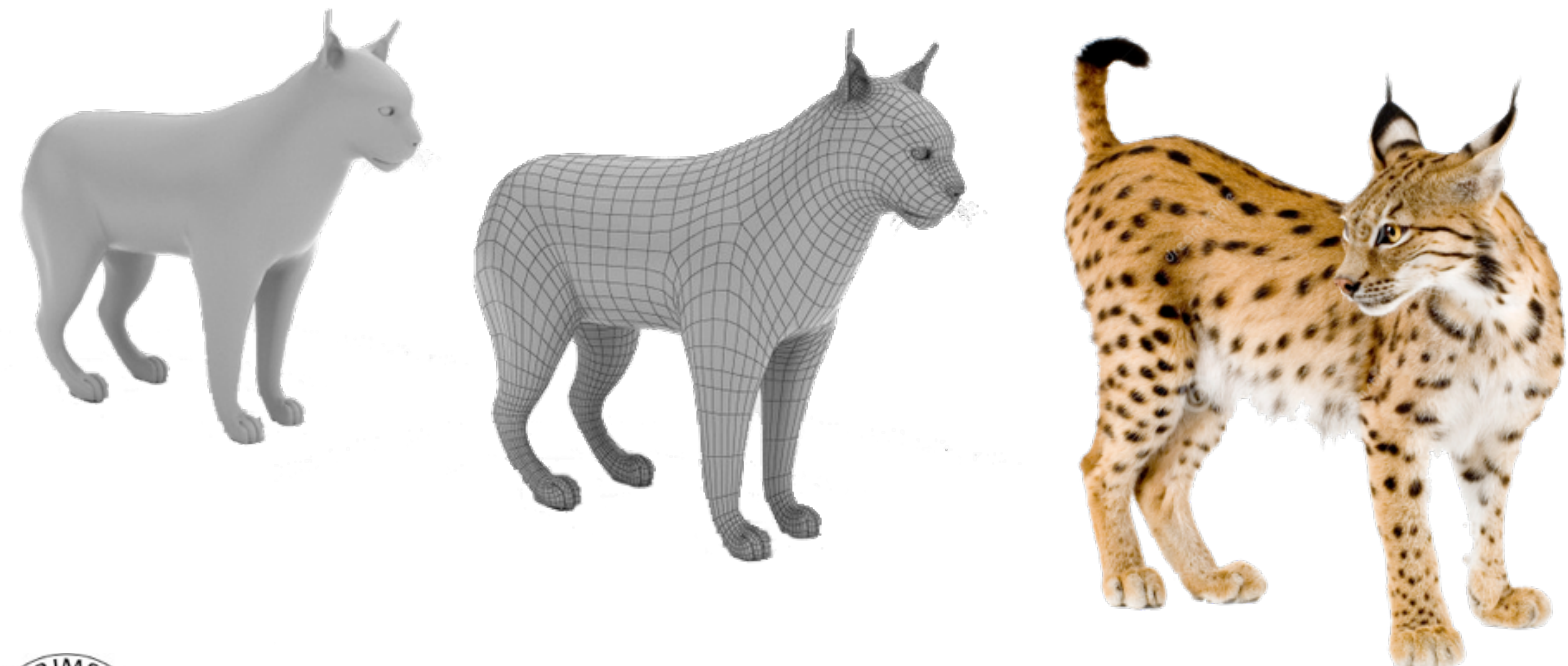
CIBIO – Managing large-carnivores in a crowded Europe

USING MODELS TO CONSERVE LARGE CARNIVORES



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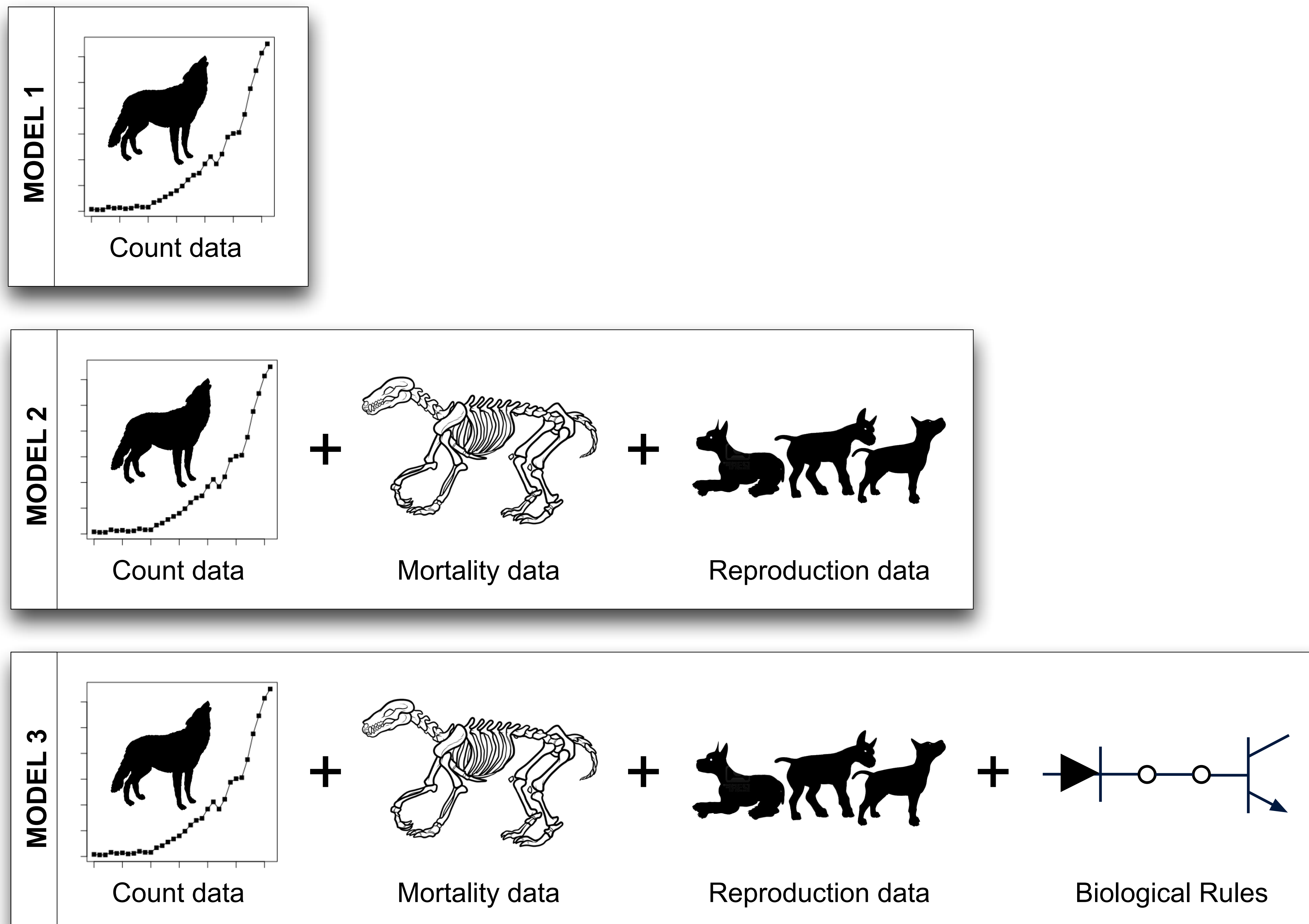
WHAT IS A MODEL?

Population models

- Mathematical formalization of demographic processes
- Explain past demographic trends, project future ones under different management strategies

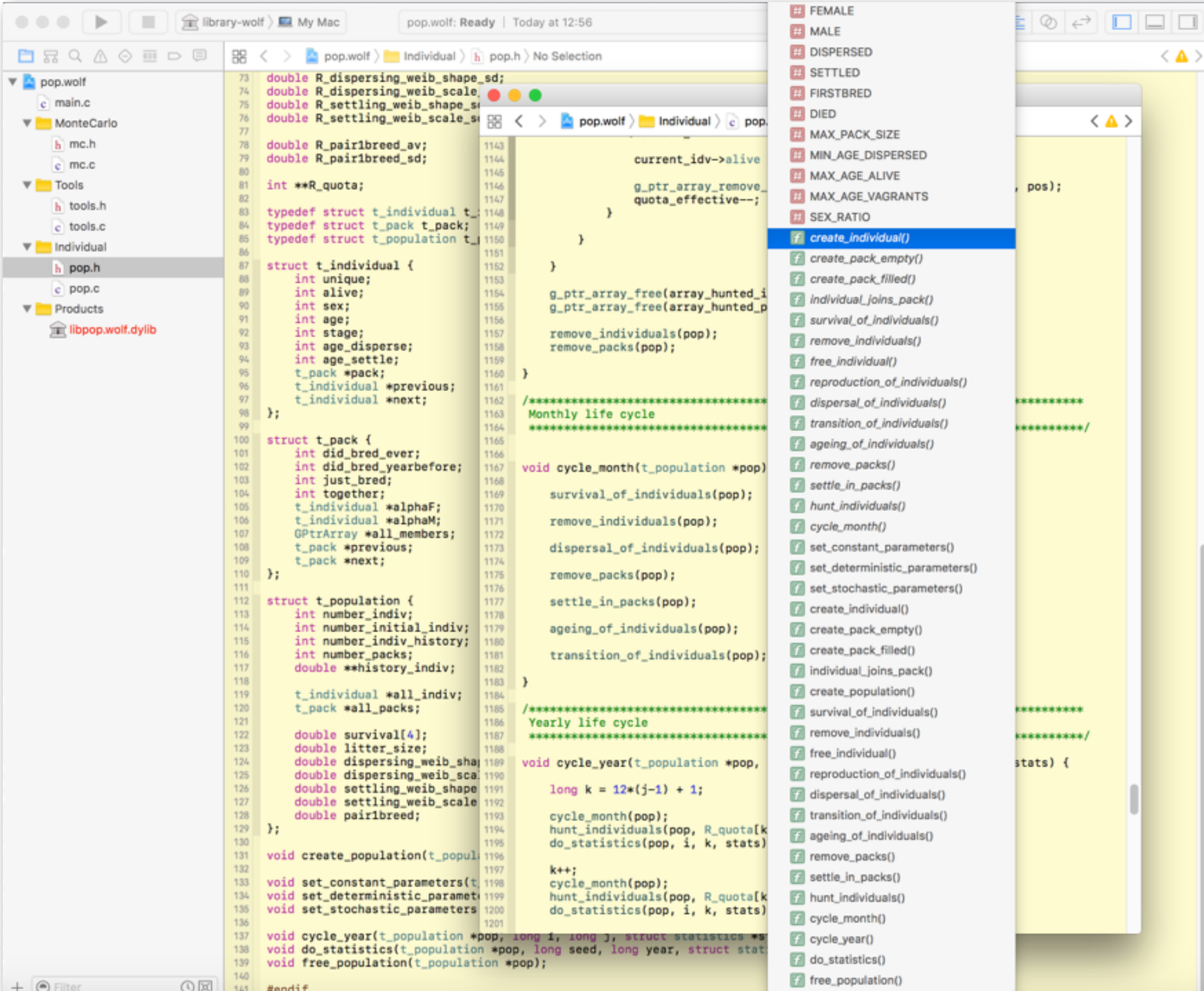
What kind of models?



