livestock, carcasses).**

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Discussion> Selection at the home range scale> human disturbance & fragmentation

✓**Wolves selected for the least fragmented forest patches, which provide:**
✓**More difficult access &**
✓**Easier auditory detection of intruders** (Wam 2003; Karlsson et al. 2007).

Discussion> Selection at the home range scale> water

✓**Wolves select RS closer to water:** was the second most important factor (also in other areas e.g Unger et al. (2009); Ausband et al.,2010).

✓**Reduce need for pups to travel long distances and exposed to fatal danger**

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Discussion> Selection at the home range scale > reuse

✓**Rendezvous site were rather "traditional"**
✓**Some reuses after many years from initial use (e.g 12 years)**

✓**Associated with breeder persistence** (Capitani et al., 2006)
✓**Proximity to important or limited resources** ((Ballard and Dau 1983; Ciucci and Mech 1992).

Both hypothesis seem valid:

✓**Breeder losses ceased occupancy of long term-used RS**
✓**Undisturbed core areas (above 0.8 probability) was a limited resource as:**
✓**Prediction maps showed to be less than 10%**

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Discussion> Selection at the home range scale> management implications

RS suitability prediction maps could be used:

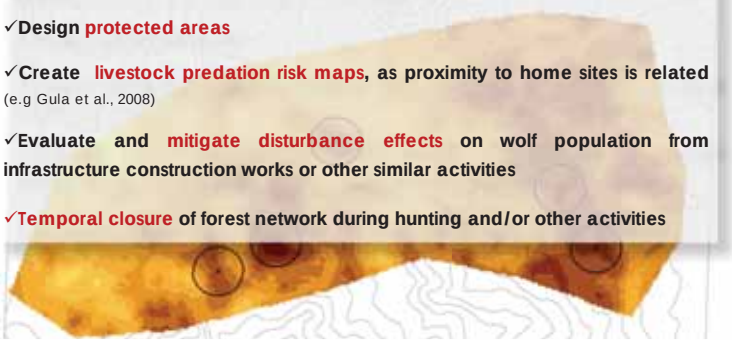
✓**Facilitate monitoring especially with genetic analysis by reducing field efforts** (e.g Ausband et al. 2010; Stenglein et al. 2010).

✓**Design protected areas**

✓**Create livestock predation risk maps, as proximity to home sites is related** (e.g Gula et al., 2008)

✓**Evaluate and mitigate disturbance effects on wolf population from infrastructure construction works or other similar activities**

✓**Temporal closure of forest network during hunting and/or other activities**



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http://link.springer.com/article/10.1007%2Fs10344-013-0746-3


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