Centre for Biology and Management of Populations
CBGP
Centre de Biologie pour la Gestion des Populations

5 décembre 2023

Better understanding the links between wolf depredation behavior, culling and depredation levels with an

INDIVIDUAL-BASED MODEL

presented by

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cnrs

CENTRE D'ECOLOGIE FONCTIONNELLE & EVOLUTIVE

SUMMARY

The point of **INDIVIDUAL-BASED MODEL** for wolf research

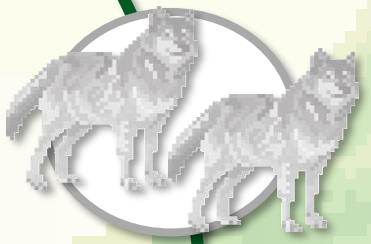
Modeling a wolf population

Simulating depredation and culling

Conclusion and perspectives

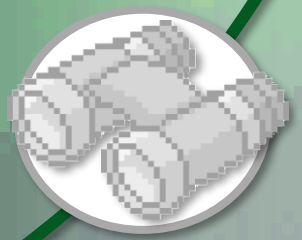
SUMMARY

The point of **INDIVIDUAL-BASED MODEL** for wolf research



Modeling a wolf population

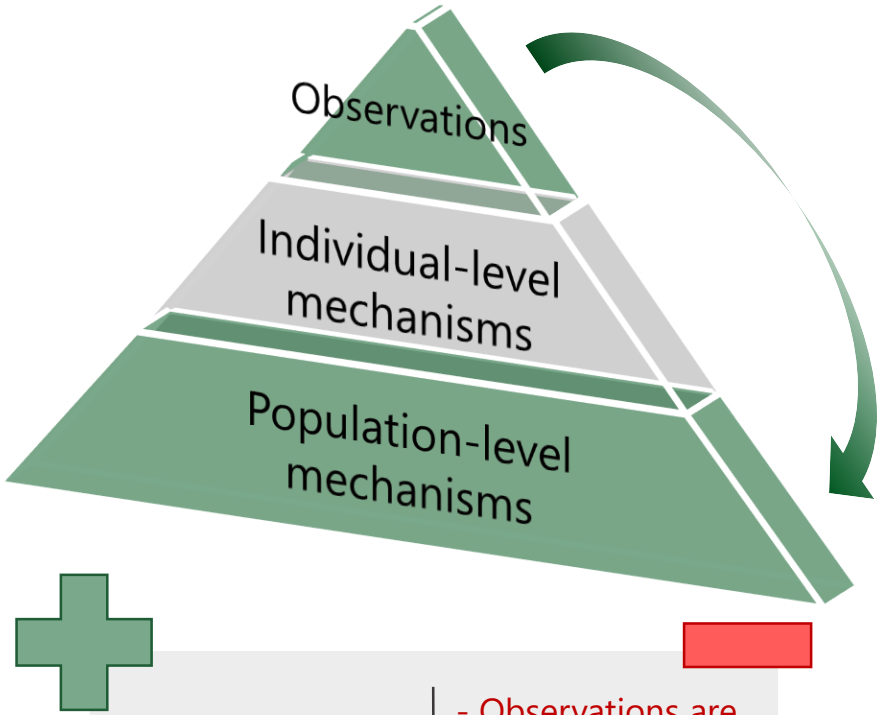
Simulating depredation and culling



Conclusion and perspectives

The point of **INDIVIDUAL-BASED MODEL** for wolf research

Correlation



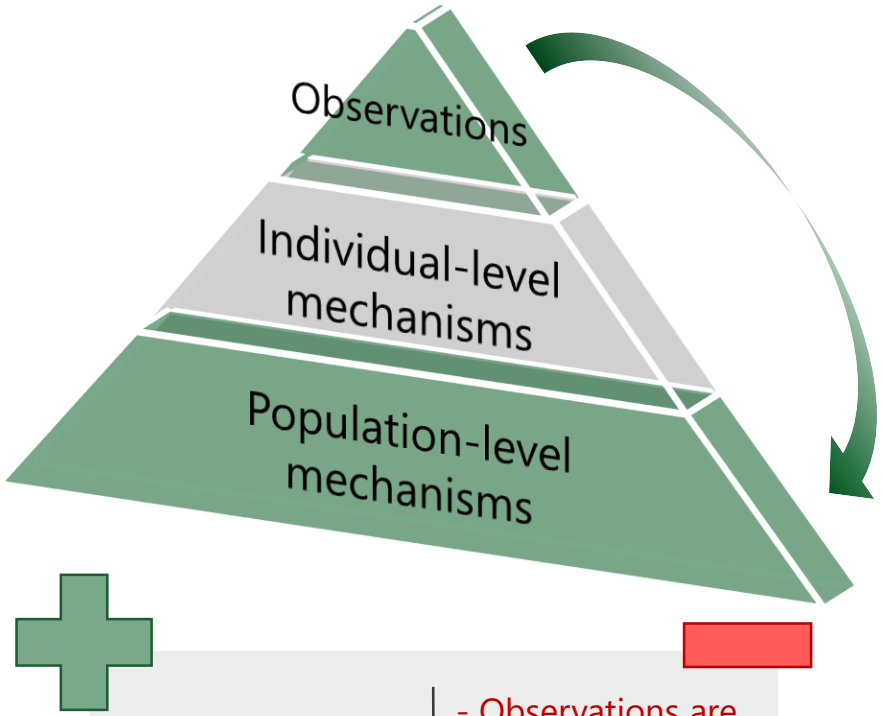
- Easy to apply

- Observations are incomplete
- Potential confounding effects
- No cause-effect directionality

$$Depredation \sim Flock\ protection + Wolf\ number + Wolf\ culling$$

The point of INDIVIDUAL-BASED MODEL for wolf research

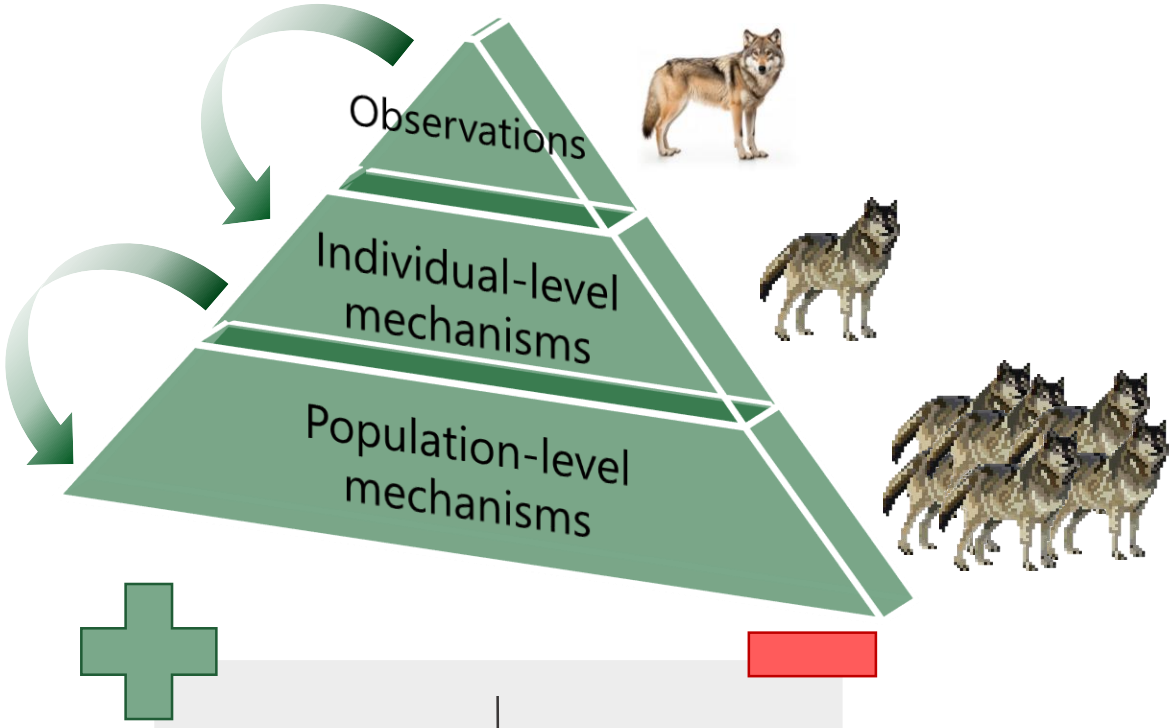
Correlation



- Easy to apply

- Observations are incomplete
- Potential confounding effects
- No cause-effect directionality

INDIVIDUAL-BASED MODEL



- Understanding of the results
- Adapted to social species
- Easy to code

- Requires substantial amount of information about the species

SUMMARY

The point of INDIVIDUAL-BASED MODEL for wolf research

Modeling a wolf population

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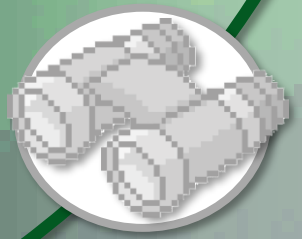
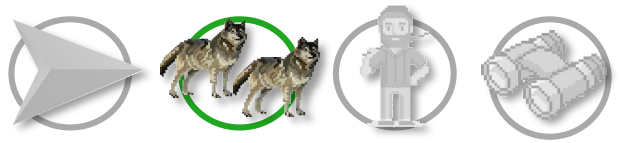


Conclusion and perspectives

Modeling a wolf population



Haight *et al.*, 2002 - Marucco and McIntire, 2010 - Chapron *et al.*, 2016

Pack dissolution modeling (Brainerd *et al.*, 2008 - Cassidy *et al.*, 2023)