ESTIMATE POPULATION SIZE

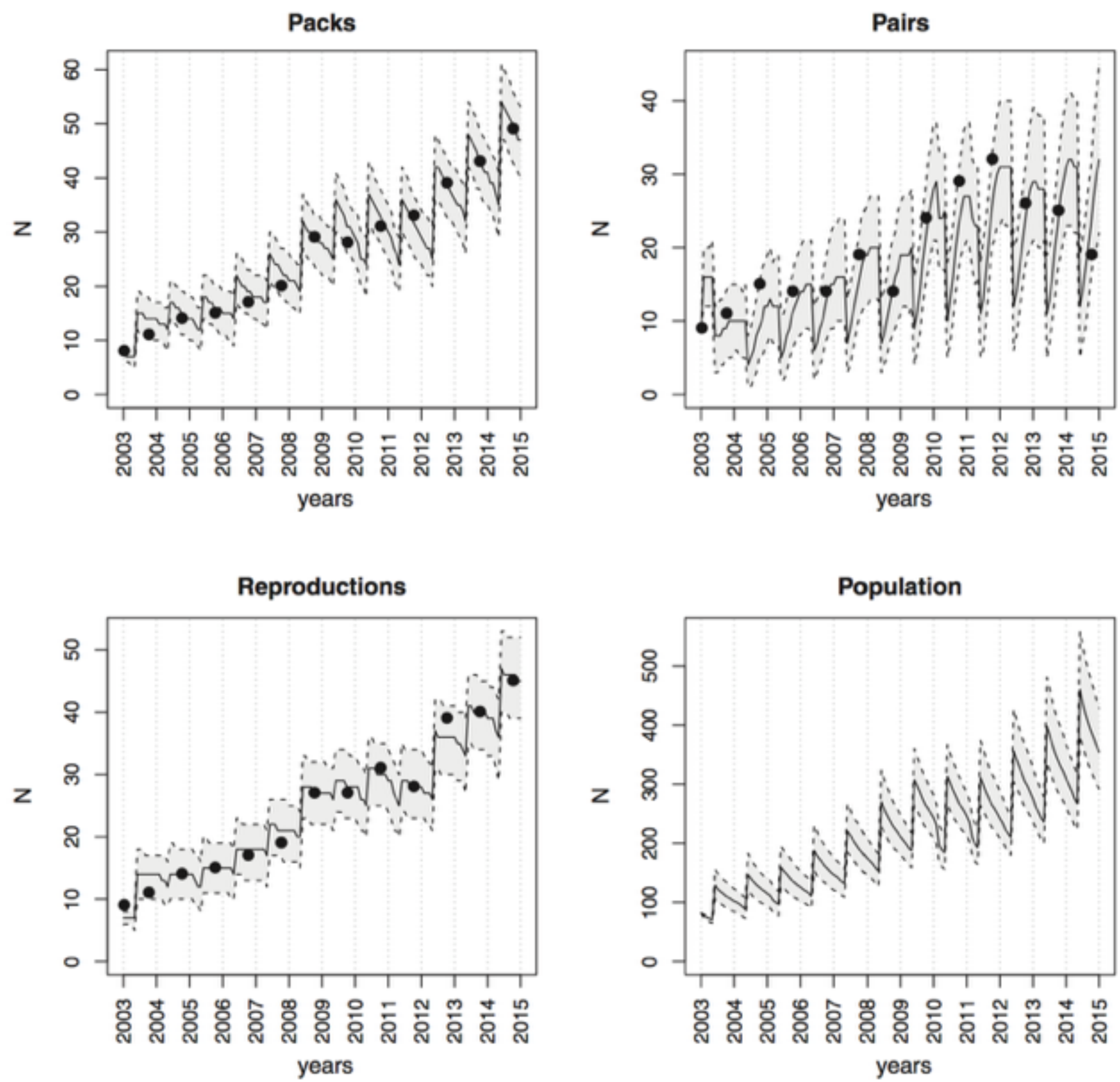
How many wolves in Sweden?

- Monitoring of packs, pairs and reproductions but total population estimates required
- Develop a complex wolf specific individual based model
- We fit the model to monitoring data and the model also gives us total number of wolves
- We estimate a conversion factor from number of packs to number wolves

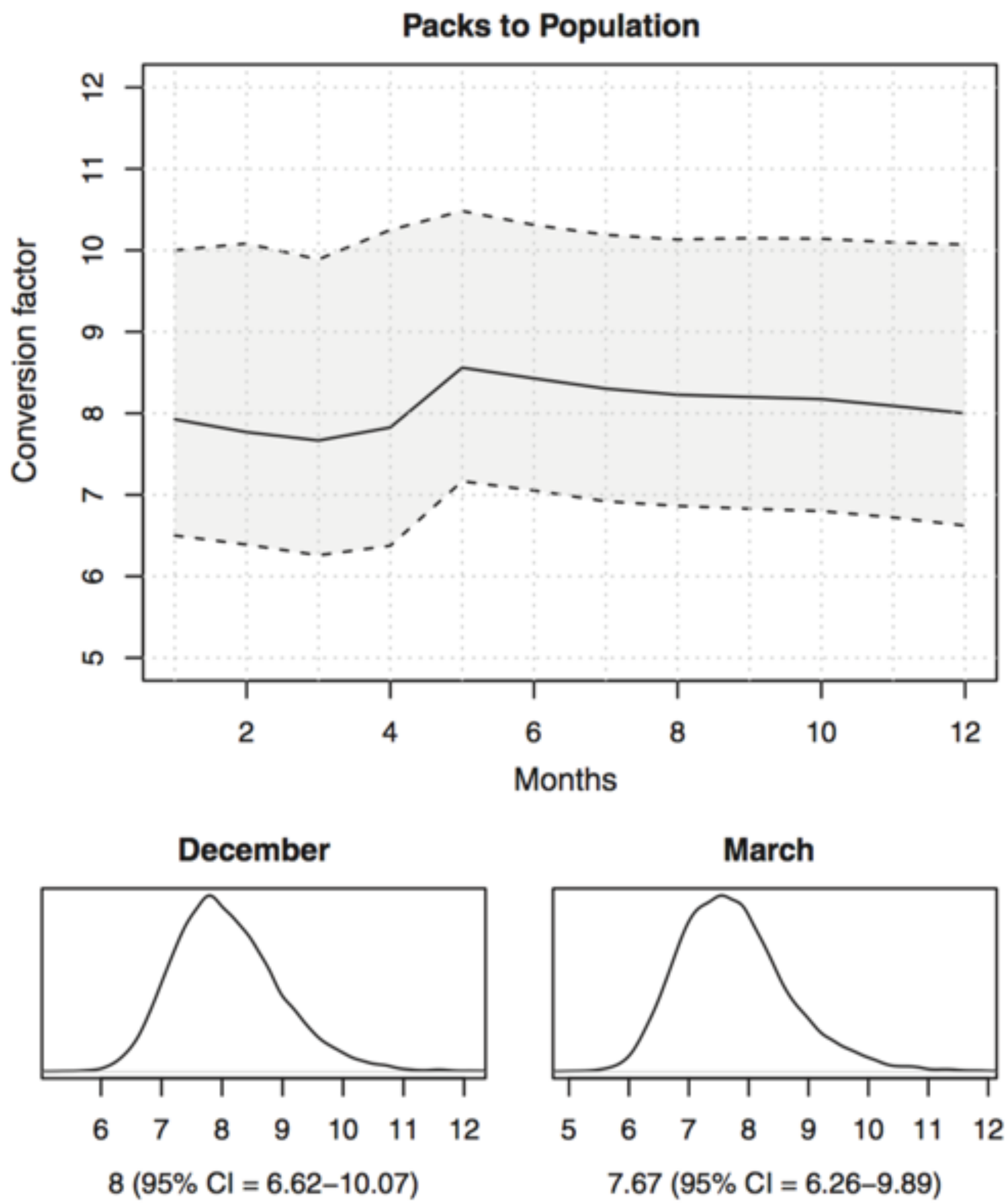


library-wolf
My Mac
pop.wolf: Ready | Today at 12:56
pop.wolf
main.c
MonteCarlo
mc.h
mc.c
Tools
tools.h
tools.c
Individual
pop.h
pop.c
Products
libpop.wolf.dylib
Filter
pop.wolf › Individual › pop.h › No Selection
double R_dispersing_weib_shape_sd;
double R_pair1breed_av;
double R_pair1breed_sd;
int **R_quota;
typedef struct t_pack t_pack;
struct t_individual {
int unique;
int alive;
int sex;
int age;
int stage;
int age_disperse;
int age_settle;
t_pack *pack;
t_individual *previous;
t_individual *next;
};
struct t_pack {
int did_bred_ever;
int did_bred_yearbefore;
int just_bred;
int together;
t_individual *alphaF;
t_individual *alphaM;
GPtrArray *all_members;
t_pack *previous;
t_pack *next;
};
struct t_population {
int number_indiv;
int number_initial_indiv;
int number_indiv_history;
int number_packs;
double **history_indiv;
t_individual *all_indiv;
t_pack *all_packs;
double survival[4];
double litter_size;
double pair1breed;
};
void free_population(t_population *pop);
#endif
pop.wolf › Individual › pop.
current_idv->alive
quota_effective--;
remove_individuals(pop);
remove_packs(pop);
Monthly life cycle
void cycle_month(t_population *pop)
survival_of_individuals(pop);
remove_individuals(pop);
dispersal_of_individuals(pop);
remove_packs(pop);
settle_in_packs(pop);
ageing_of_individuals(pop);
transition_of_individuals(pop);
Yearly life cycle
void cycle_year(t_population *pop,
long k = 12*(j-1) + 1;
cycle_month(pop);
do_statistics(pop, i, k, stats)
k++;
cycle_month(pop);
do_statistics(pop, i, k, stats)
FEMALE
MALE
DISPERSED
SETTLED
FIRSTBRED
DIED
MAX_PACK_SIZE
MIN_AGE_DISPERSED
MAX_AGE_ALIVE
MAX_AGE_VAGRANTS
SEX_RATIO
create_individual()
create_pack_empty()
create_pack_filled()
individual_joins_pack()
survival_of_individuals()
remove_individuals()
free_individual()
reproduction_of_individuals()
dispersal_of_individuals()
transition_of_individuals()
ageing_of_individuals()
remove_packs()
settle_in_packs()
hunt_individuals()
cycle_month()
set_constant_parameters()
set_deterministic_parameters()
set_stochastic_parameters()
create_individual()
create_pack_empty()
create_pack_filled()
individual_joins_pack()
create_population()
survival_of_individuals()
remove_individuals()
free_individual()
reproduction_of_individuals()
dispersal_of_individuals()
transition_of_individuals()
ageing_of_individuals()
remove_packs()
settle_in_packs()
hunt_individuals()
cycle_month()
cycle_year()
do_statistics()
free_population()

Fit model to data



Conversion factors



CRAN - Package pop.wolf

https://cran.r-project.org/web/packages/pop.wolf/index.html

pop.wolf: Models for Simulating Wolf Populations

Simulate the dynamic of wolf populations using a specific Individual-Based Model (IBM) compiled in C.