Modeling a wolf population

ID CARD

LUPA

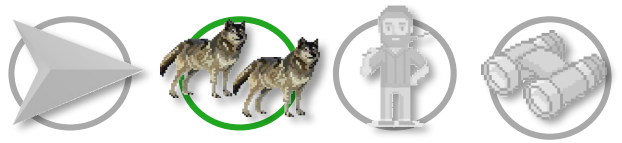
5 years old
Female
Pack n°1
Breeder

ID CARD

LUPO

4 years old
Male
Pack n°2
Subordinate

Modeling a wolf population



START

ID CARD

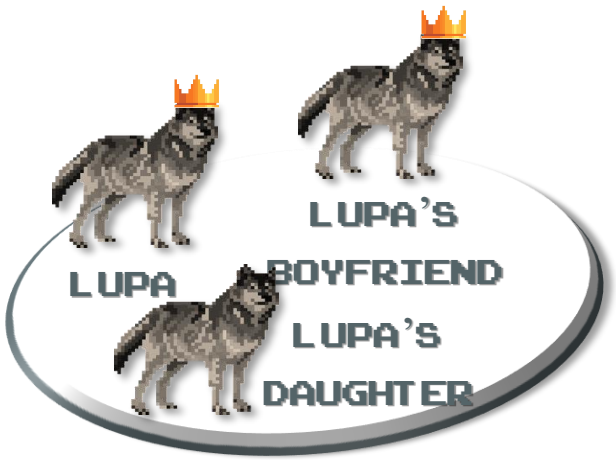
LUPA

5 years old
Female
Pack n°1
Breeder

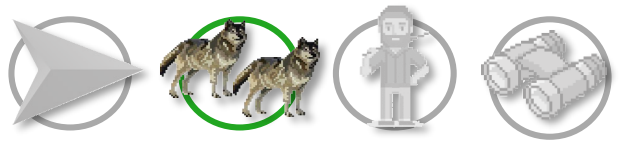
ID CARD

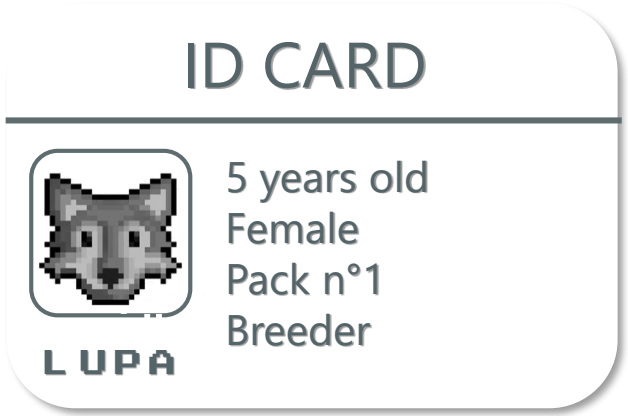
LUPO

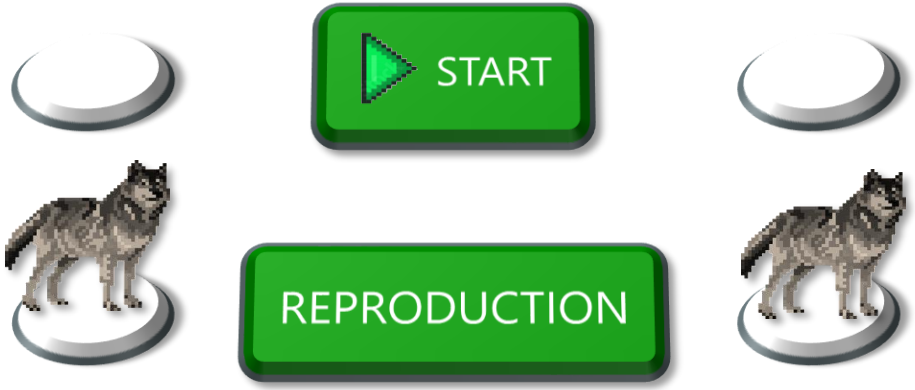
4 years old
Male
Pack n°2
Subordinate



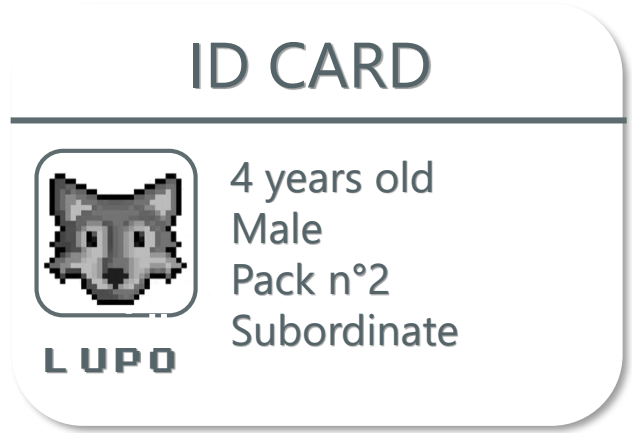
Modeling a wolf population

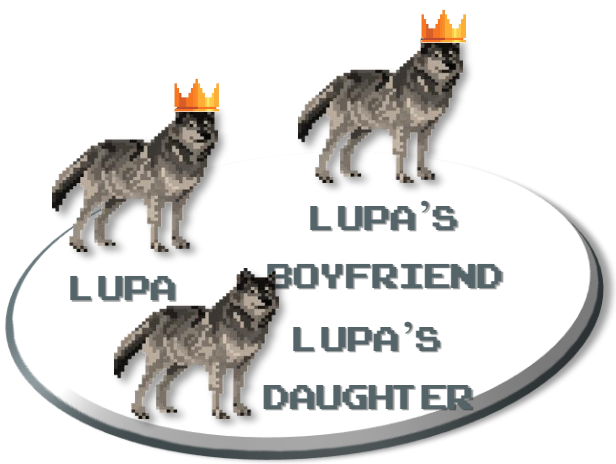






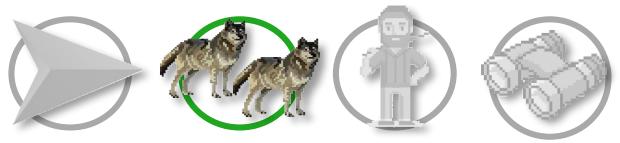
$\sim Poisson(6.1)$

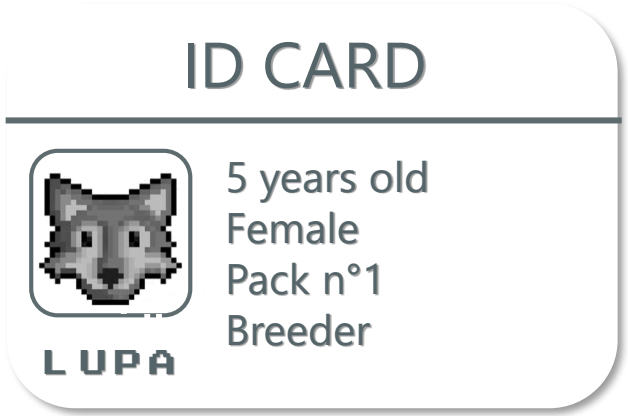


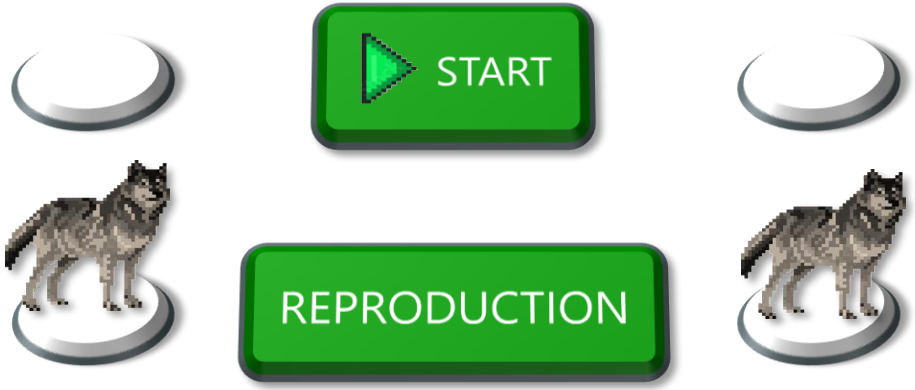


Sidorovich *et al.* 2007

Modeling a wolf population







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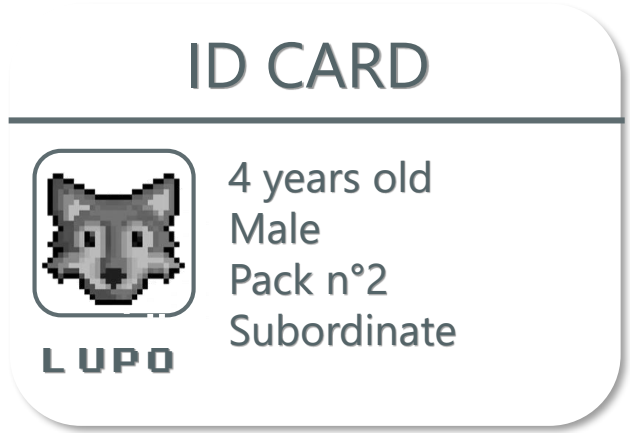
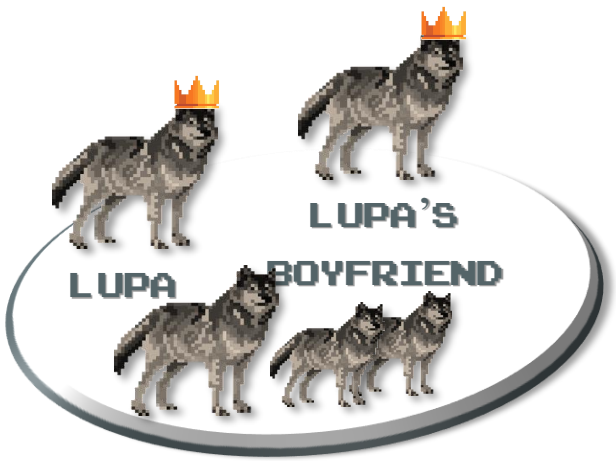
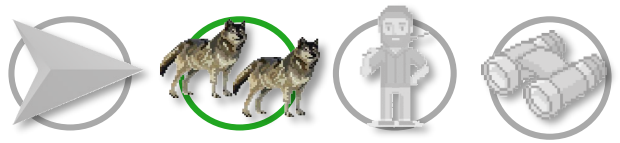