Version:	0.1
Depends:	parallel, abind
Published:	2016-04-06
Author:	Guillaume Chapron [aut, cre], Camilla Wikenros [ctb], Olof Liberg [ctb], Øystein Flagstad [ctb], Cyril Milleret [ctb], Johan Månsson [ctb], Linn Svensson [ctb], Barbara Zimmermann [ctb], Mikael Åkesson [ctb], Petter Wabakken [ctb], Håkan Sand [ctb]
Maintainer:	Guillaume Chapron <guillaume.chapron at slu.se>
BugReports:	NA
License:	GPL-3
URL:	NA
NeedsCompilation:	yes
CRAN checks:	pop.wolf results

Downloads:

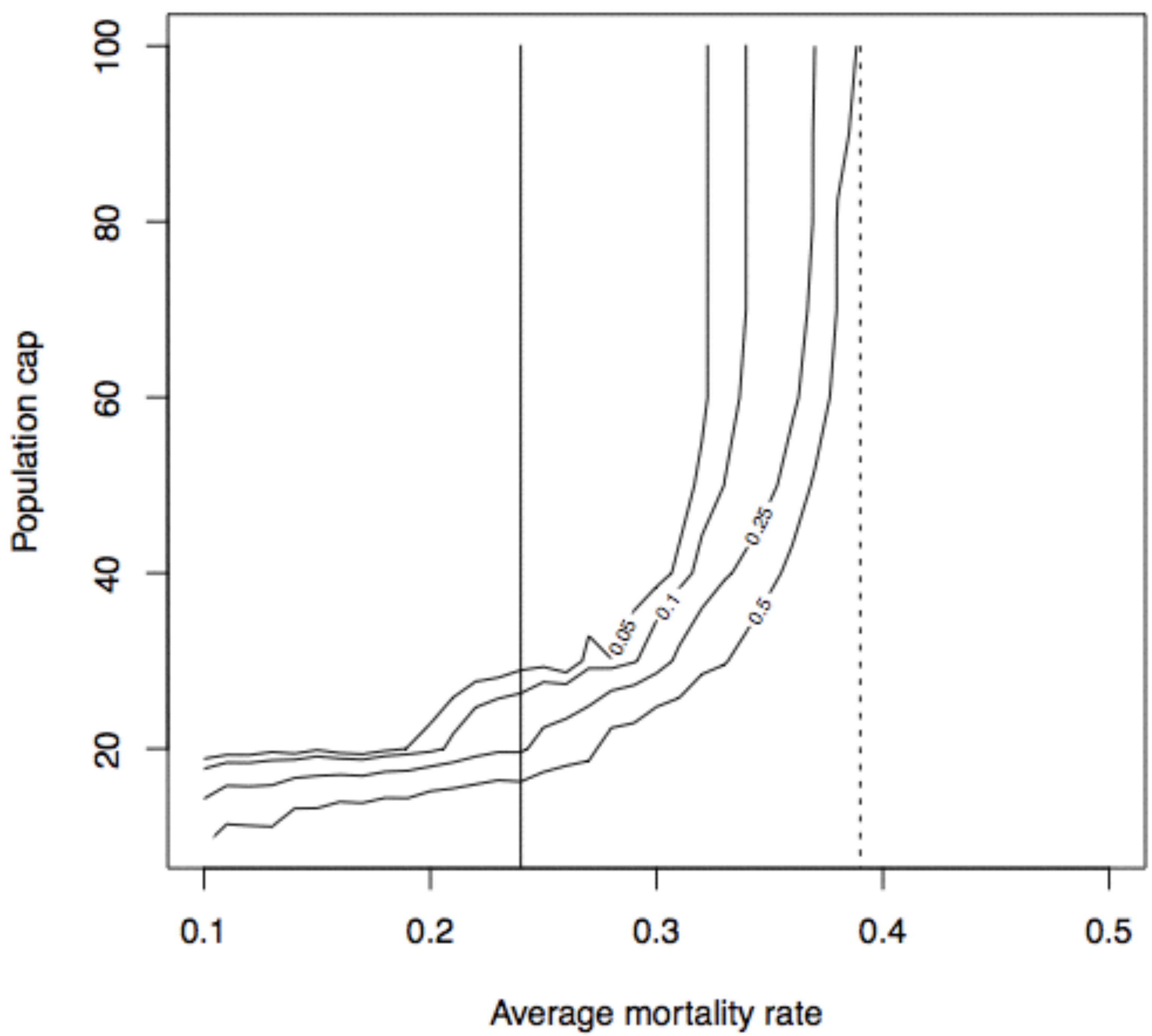
Reference manual:	pop.wolf.pdf
Package source:	pop.wolf_0.1.tar.gz
Windows binaries:	r-devel: pop.wolf_0.1.zip, r-release: pop.wolf_0.1.zip, r-oldrel: pop.wolf_0.1.zip
OS X Mavericks binaries:	r-release: pop.wolf_0.1.tgz, r-oldrel: pop.wolf_0.1.tgz

ESTIMATE POPULATION VIABILITY

How many animals are needed?

- Calculate the extinction probability during a given period of time
- Dependent on parameter estimates

Minimum Viable Population



ESTIMATE HIDDEN PARAMETERS

Estimates of poaching

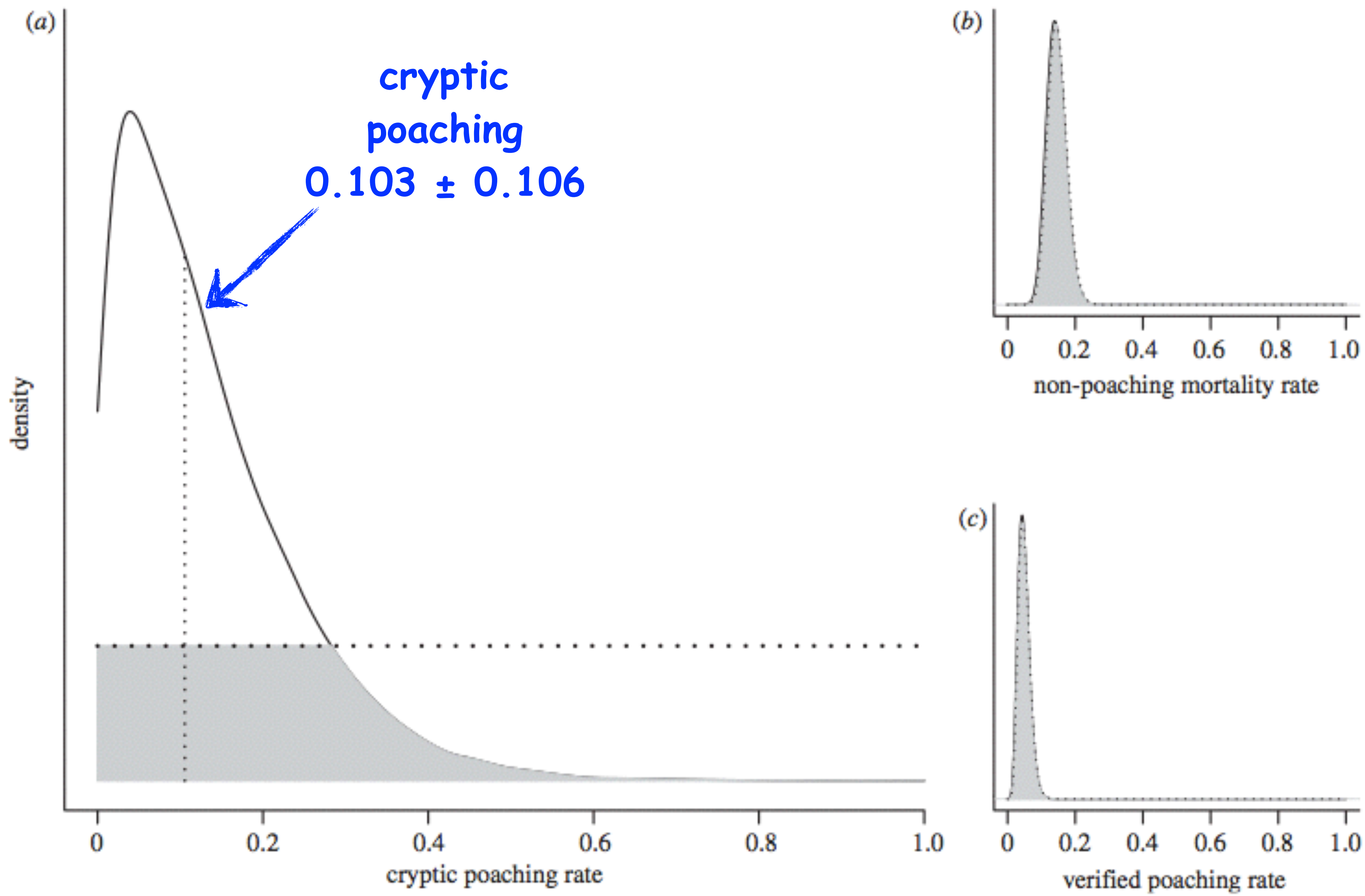
- Believed to be widespread, despite animal species are protected
- Very few robust quantitative data on most species
- Radio-tracking is of limited use because of strong incentive to conceal evidence
- So, how can we quantify something un-observable?

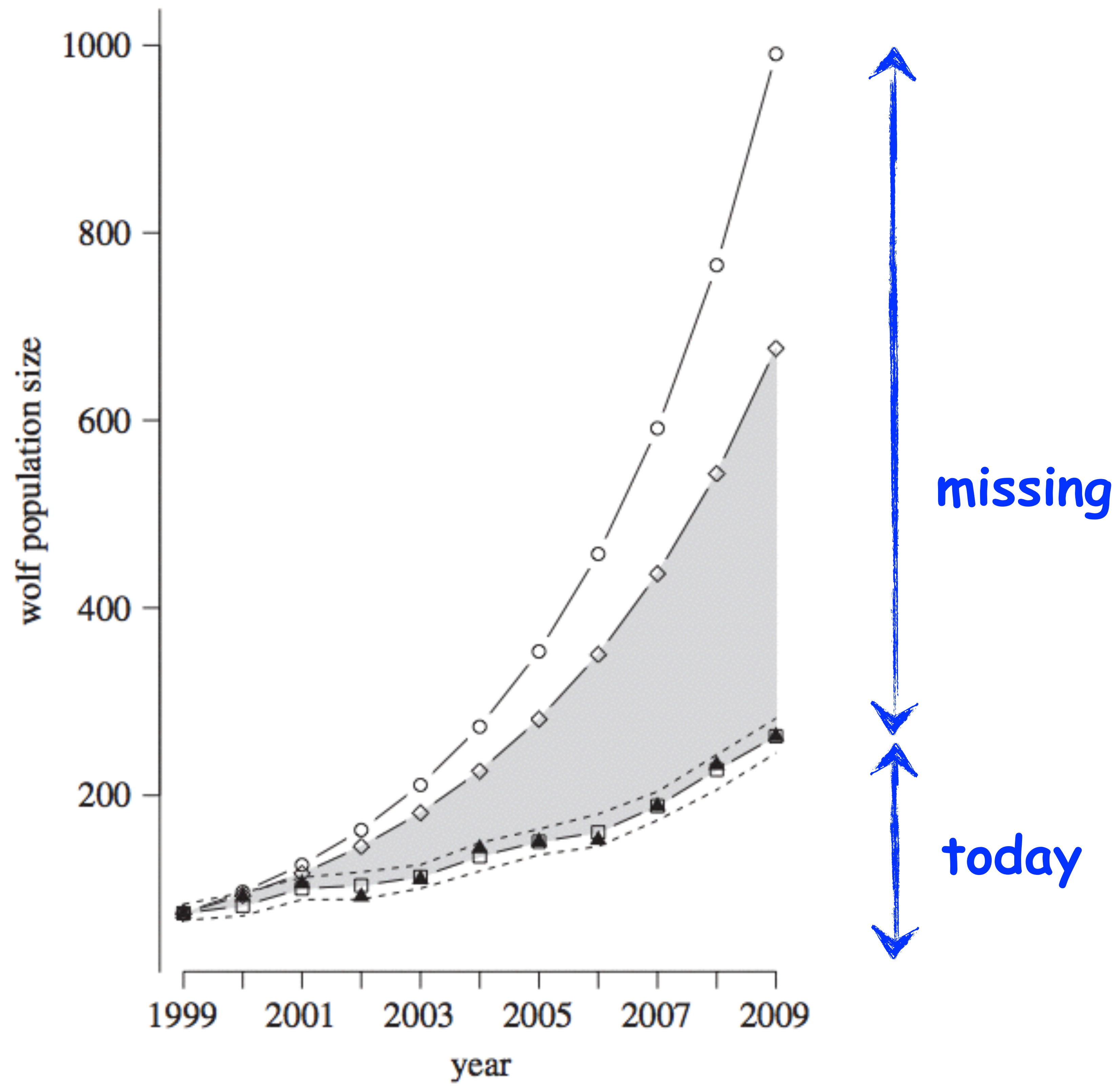
mortalities reproductions

$$\mu_t = \log\left[N_{t-1}\left(1 - m - v - c\right) + lR_{t-1}\right]$$

$$N_t \sim \text{lognormal}\left(\mu_t, \sigma_{proc}\right)$$

population size stochastic process


(a)
cryptic
poaching
0.103 ± 0.106
density
0
0.2
0.4
0.6
0.8
1.0
cryptic poaching rate
(b)
0
0.2
0.4
0.6
0.8
1.0
non-poaching mortality rate
(c)
0
0.2
0.4
0.6
0.8
1.0
verified poaching rate