Sidorovich *et al.* 2007

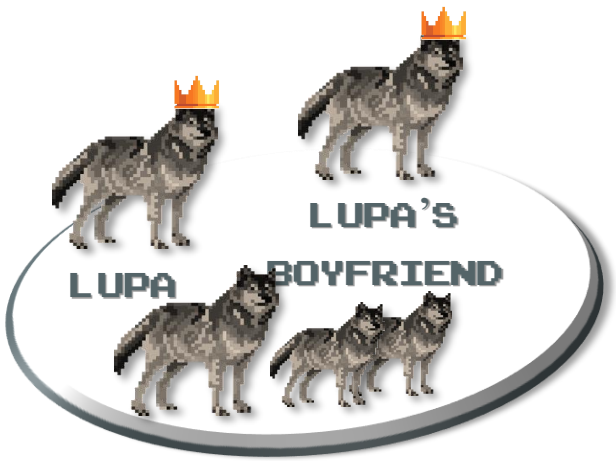
Modeling a wolf population



ID CARD

LUPA

5 years old
Female
Pack n°1
Breeder



$\sim Bernoulli(p_{(age\ \&\ status)})$

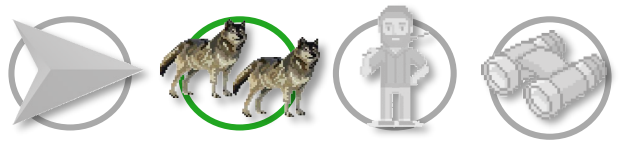
ID CARD

LUPO

4 years old
Male
Pack n°2
Subordinate

Marucco *et al.* 2009
Smith *et al.* 2010

Modeling a wolf population



ID CARD

5 years old
Female
Pack n°1
Breeder

LUPA

START

REPRODUCTION

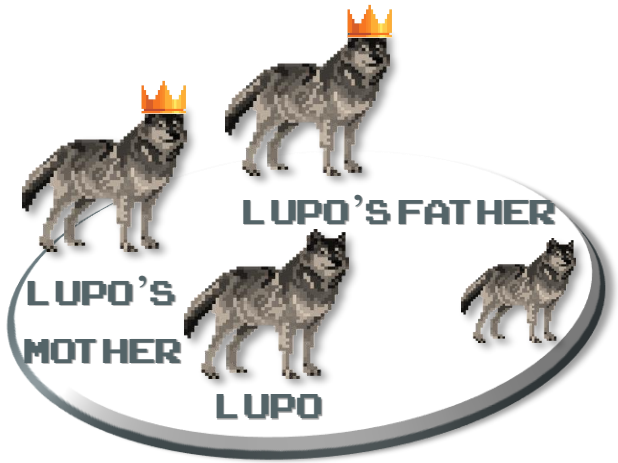
MORTALITY

$\sim Bernoulli(p_{(age\ \&\ status)})$

ID CARD

4 years old
Male
Pack n°2
Subordinate

LUPO



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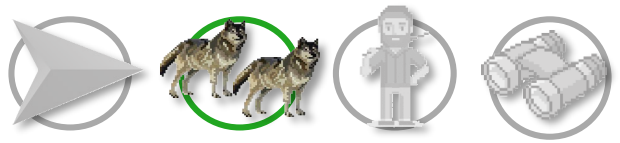
Modeling a wolf population



ID CARD

LUPA

5 years old
Female
Pack n°1
Breeder

START

REPRODUCTION

MORTALITY

PACK DISSOLUTION

$\sim Bernoulli(0.26)$

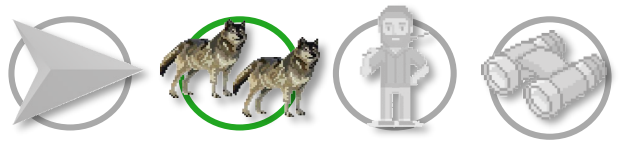
ID CARD

LUPO

4 years old
Male
Pack n°2
Subordinate

Brainerd *et al.* 2008

Modeling a wolf population



ID CARD

LUPA

5 years old
Female
No pack
Disperser

LUPA

START

REPRODUCTION

MORTALITY

PACK DISSOLUTION

$\sim Bernoulli(0.26)$

ID CARD

LUPO

4 years old
Male
Pack n°2
Subordinate

Brainerd *et al.* 2008

Modeling a wolf population

DISPERSAL

$\sim Normal(4.4,1.3)$

$\sim Bernoulli(p_{age})$

ID CARD

LUPA

5 years old
Female
No pack
Disperser

LUPA

ID CARD

LUPO

4 years old
Male
Pack n°2
Subordinate

Marucco and McIntire, 2010

Haight and Mech, 1997

Modeling a wolf population

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Marucco and McIntire, 2010

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Modeling a wolf population

ID CARD

LUPA

5 years old
Female
No pack
Disperser

DISPERSAL

REPLACEMENT BY DISPERSERS

ID CARD

LUPO

4 years old
Male
No pack
Disperser

LUPA

LUPO

Marucco and McIntire, 2010
Haight and Mech, 1997

Modeling a wolf population

ID CARD

LUPA

5 years old
Female
No pack
Disperser

LUPA

DISPERSAL

REPLACEMENT BY DISPERSERS

PAIR BONDING

$$\sim Bernoulli(\frac{N_{Free\ territories}}{Carrying\ capacity})$$

ID CARD

LUPO

4 years old
Male
No pack
Disperser

LUPO

Modeling a wolf population

ID CARD

LUPA

5 years old
Female
Pack n°4
Breeder

DISPERSAL

REPLACEMENT BY DISPERSERS

PAIR BONDING

$$\sim Bernoulli(\frac{N_{Free\ territories}}{Carrying\ capacity})$$

ID CARD

LUPO

4 years old
Male
Pack n°4
Breeder

Modeling a wolf population

ID CARD

LUPA

5 years old
Female
Pack n°4
Breeder

DISPERSAL

REPLACEMENT BY DISPERSERS

PAIR BONDING

START

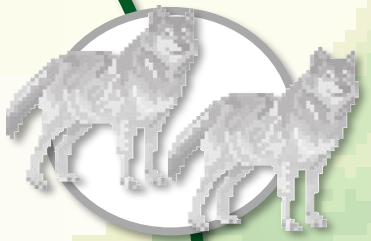
ID CARD

LUPO

4 years old
Male
Pack n°4
Breeder

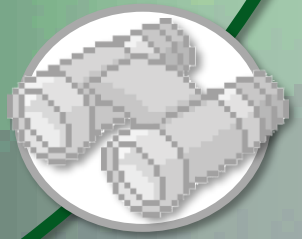
SUMMARY

The point of INDIVIDUAL-BASED MODEL for wolf research



Modeling a wolf population

Simulating depredation and culling



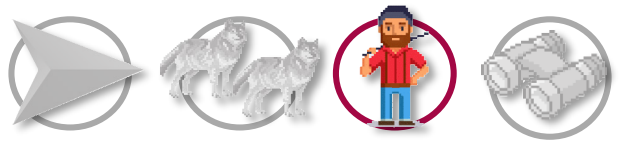
Conclusion and perspectives

Simulating depredation and culling

ID CARD

Age
Sex
Pack
Breeding status
Depredation index

Simulating depredation and culling



ID CARD

Age
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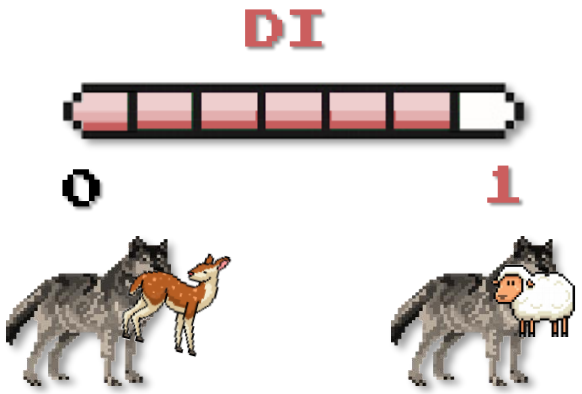
Pack
Breeding status
Depredation index



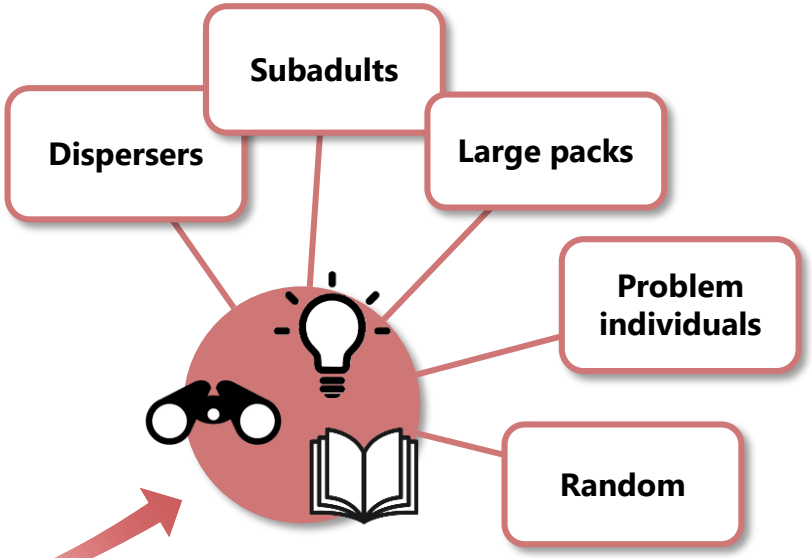
Simulating depredation and culling

ID CARD

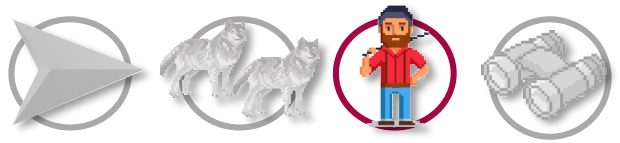
Age
Sex
Pack
Breeding status
Depredation index