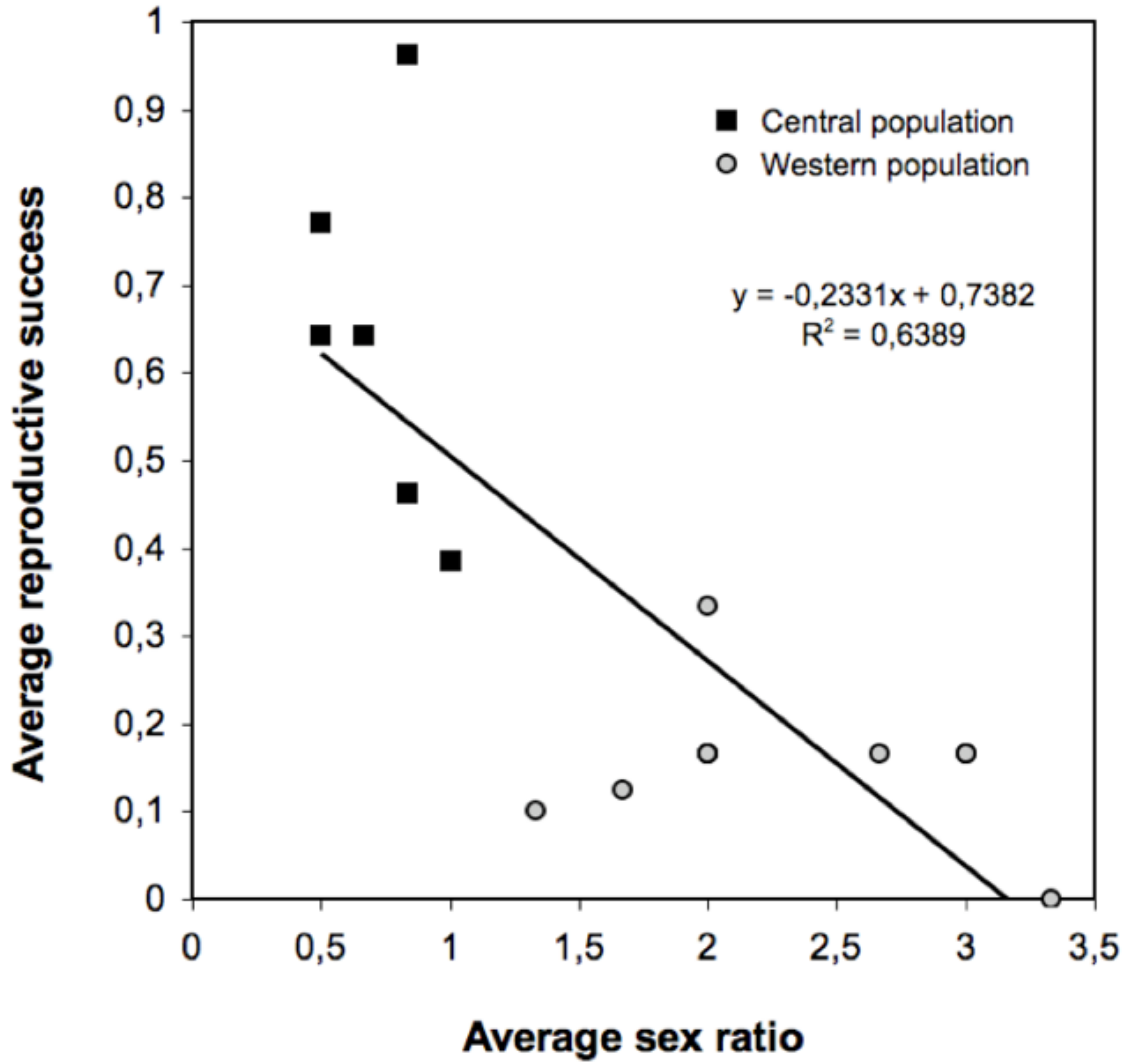


1000
800
600
400
200
wolf population size
1999
2001
2003
2005
2007
2009
year
missing
today

UNDERSTAND BEHAVIOUR

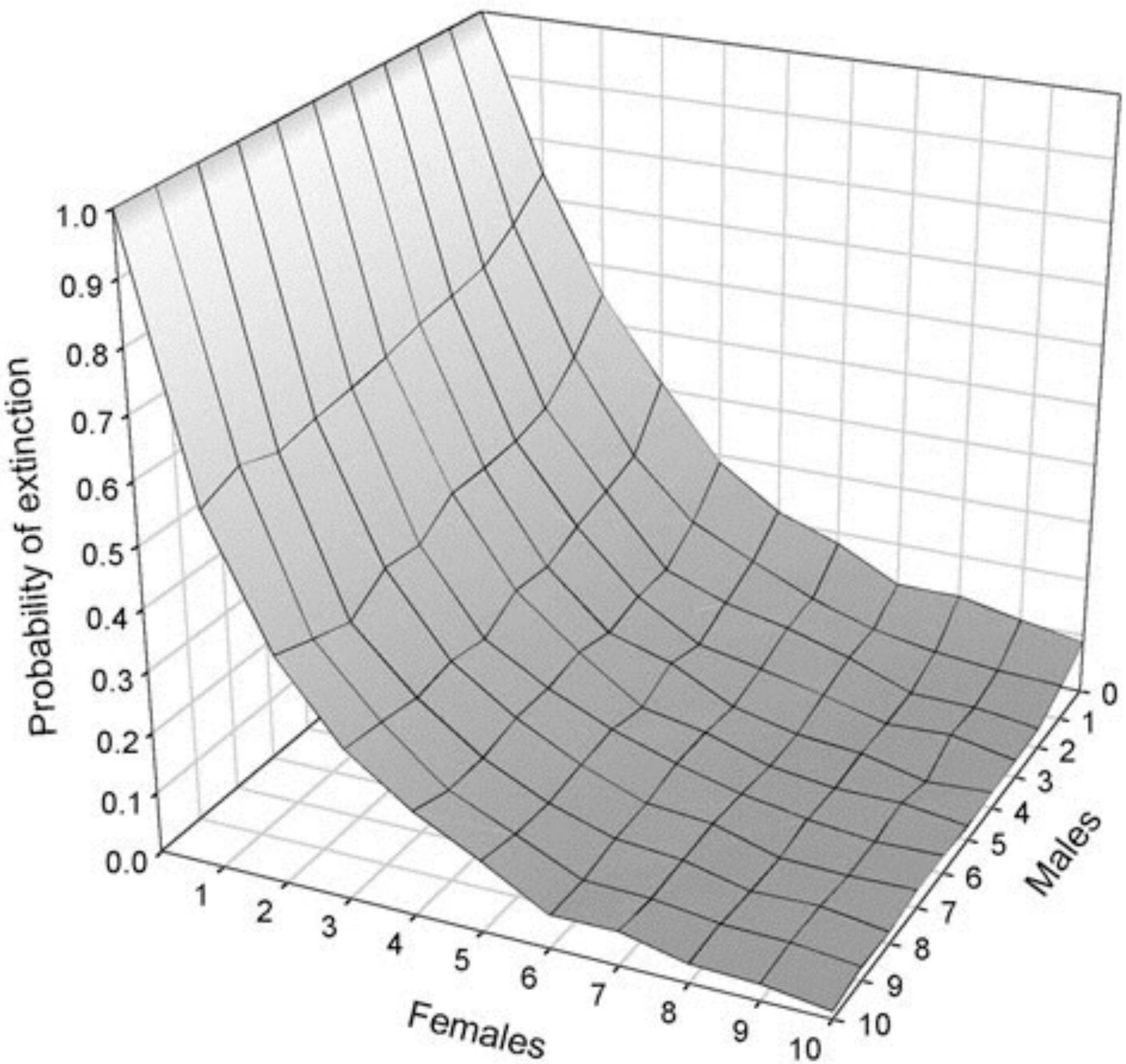
Behaviour & reintroduction

- The brown bear population in the French Pyrénées is not viable
- Reproductive success is influenced by sex-ratio due to sexually selected infanticide
- How does this behaviour affect the number of bears to reintroduce?



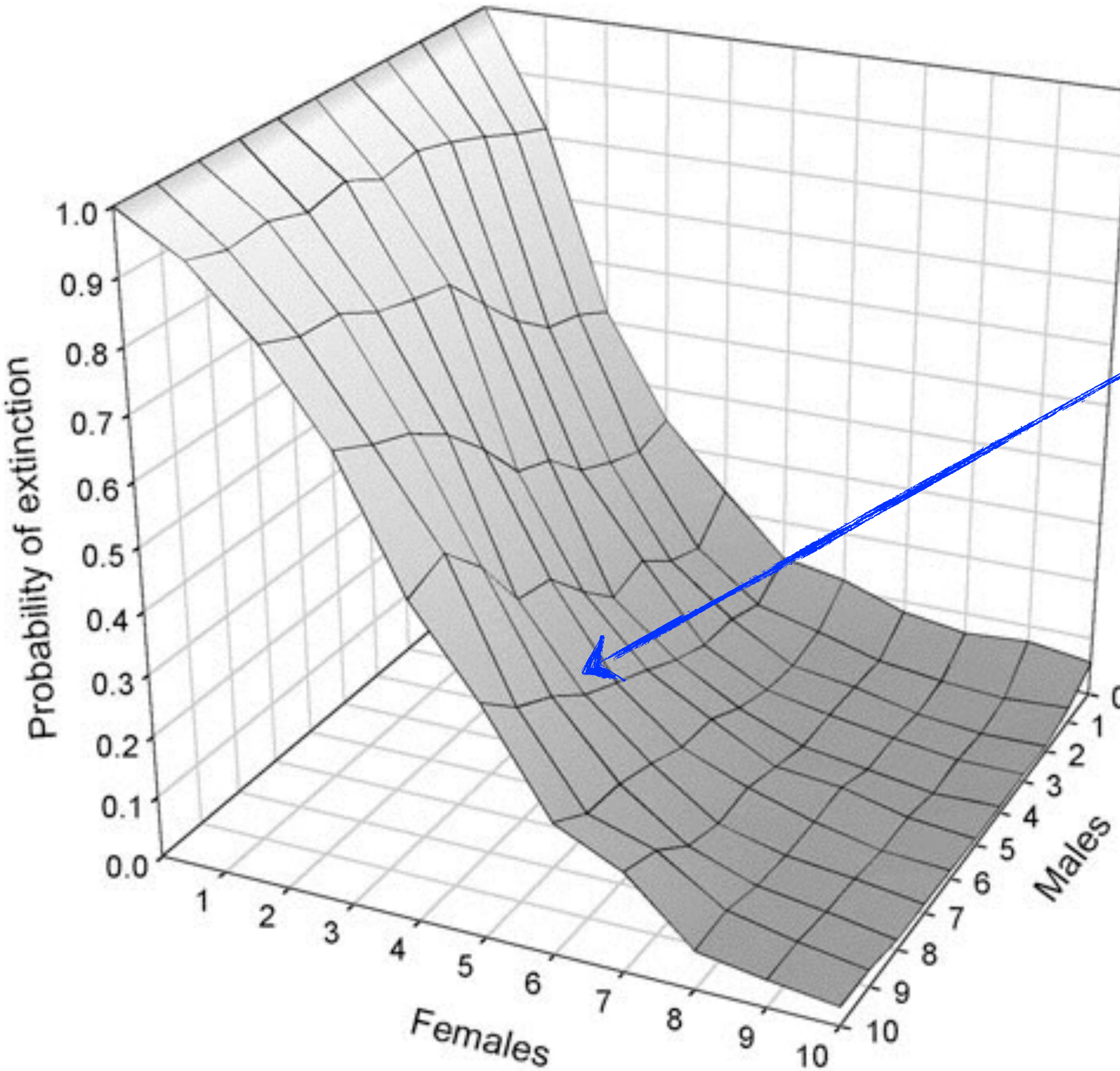
Central population
Western population
y = -0,2331x + 0,7382
R² = 0,6389
Average reproductive success
Average sex ratio
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
0
0,5
1
1,5
2
2,5
3
3,5