DI

0 1



Simulating depredation and culling



ID CARD

Age
Sex
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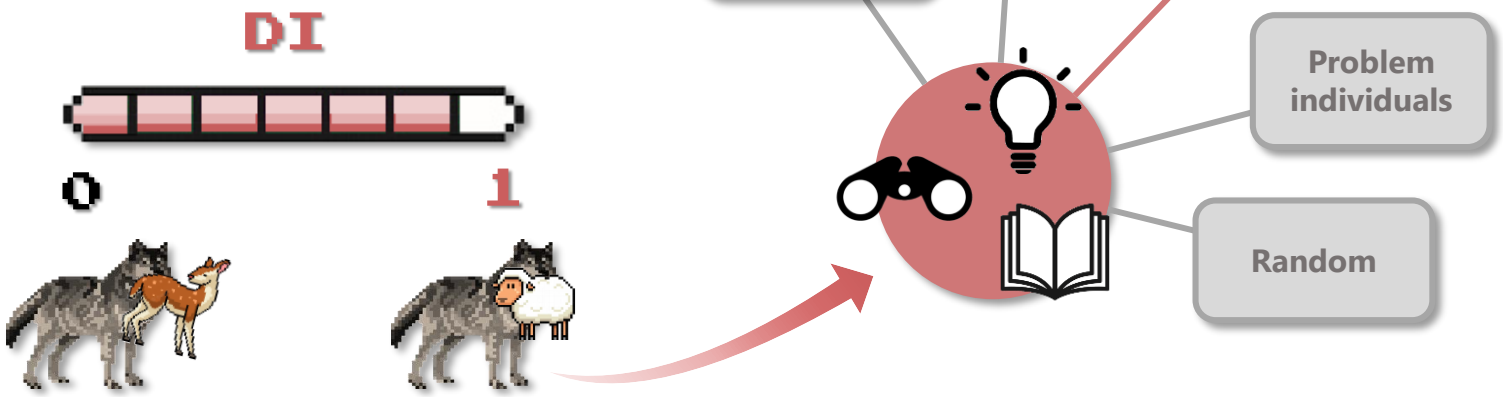
Depredation index



Simulating depredation and culling

ID CARD

Age
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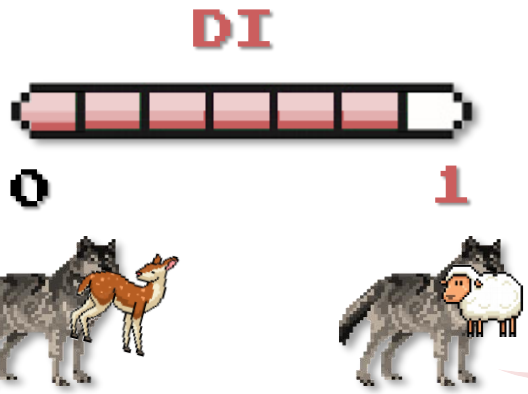
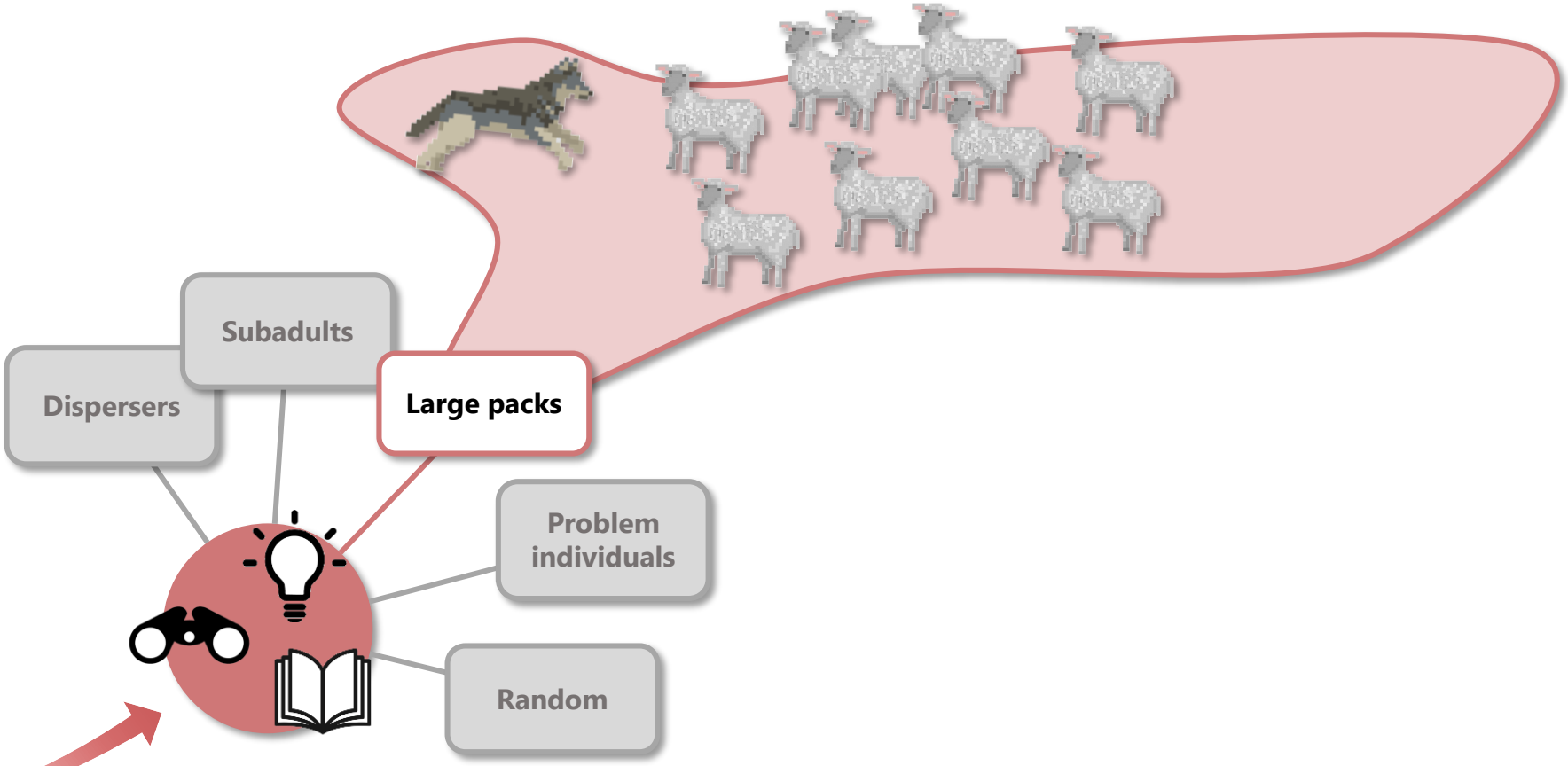
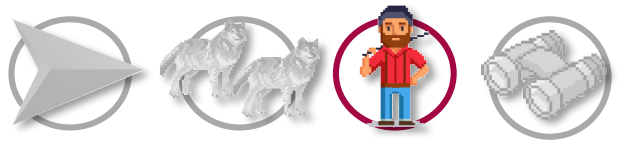


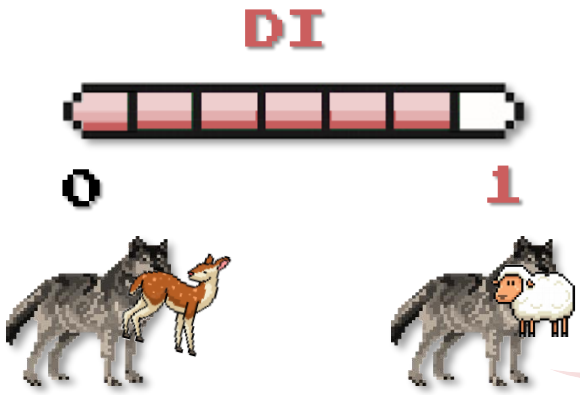


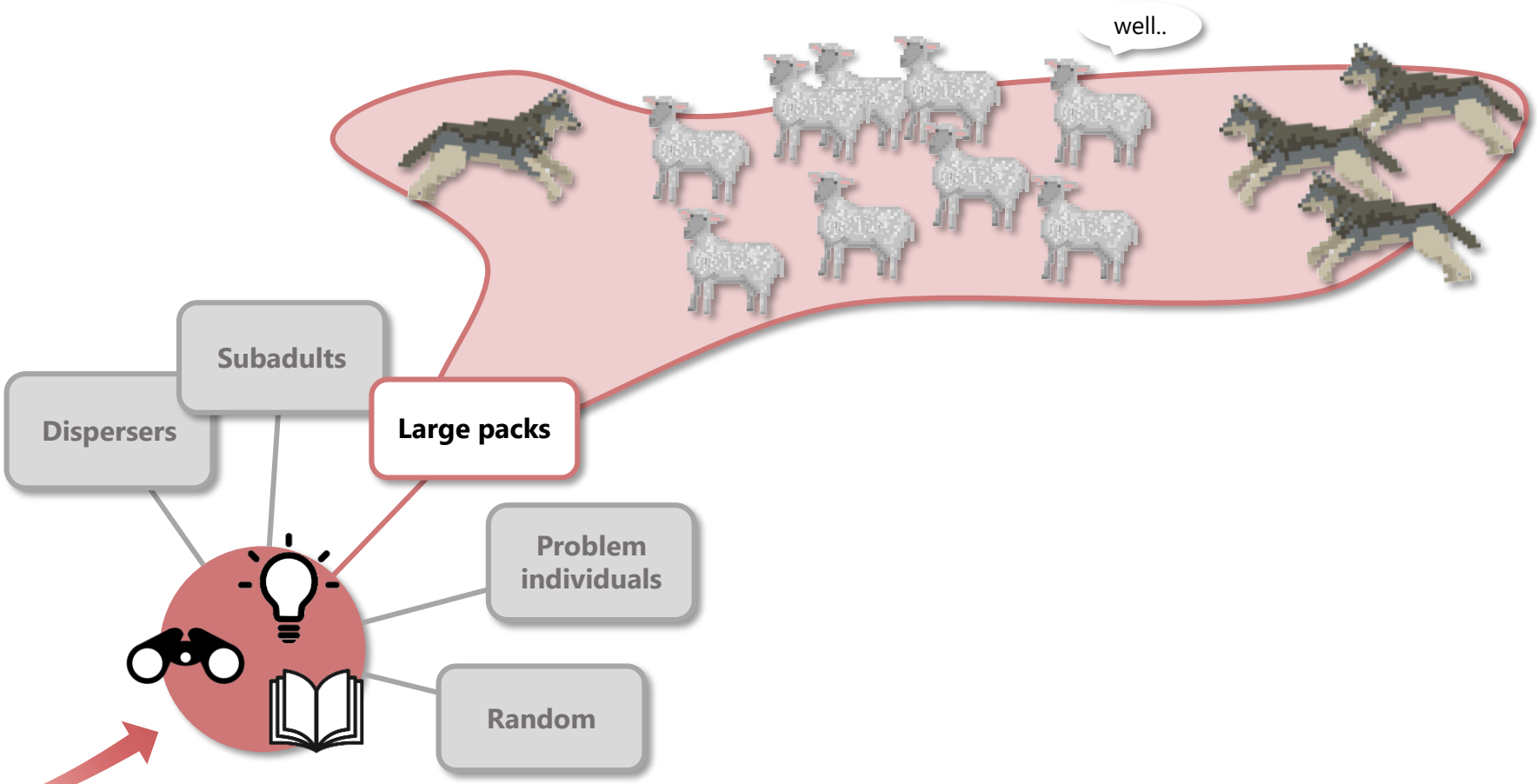
Simulating depredation and culling



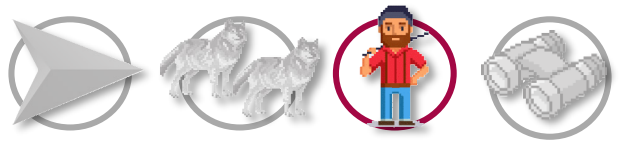
ID CARD

Age
Sex
Pack
Breeding status
Depredation index



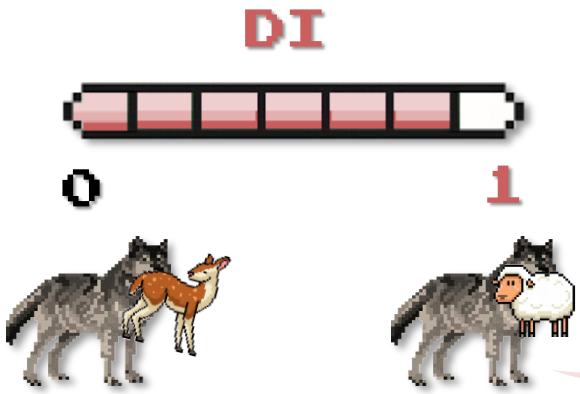


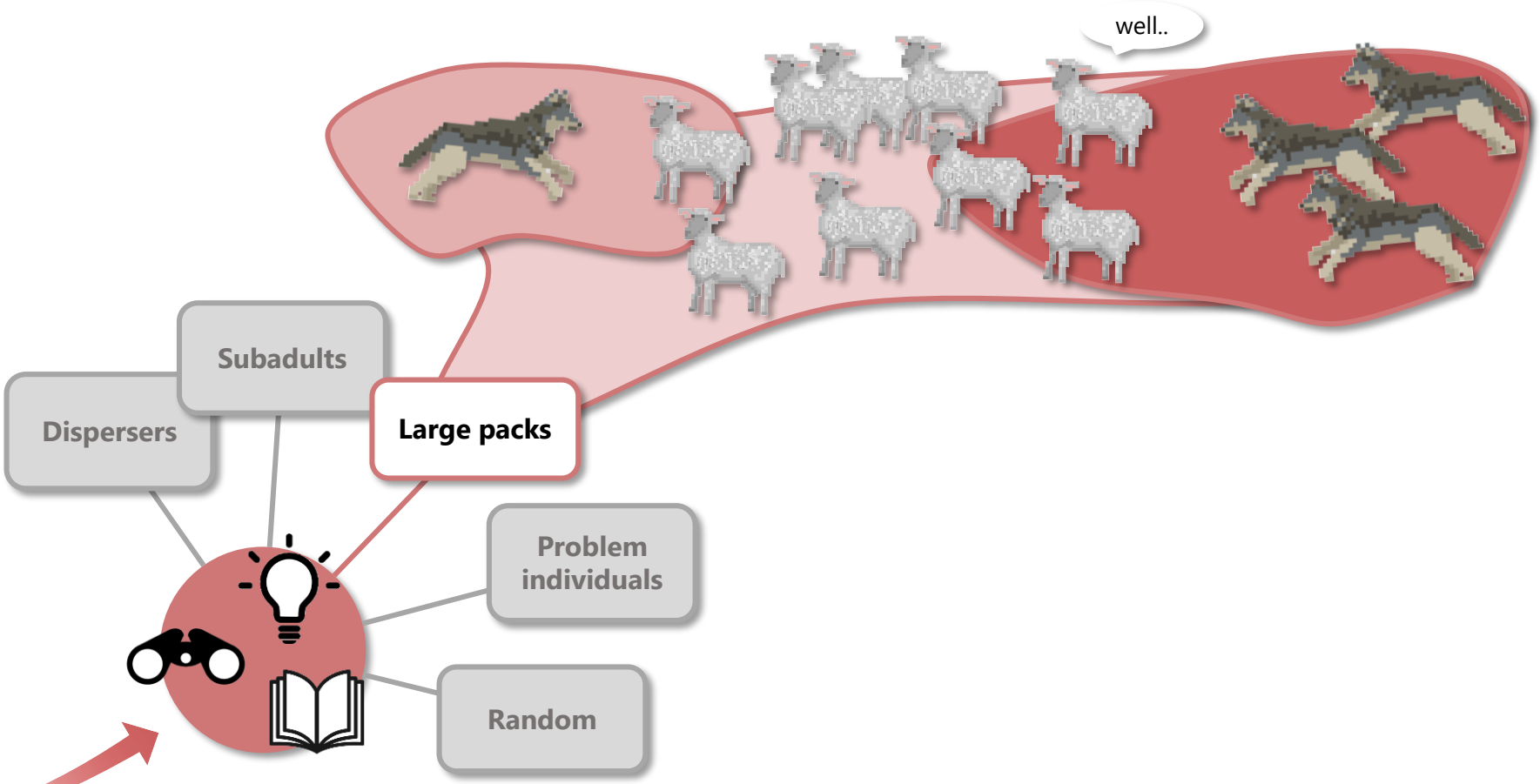
Simulating depredation and culling



ID CARD

Age
Sex
Pack
Breeding status
Depredation index





Simulating depredation and culling