Null model



Probability of extinction
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Females
1
2
3
4
5
6
7
8
9
10
Males
0
1
2
3
4
5
6
7
8
9
10

Model with infanticide



more males
is worse

MAKE SURE HUNTING IS SUSTAINABLE

Population growth model

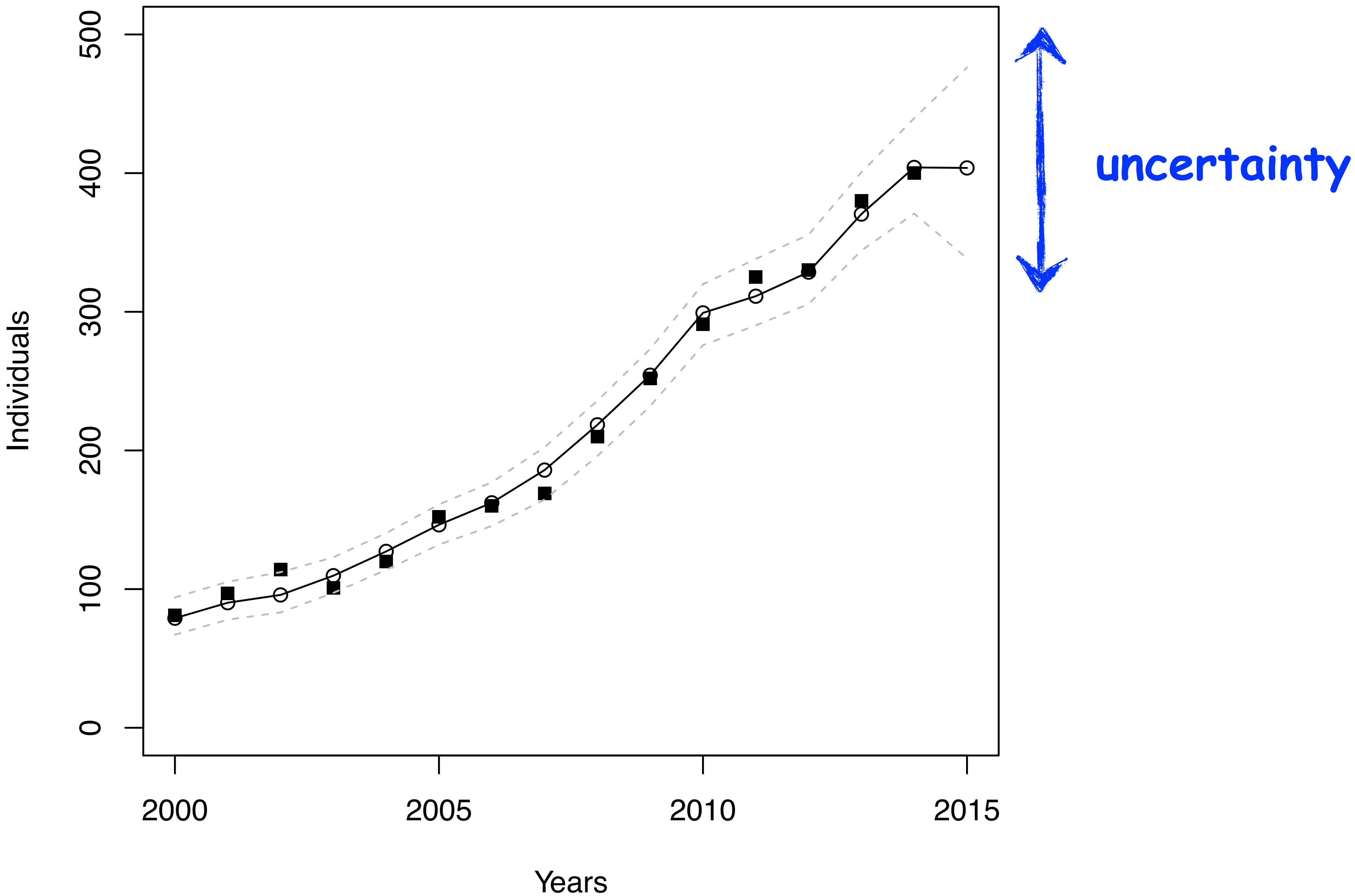
data process

$$\begin{cases} \mu_t = \log(\lambda \cdot (N_t - H_t^b) - H_t^a) \\ N_t \sim \text{lognormal}(\mu_t, \sigma_{proc}) \end{cases}$$

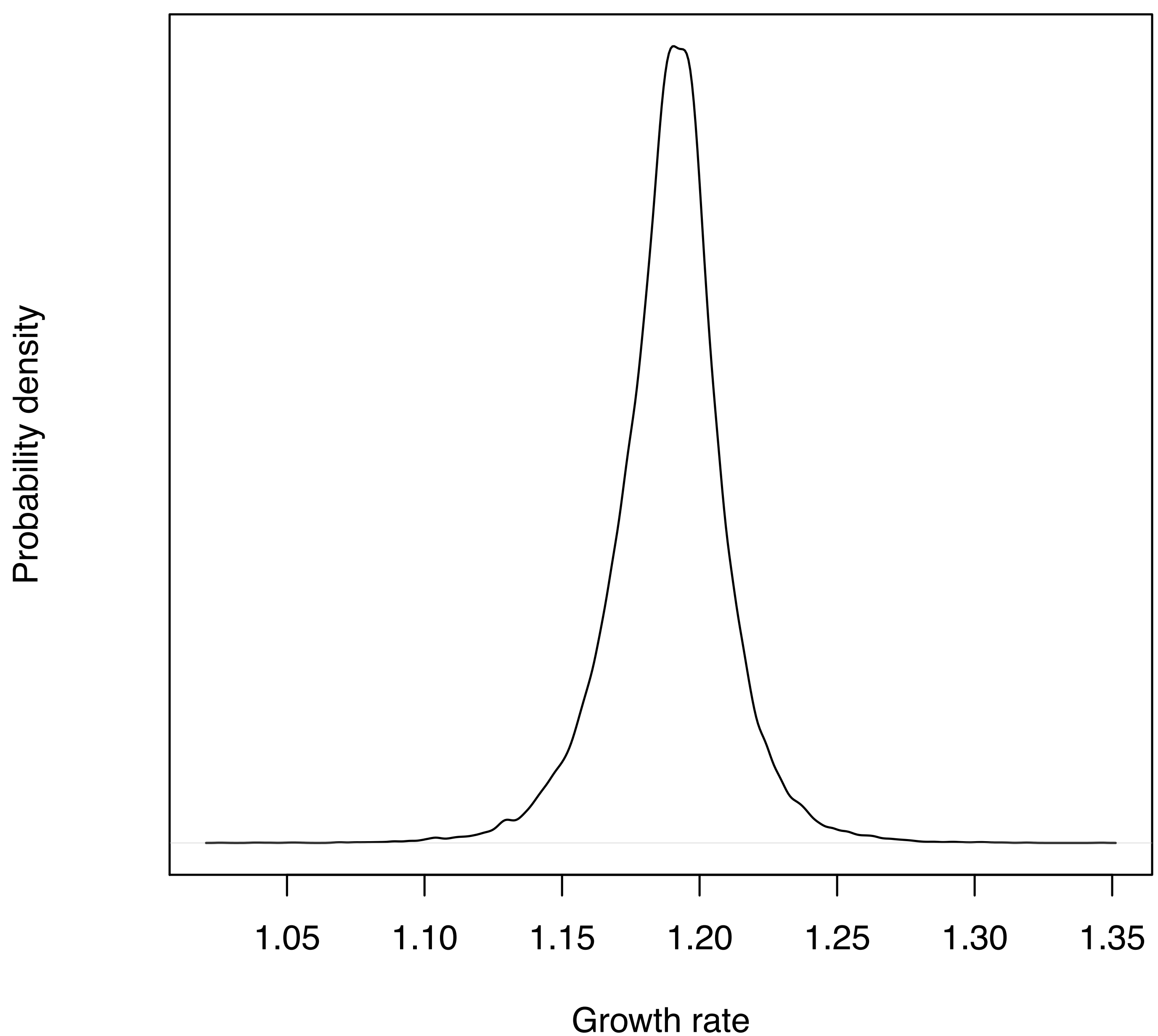
observation process

$$\begin{cases} \alpha_t = \frac{N_t^2}{\sigma^2_{Nobs}} \\ \beta_t = \frac{N_t}{\sigma^2_{Nobs}} \\ \psi_t \sim \text{gamma}(\alpha_t, \beta_t) \\ Nobs_t = \text{Poisson}(\psi_t) \end{cases}$$