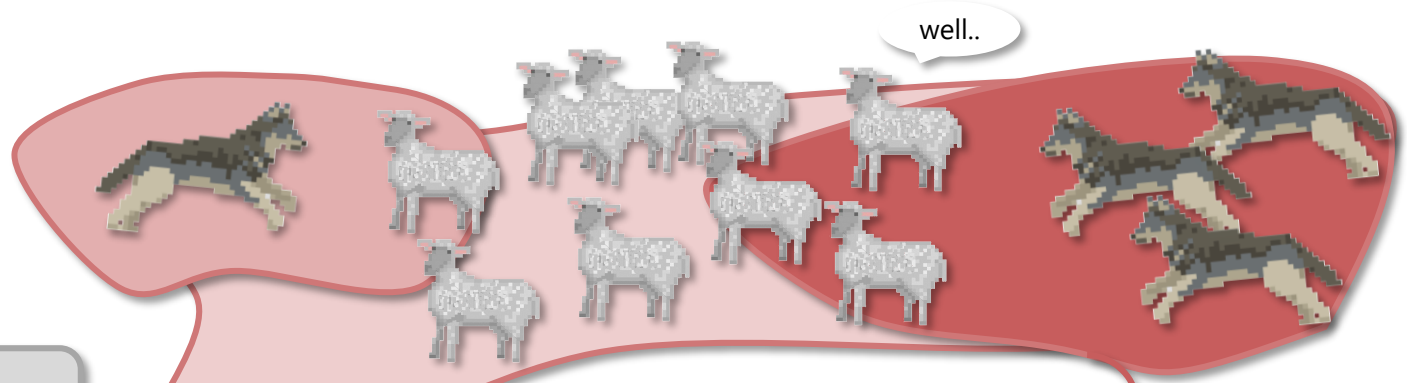
ID CARD

Age
Sex
Pack
Breeding status
Depredation index

DI

0 1

Dispersers
Subadults
Large packs
Problem individuals
Random



Simulating depredation and culling

ID CARD

Age
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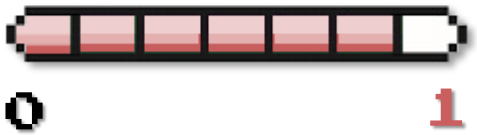
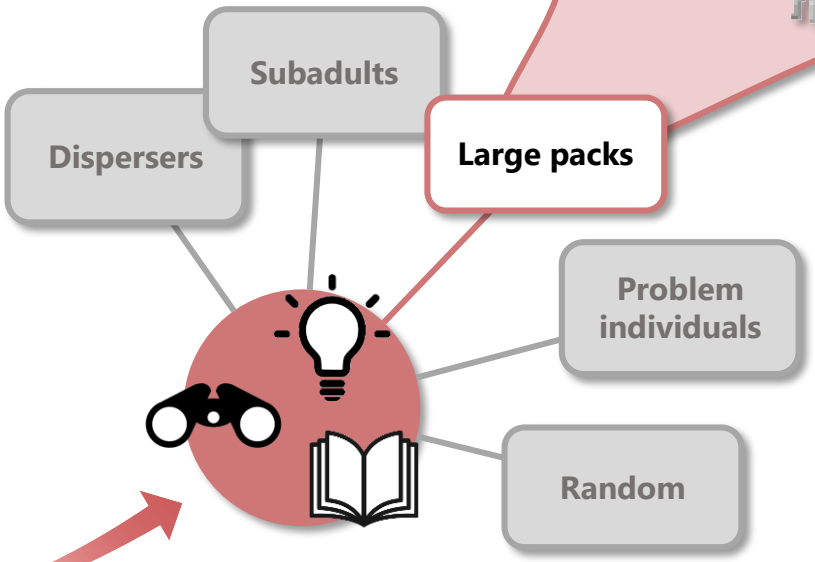
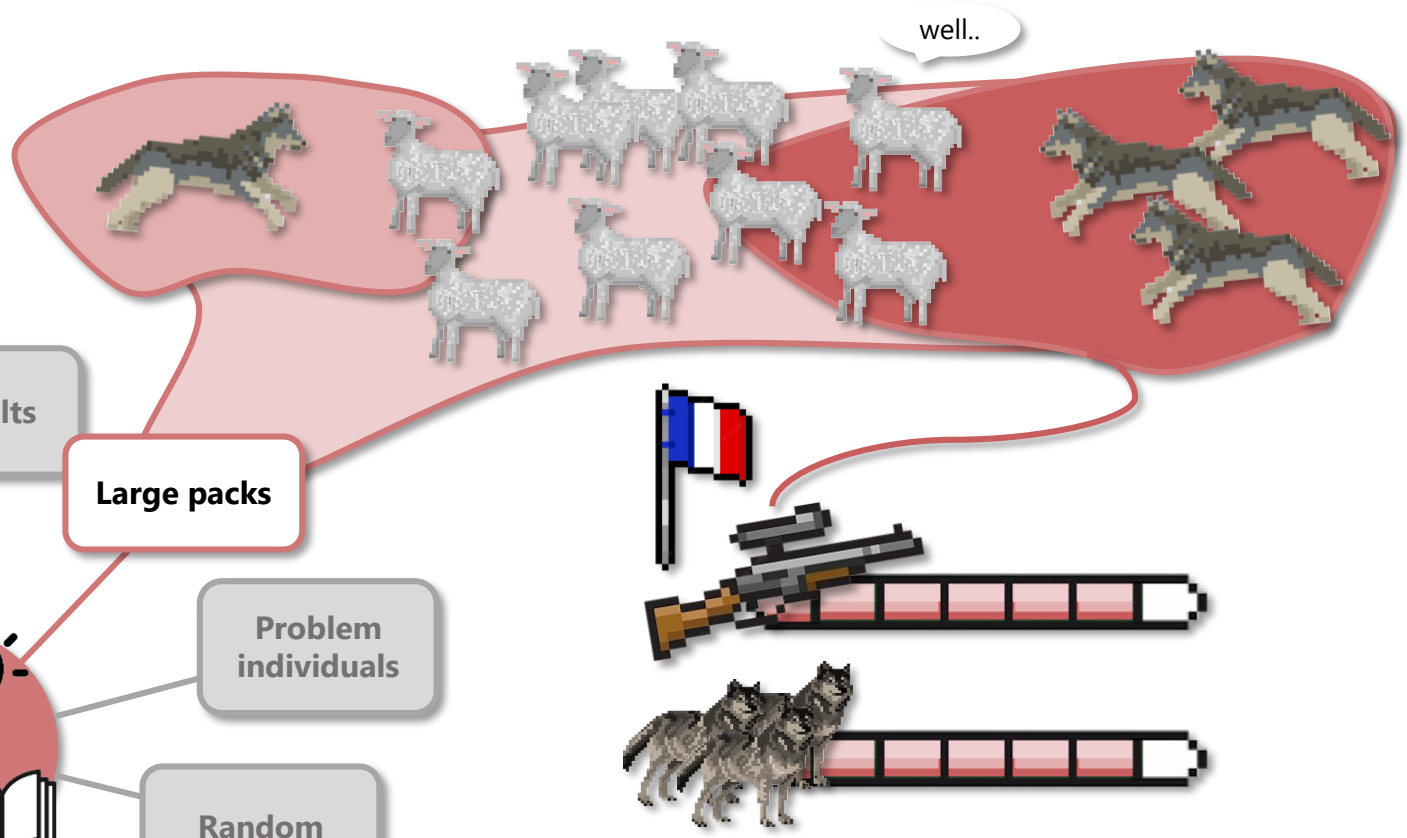
Depredation index