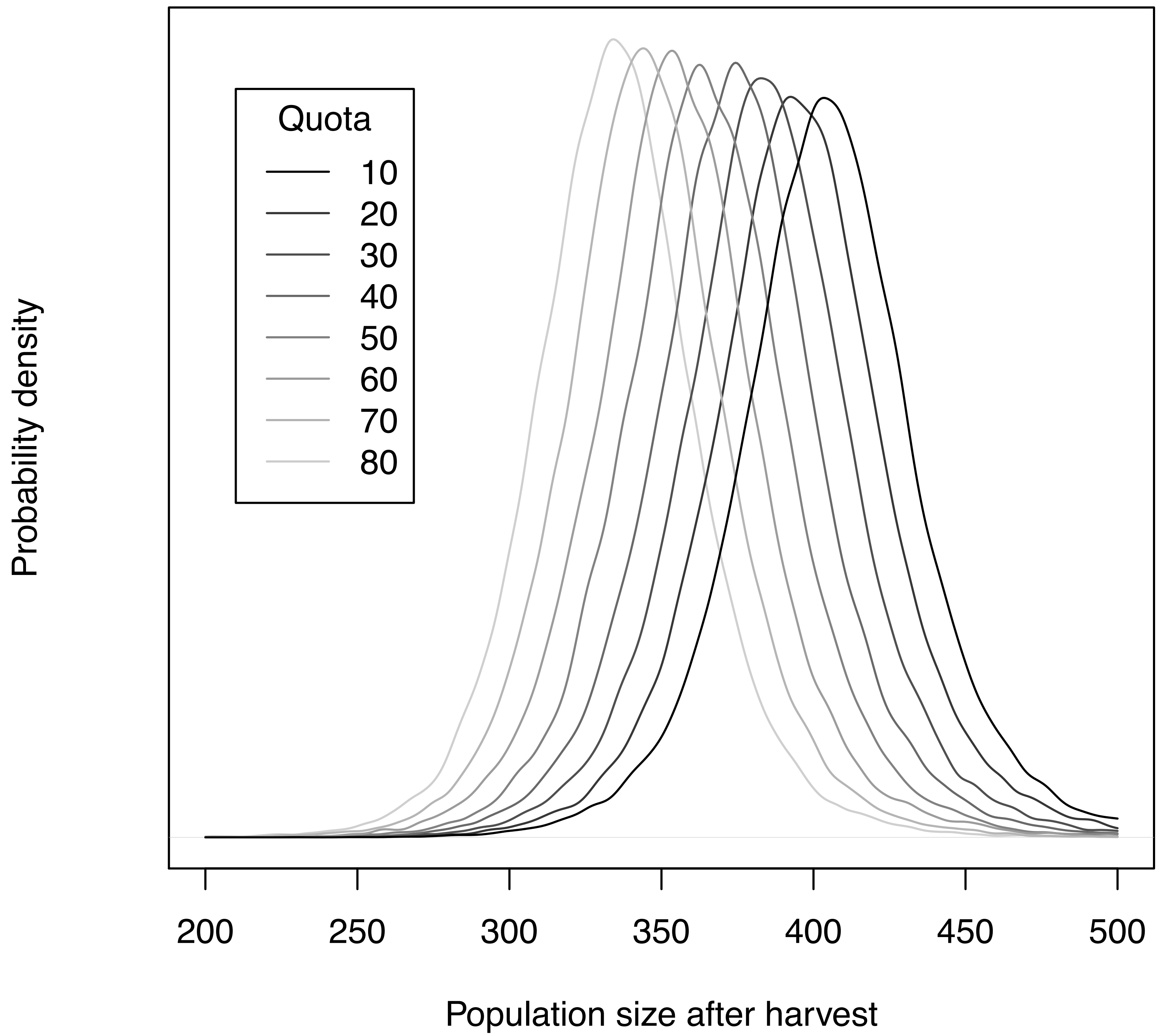
Model fitted to data



Estimates of growth rate lambda



Forecasted population sizes

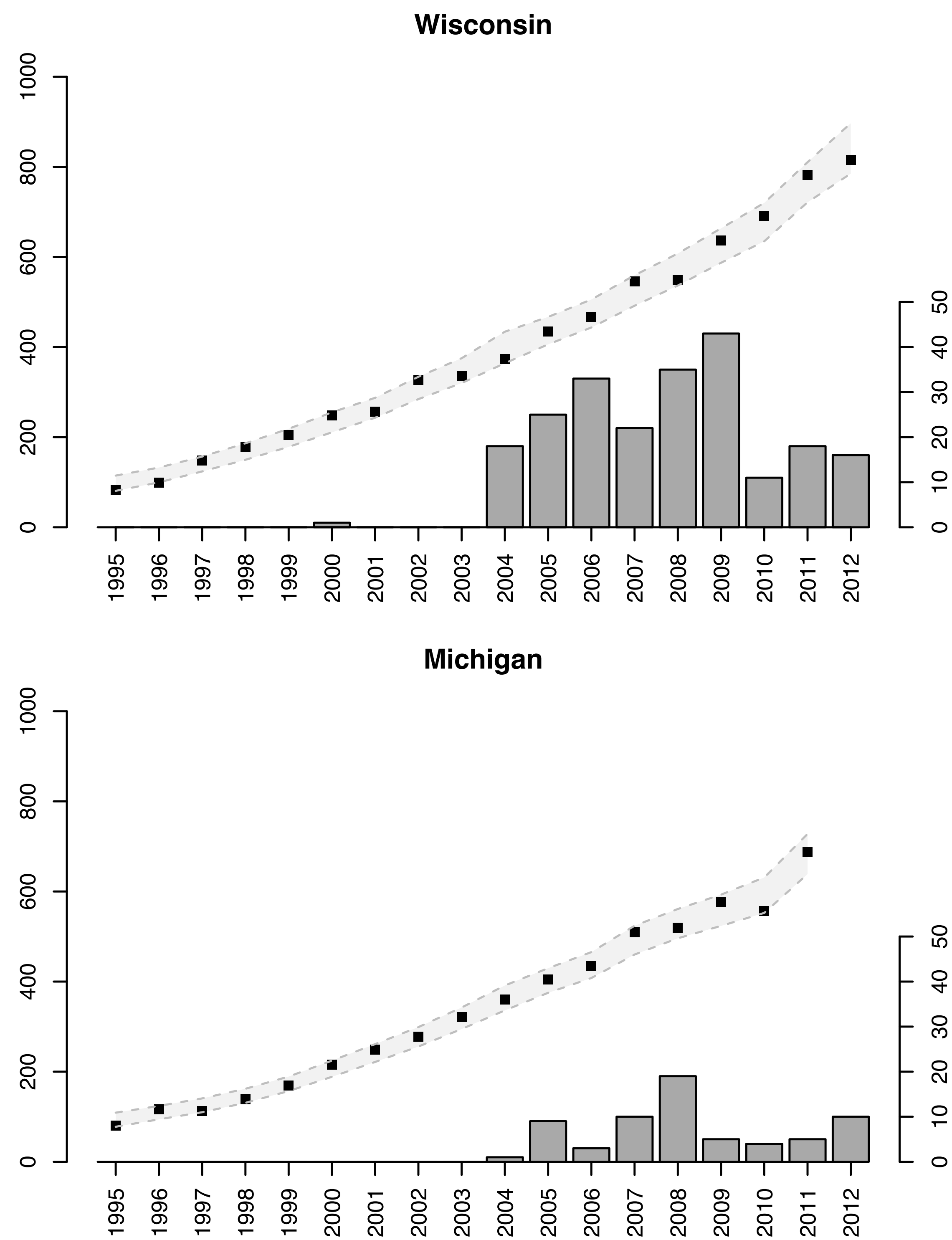


UNDERSTAND POLICIES

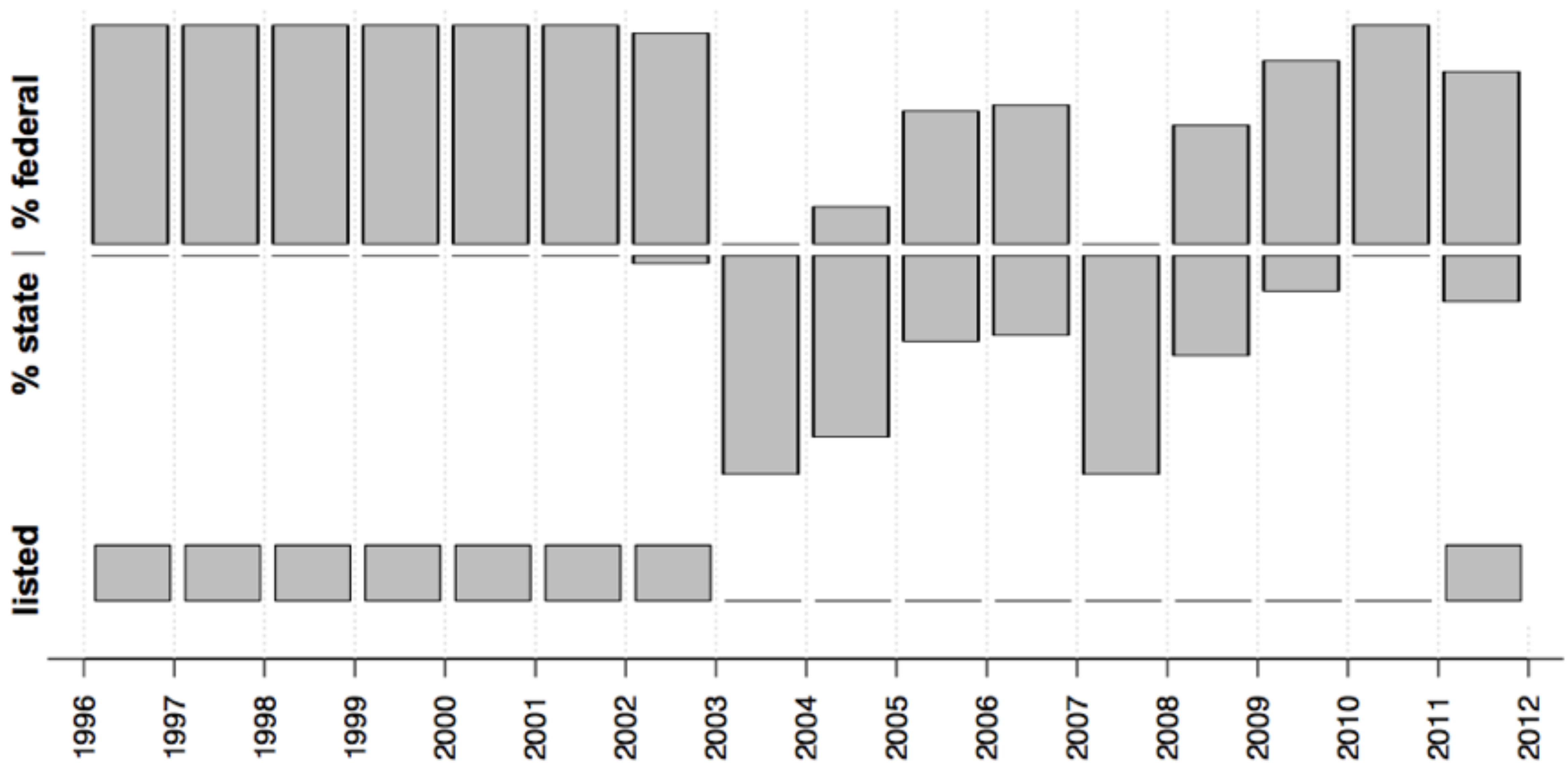
Hunting & poaching

- Untested but often repeated assumption that hunting is a conservation tool
- USFWS: "*legal lethal control would reduce poaching and other forms of intolerance for wolves*"

Population data



Policy data



% state | % federal
listed
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

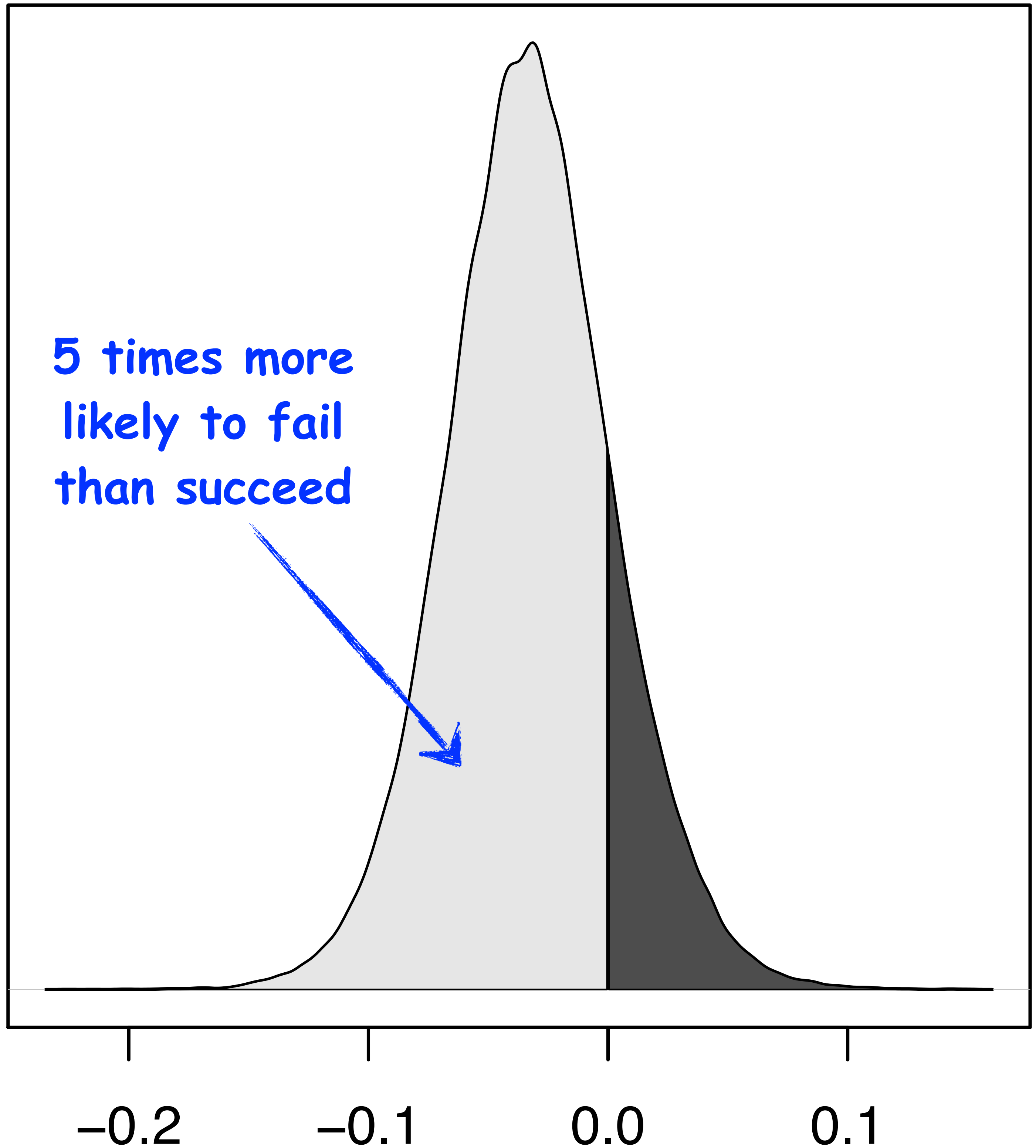
Process likelihood

$$\mu_t^S = \log\left(N_t^S \cdot e^{r_t^S} - \gamma \cdot H_t^S\right)$$

implemented cull
with a compensation
factor

wolves that have died
because of a policy
signal (%days with
culling allowed)