PACK NEEDS







Simulating depredation and culling

Simulating depredation and culling

Simulating depredation and culling

Simulating depredation and culling

A LOCAL AREA OF UNIFORM SHEEP HUSBANDRY

WOLF CARRYING CAPACITY: 10 PACKS

SELECTIVE CULLING

20%

RANDOM CULLING

20%

NO CULLING

0%

START

REPRODUCTION

MORTALITY

PACK DISSOLUTION

DISPERSAL

REPLACEMENT BY DISPERSERS

PAIR BONDING

START

Simulating depredation and culling

RANDOM CULLING

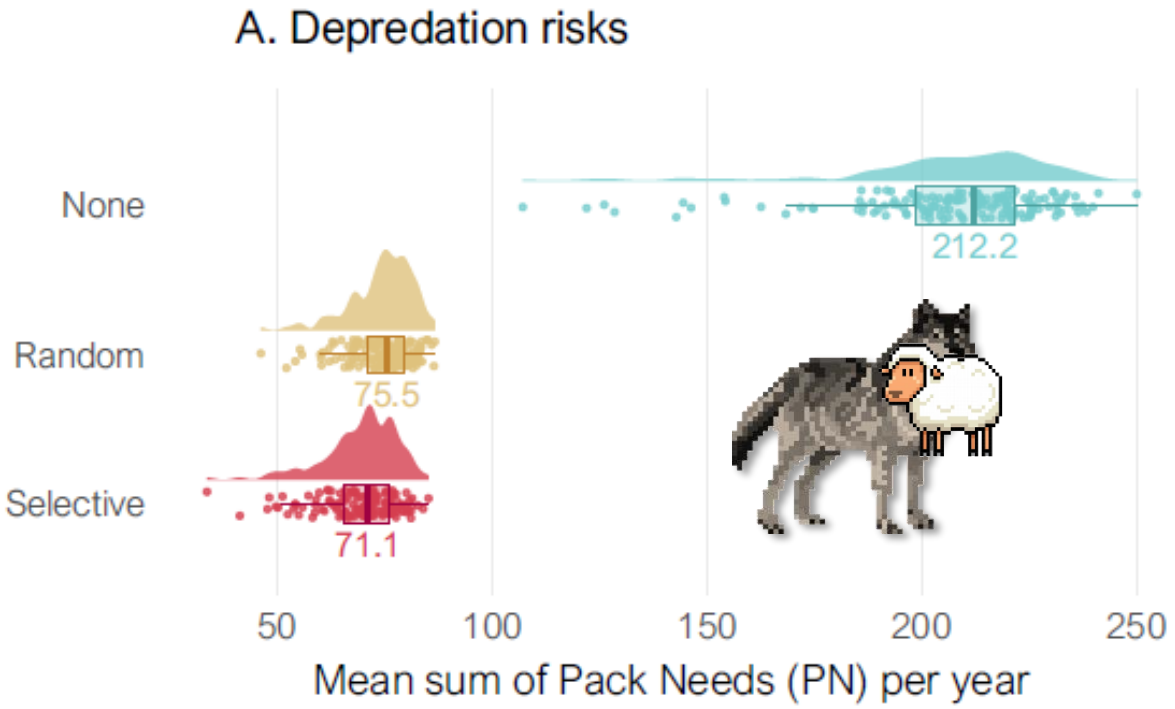
IBM X 150

SELECTIVE CULLING

IBM X 150

NO CULLING

IBM X 150



Simulating depredation and culling

RANDOM CULLING

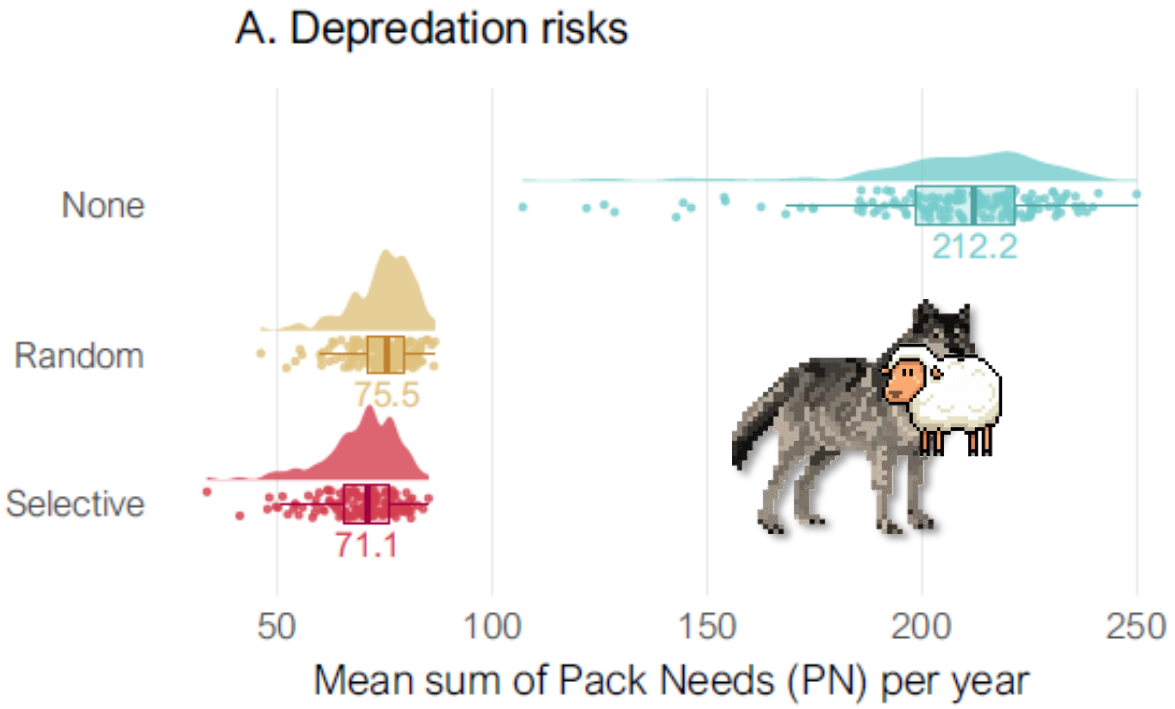
IBM X 150

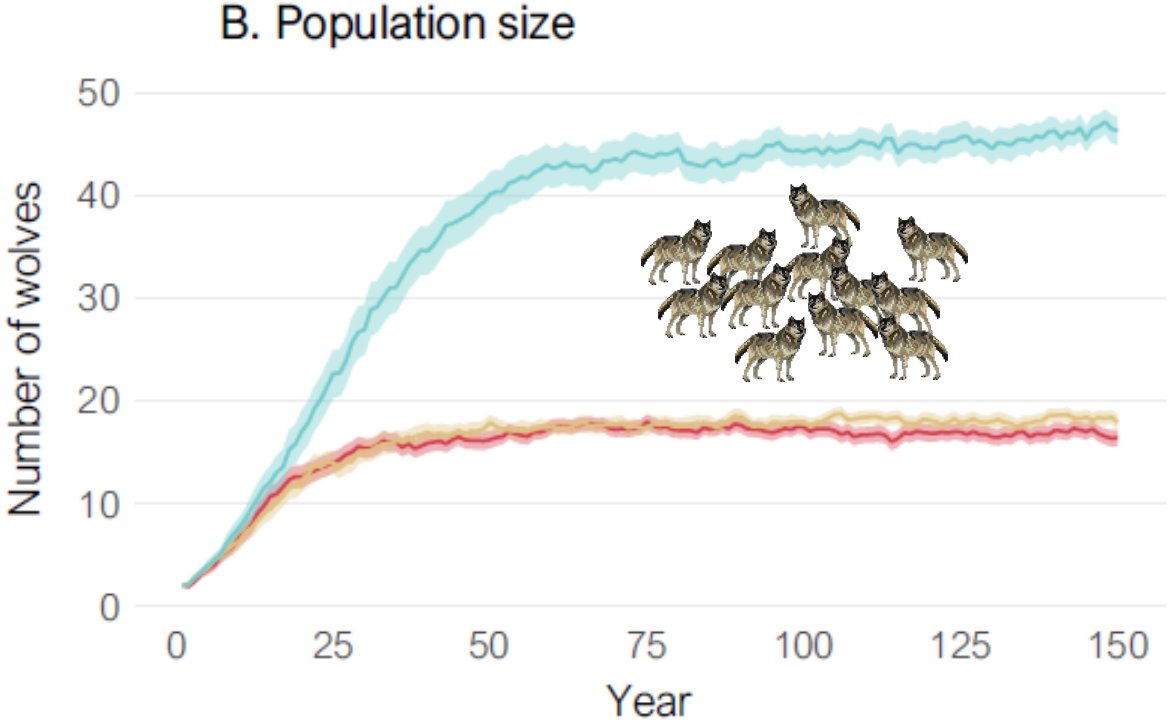
SELECTIVE CULLING

IBM X 150

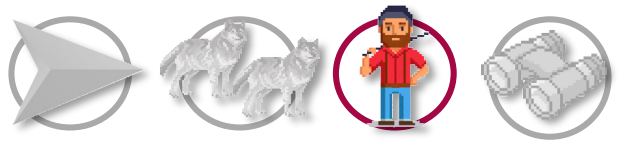
NO CULLING

IBM X 150





Simulating depredation and culling



RANDOM CULLING

IBM X 150

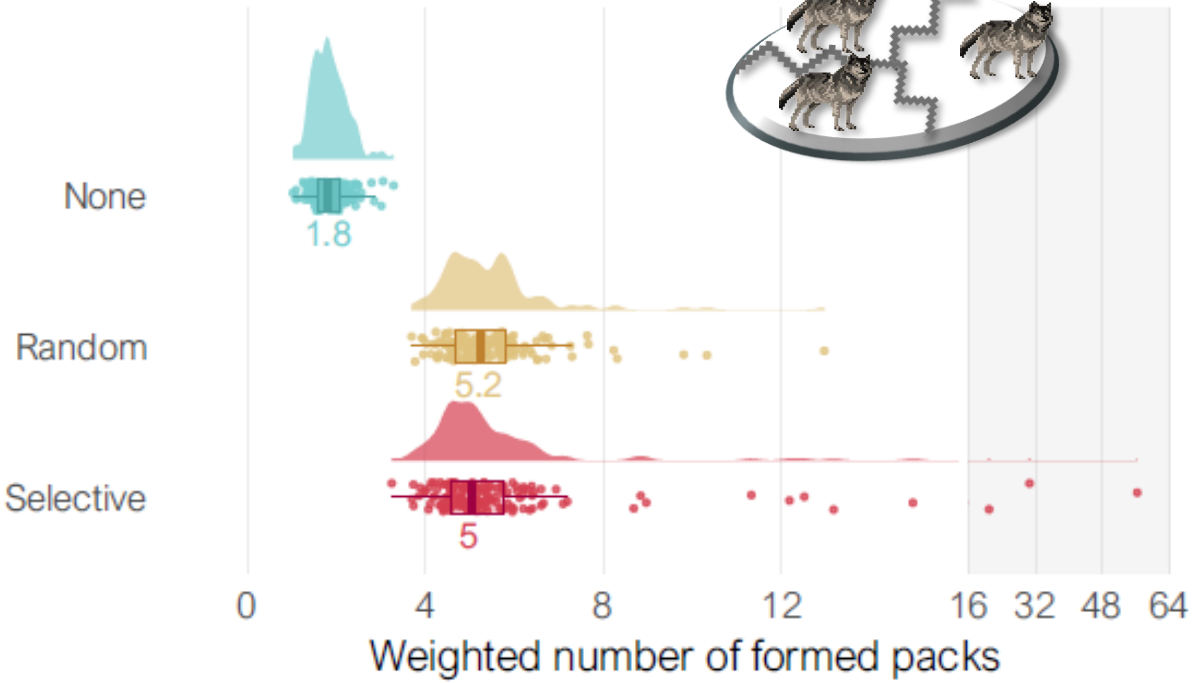
SELECTIVE CULLING

IBM X 150

NO CULLING

IBM X 150

C. Pack turnover



Simulating depredation and culling

RANDOM CULLING

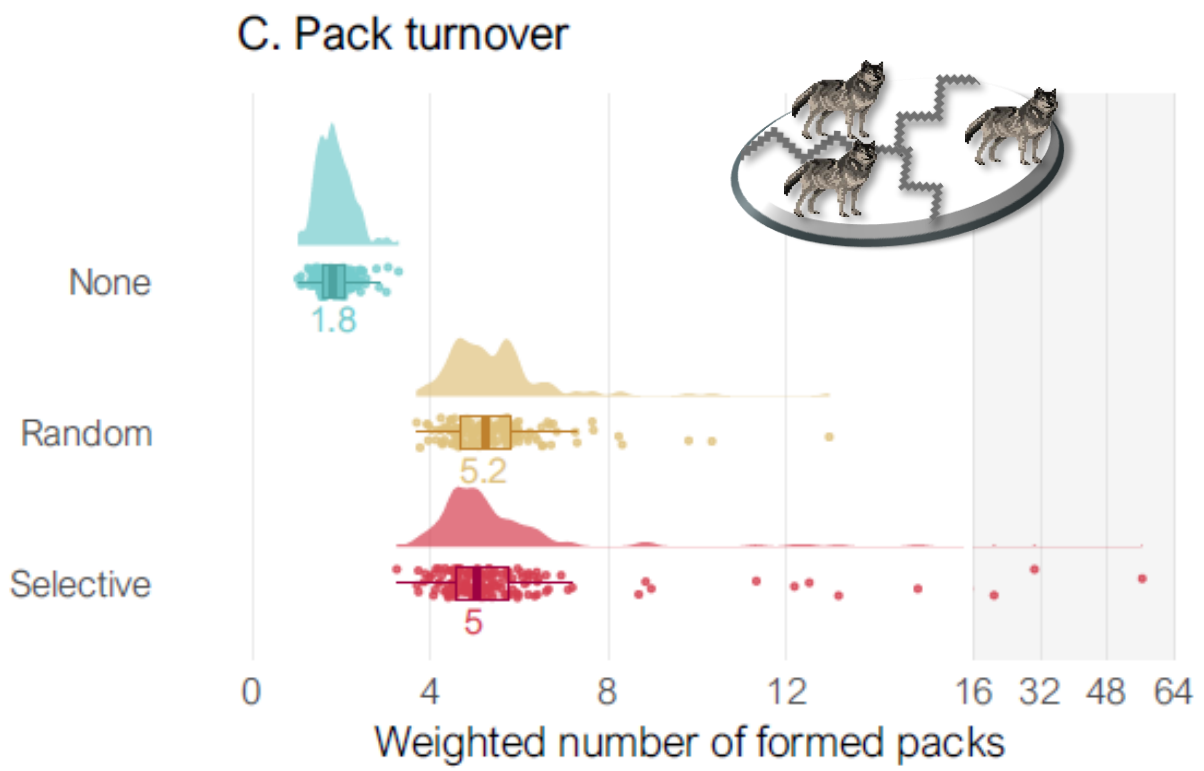
IBM X 150

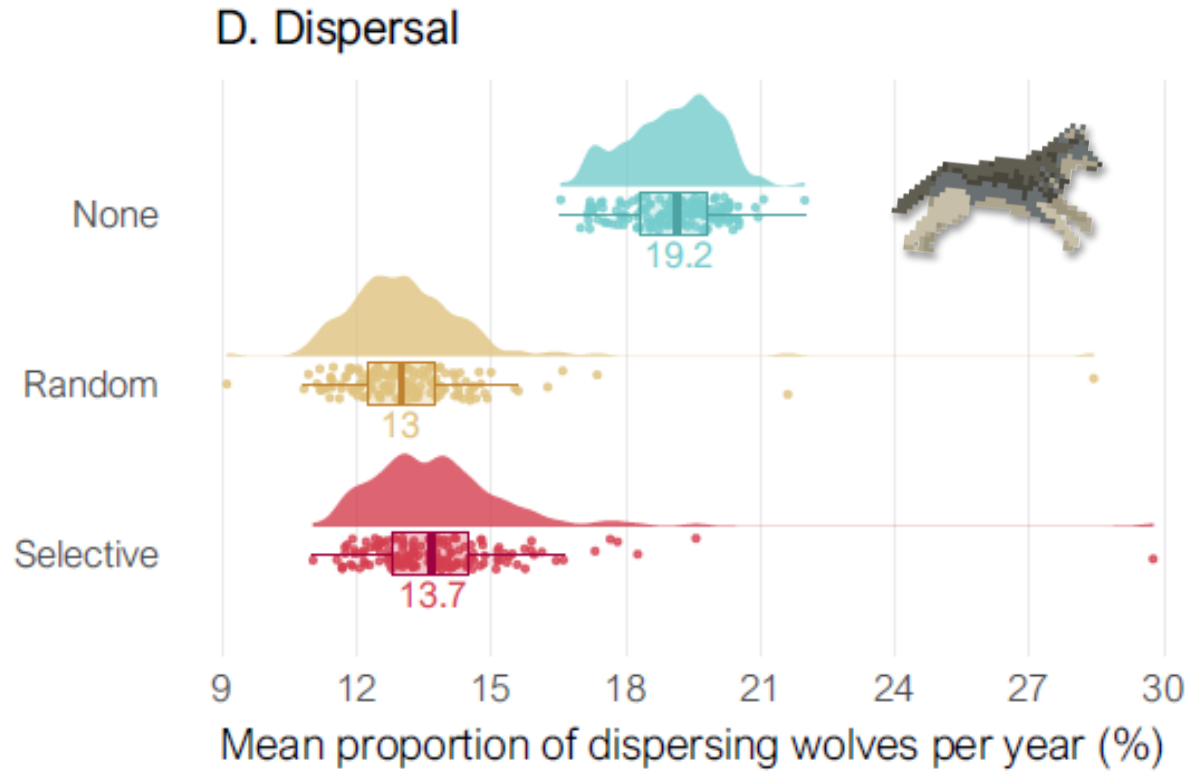
SELECTIVE CULLING

IBM X 150

NO CULLING

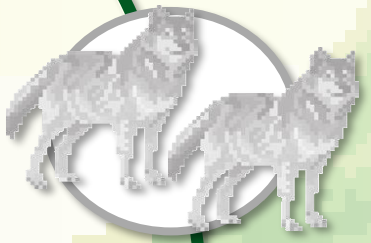
IBM X 150





SUMMARY

The point of INDIVIDUAL-BASED MODEL for wolf research

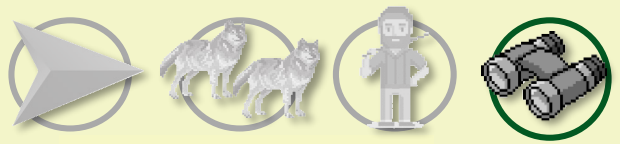


Modeling a wolf population

Simulating depredation and culling

Conclusion and perspectives

Conclusion and perspectives



INDIVIDUAL-BASED MODELS ...

- are highly flexible to study population dynamics, especially for social species
- can help us to catch population-level mechanisms that are hard to understand with correlation approach
- provided interesting insights about culling effects on wolf population dynamics
- are mostly research tools but can be useful in certain well-informed contexts for management

Conclusion and perspectives

OUR WOLF INDIVIDUAL-BASED MODEL

Ecological Modelling 433 (2020) 109209

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An individual-based model to explore the impacts of lesser-known social dynamics on wolf populations

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Keywords:
Gray wolf
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Population projection
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ABSTRACT

The occurrence of wolf populations in human-dominated landscapes is challenging worldwide because of conflicts with human activities. Modeling is an important tool to project wolf dynamics and expansion, and help in decision making concerning management and conservation. However, some individual behaviors and pack dynamics of the wolf life cycle are still unclear to ecologists. Here we present an individual-based model (IBM) to project wolf populations while exploring the lesser-known processes of the wolf life cycle. IBMs are bottom-up models that simulate the fate of individuals interacting with each other, with population-level properties emerging from the individual-level simulations. IBMs are particularly adapted to represent social species such as the wolf that exhibits complex individual interactions. Our IBM projects wolf demography including fine-scale individual behavior and pack dynamics based on up-to-date scientific literature. We explore four processes of the wolf life cycle whose consequences on population dynamics are still poorly understood: the pack dissolution following the loss of a breeder, the adoption of young dispersers by packs, the establishment of new packs through budding, and the different breeder replacement strategies. While running different versions of the IBM to explore these processes, we also illustrate the modularity and flexibility of our model, an asset to model wolf populations experiencing different ecological and demographic conditions. The different parameterization of pack dissolution, territory establishment by budding, and breeder replacement processes influence the projections of wolf populations. As such, these processes require further field investigation to be better understood. The adoption process has a lesser impact on model projections. Being coded in R to facilitate its understanding, we expect that our model will be used and further adapted by ecologists for their own specific applications.