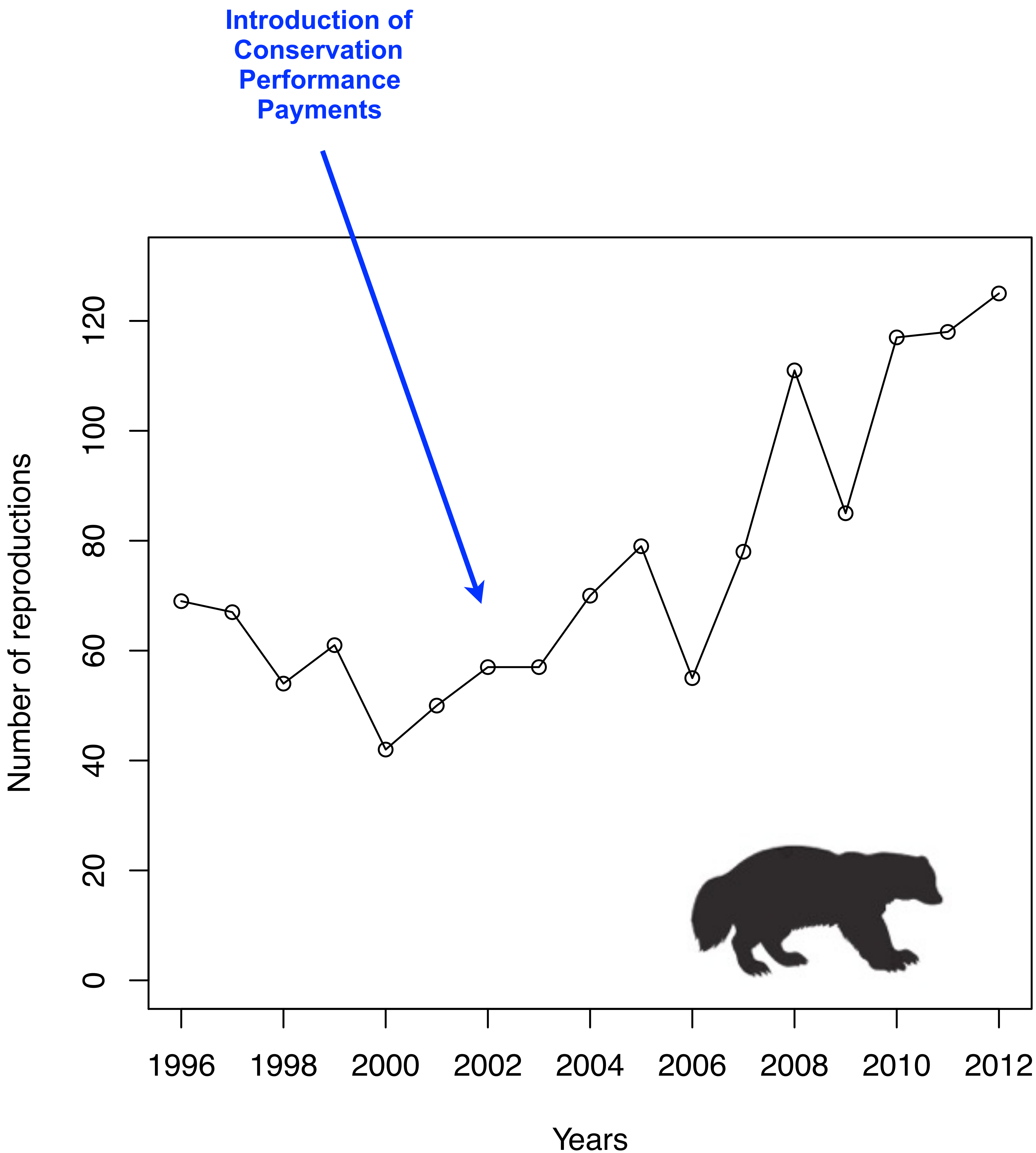
$$r_t^S = \beta_0^{rS} + \beta_1^r \cdot D_t^S$$

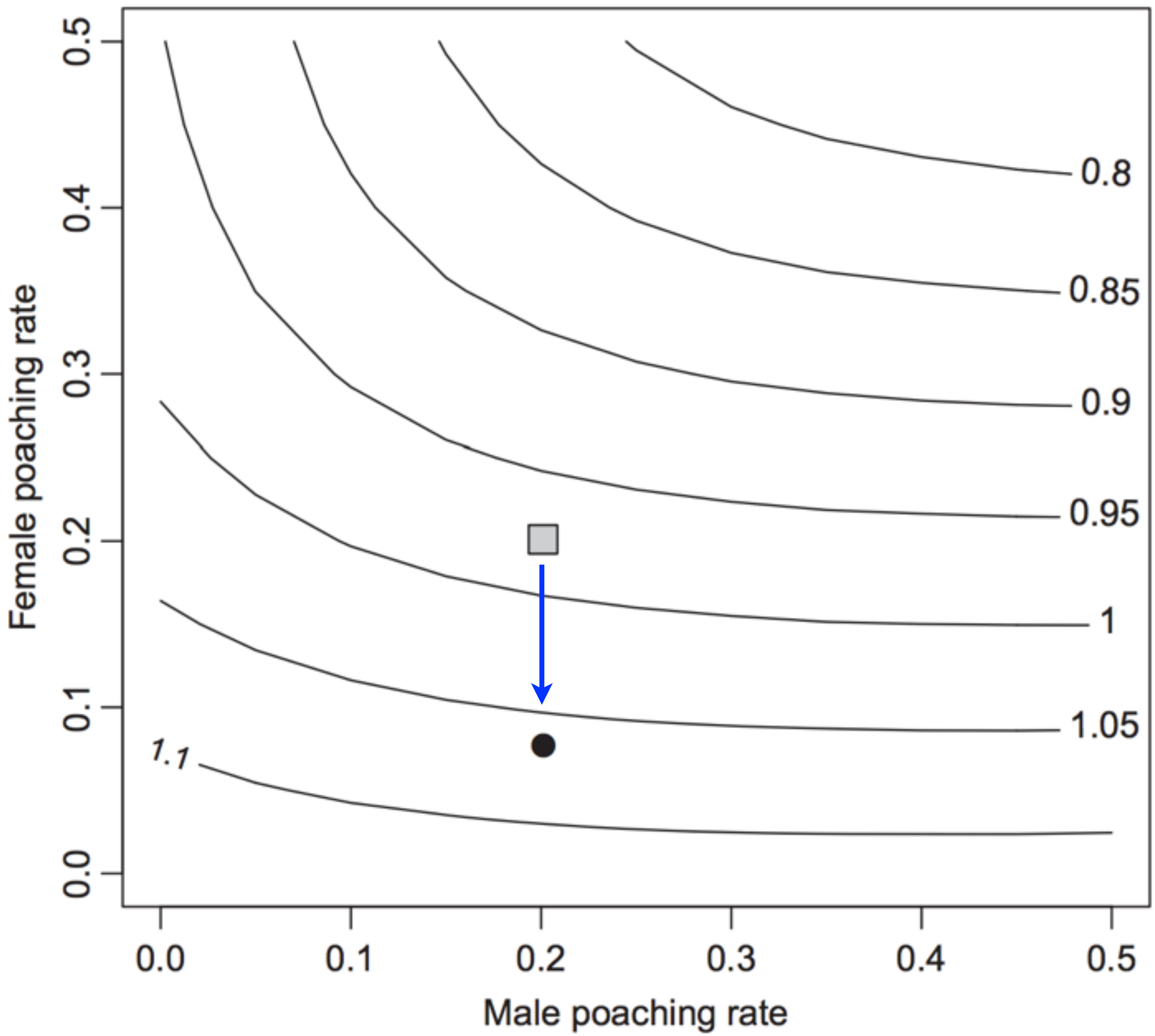


$\beta_1^r = -0.03 \pm 0.03 \quad$ 95% CI = (−0.1, 0.04)

Conservation payments

- Carnivores are globally valued but locally controversial
- Conservation performance payments are linked specifically to the production of a desired environmental output
- Paying Sami reindeer herders for wolverine reproductions has been instrumental in the recovery of wolverines in Sweden

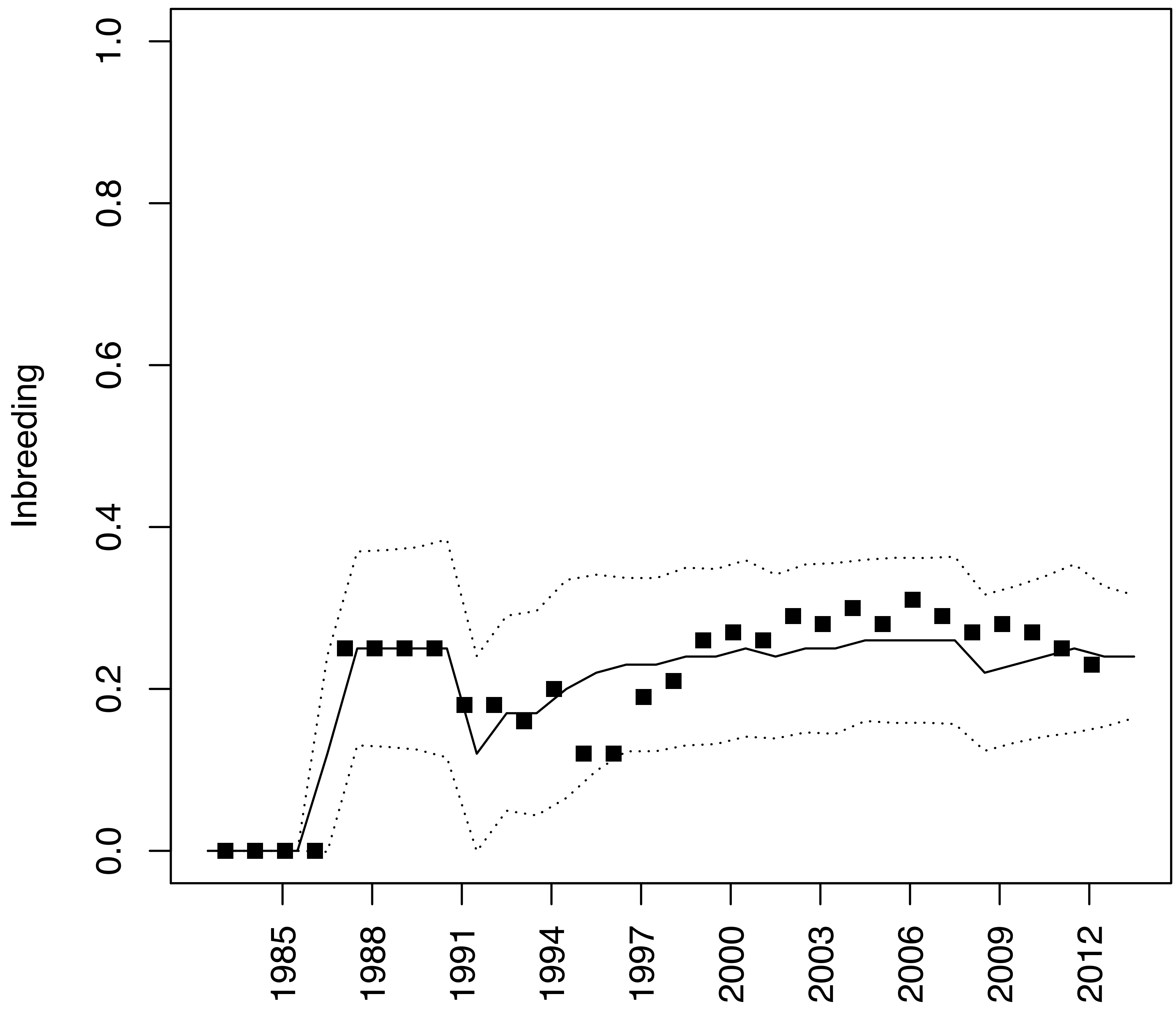

Introduction of
Conservation
Performance
Payments
Number of reproductions
0
20
40
60
80
100
120
1996
1998
2000
2002
2004
2006
2008
2010
2012
Years



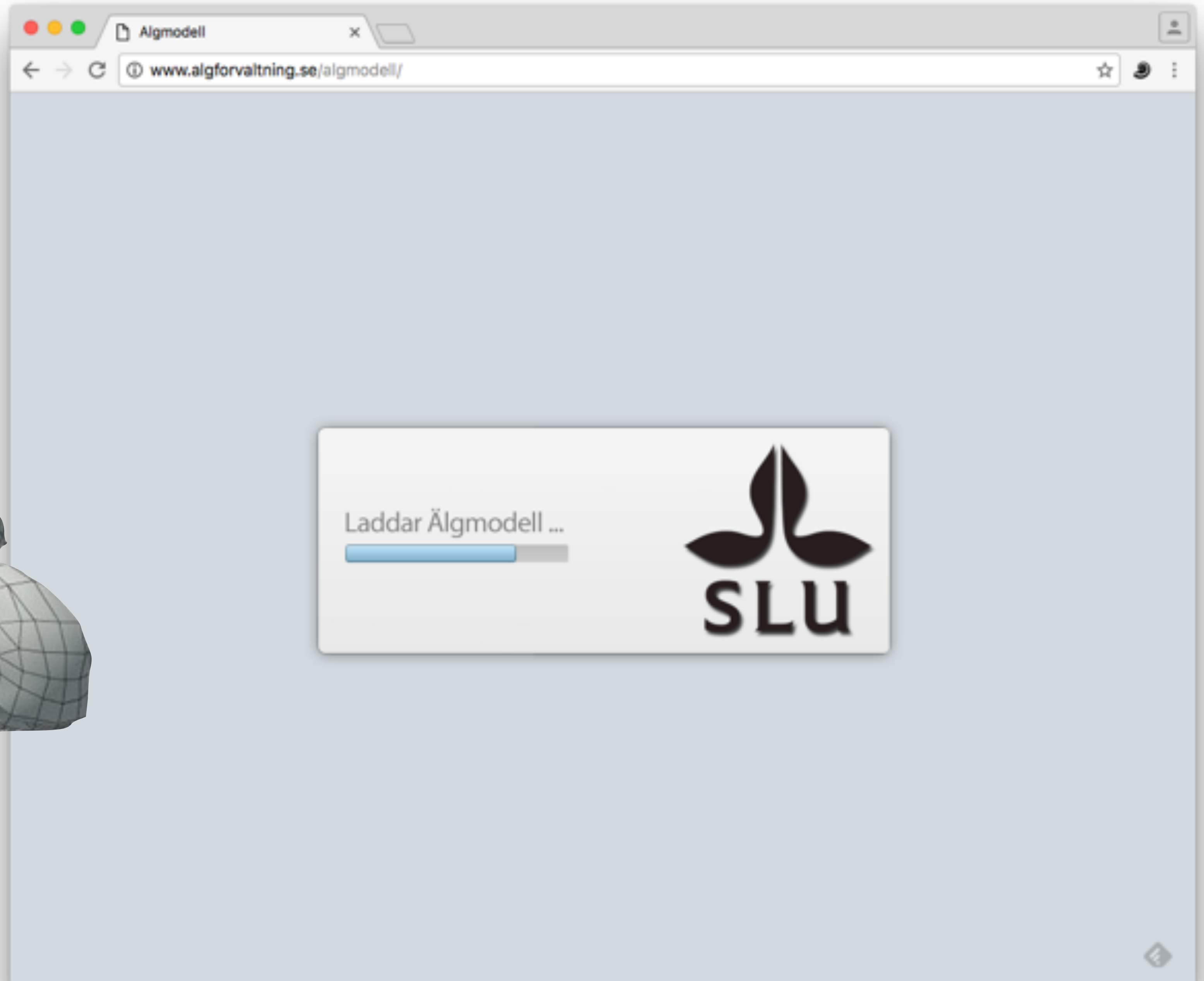
0.8
0.85
0.9
0.95
1
1.05
1.1
0.0
0.1
0.2
0.3
0.4
0.5
Male poaching rate
Female poaching rate

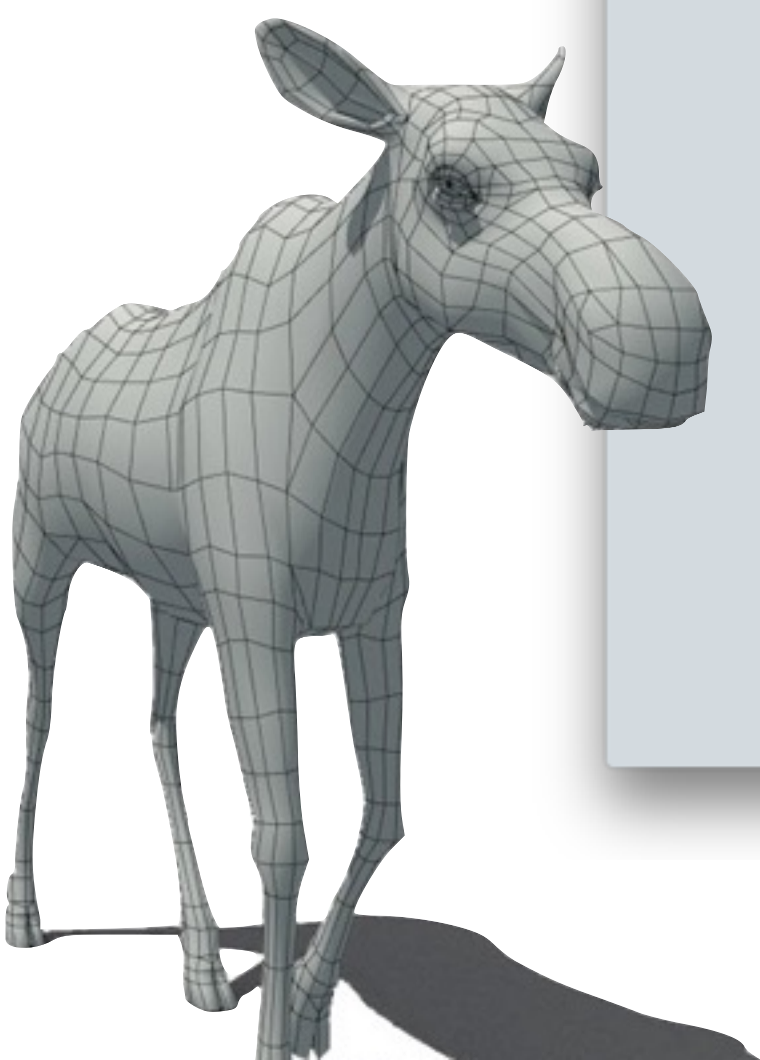
AND MORE…

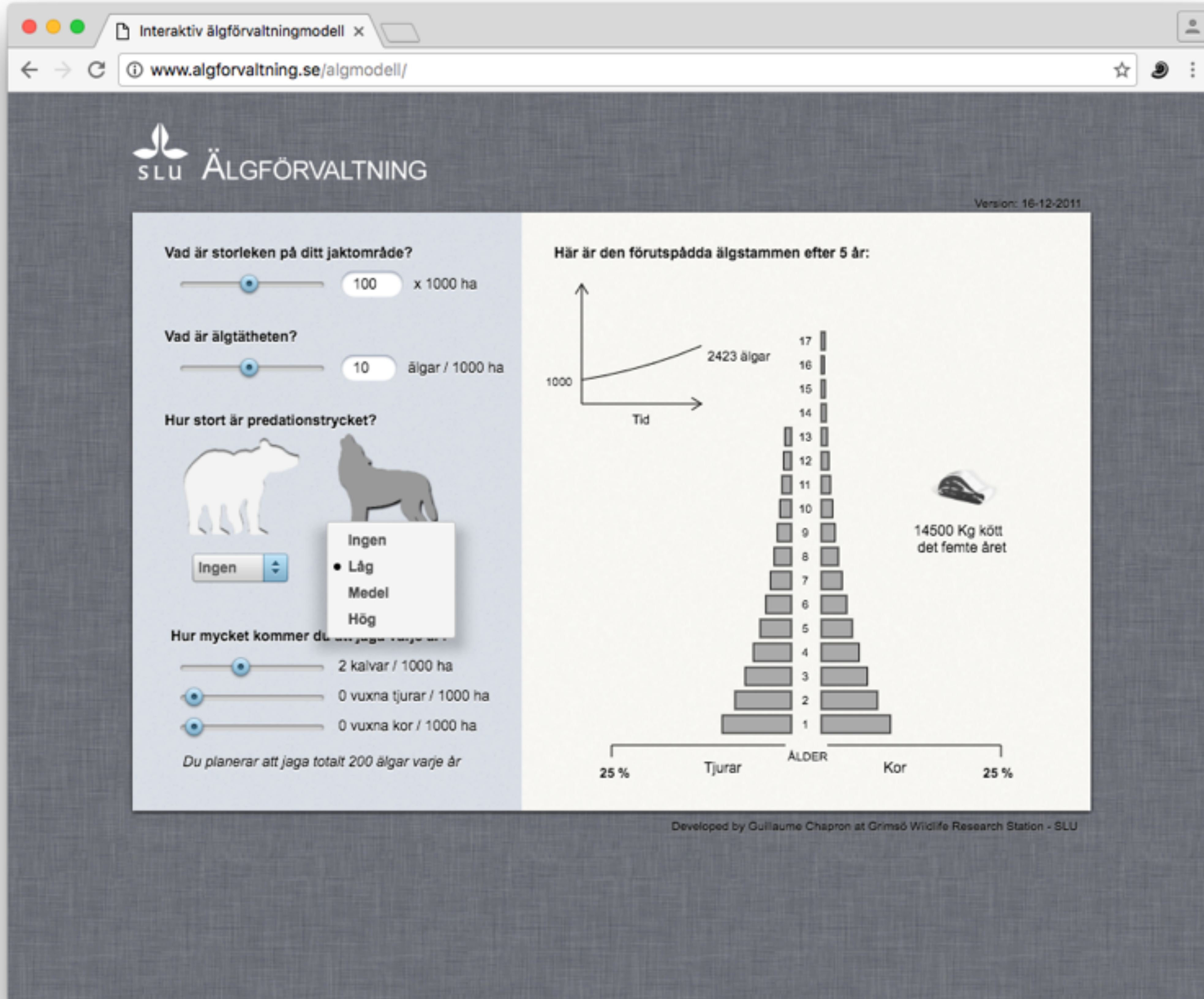
Include genetics



Outreach


Algmodell
www.algforvaltning.se/algmodell/
Laddar Älgmodell ...
SLU




Interaktiv älgförvaltningmodell
www.algforvaltning.se/algmodell/
SLU
ÄLGFÖRVALTNING
Version: 16-12-2011
Vad är storleken på ditt jaktområde?
100
x 1000 ha
Vad är älgtätheten?
10
älgar / 1000 ha
Hur stort är predationstrycket?
Ingen
Ingen
Låg
Medel
Hög
Hur mycket kommer du
2 kalvar / 1000 ha
0 vuxna tjurar / 1000 ha
0 vuxna kor / 1000 ha
Du planerar att jaga totalt 200 älgar varje år
Här är den förutspådda älgstammen efter 5 år:
2423 älgar
1000
Tid
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
14500 Kg kött
det femte året
ÅLDER
25 %
Tjurar
Kor
25 %
Developed by Guillaume Chapron at Grimsö Wildlife Research Station - SLU

THANKS