1. Introduction

The gray wolf (*Canis lupus*) has been extirpated from most of the globe during the last century due to its competition with humans for wild prey, depredations on livestock and general persecution (Ripple et al., 2014). Most of the remaining populations were considered endangered in the early 20th century (Mech and Boitani, 2003). However, numerous wolf populations are now under protection regimes and management actions favor species persistence or comeback (Chapron et al., 2014). Even though the presence of this large carnivore may play an important role in maintaining a healthy ecosystem and increase biodiversity, its recolonization is challenging. For example, the impact wolves exert on human activities such as livestock farming (Kaczensky, 1999; Lute et al., 2018), or the increasing threat of hybridization with dogs in human-dominated landscapes (Pilot et al., 2018; Randi, 2011; Randi et al., 2014) require informed and effective management of the populations (Hindrikson et al., 2017). Management interventions may involve control of wolf populations through legal killings (Bradley et al., 2015; Harper et al., 2008; Santiago-Avila et al., 2018) or non-lethal management options (McManus et al., 2015; Treves et al., 2016) such as sterilization of breeders (Donfrancesco et al., 2019; Haight and Mech, 1997). In order to inform

Abbreviations: IBMs, individual-based models; ID, identity; Fig., Figure; ODD, Overview, Design concepts, and Details; popDensStd, wolf density per 1000 km² standardized with mean and standard deviation from Cubaynes et al. (2014); sd, standard deviation

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Conclusion and perspectives

OUR WOLF INDIVIDUAL-BASED MODEL

Wildlife Biology

WILDLIFE BIOLOGY Open Access — A JOURNAL FOR WILDLIFE SCIENCE

Evaluating the effects of wolf culling on livestock predation when considering wolf population dynamics in an individual-based model

Journal:	*Wildlife Biology*
Manuscript ID	Draft
Wiley - Manuscript type:	Research Article
Keywords:	Canis lupus, damages, integrated model, lethal removal, pack turnover, simulation
Abstract:	The efficiency of the management of predations on livestock by gray wolves (Canis lupus) through culling is under debate. Evaluating wolf culling efficiency requires to simultaneously analyze the effects of culling on the wolf population and the repercussions of these population changes on livestock predation. This protocol is technically difficult to implement in the field. To properly assess culling efficiency, we provide an integrated and flexible individual-based model that simulates interactions between wolf population dynamics, predation behavior and culling management. We considered a large number of social processes in wolves and we calibrated the model to match the Western Alps. The wolf predation behavior on livestock is highly context dependent and still remains poorly understood at the individual level. By considering the opportunistic nature of wolves and the prey community in the Alps, we assumed that predation on livestock increased with pack food needs. Under this assumption and considering that predation behavior only relied on wolves' characteristics, culling maintained wolf population size and predation risks at low levels. Contrary to what was expected, culling decreased the mean annual proportions of dispersing wolves in our simulations, by increasing settlement speed. This population-level mechanism compensated for high rates of mortality and for pack instability caused by culling. Our model gives insights about culling efficiency in one specific simulated context, but we do not expect that our assumptions about predation behavior are correct for the whole area of the Western Alps. Therefore, we encourage further explorations of the model to explore other assumptions about wolf predation behavior and the strength of compensatory mechanisms to breeder loss.

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Conclusion and perspectives

THANK YOU!

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