united nations educational, scientific and cultural organization

international atomic energy agency

the
abdus salam
international centre for theoretical physics

H4.SMR/1202-9

"Fifth Course on Mathematical Ecology
including and introduction to Ecological Economics"

28 February - 24 March 2000

HARVESTING POLICIES AND CONSERVATION

*Giulio De Leo, * M. Gatto*

Universita' di Parma
Dipartimento di Scienze Ambientali
Parma, Italy

* Politecnico di Milano
Milano

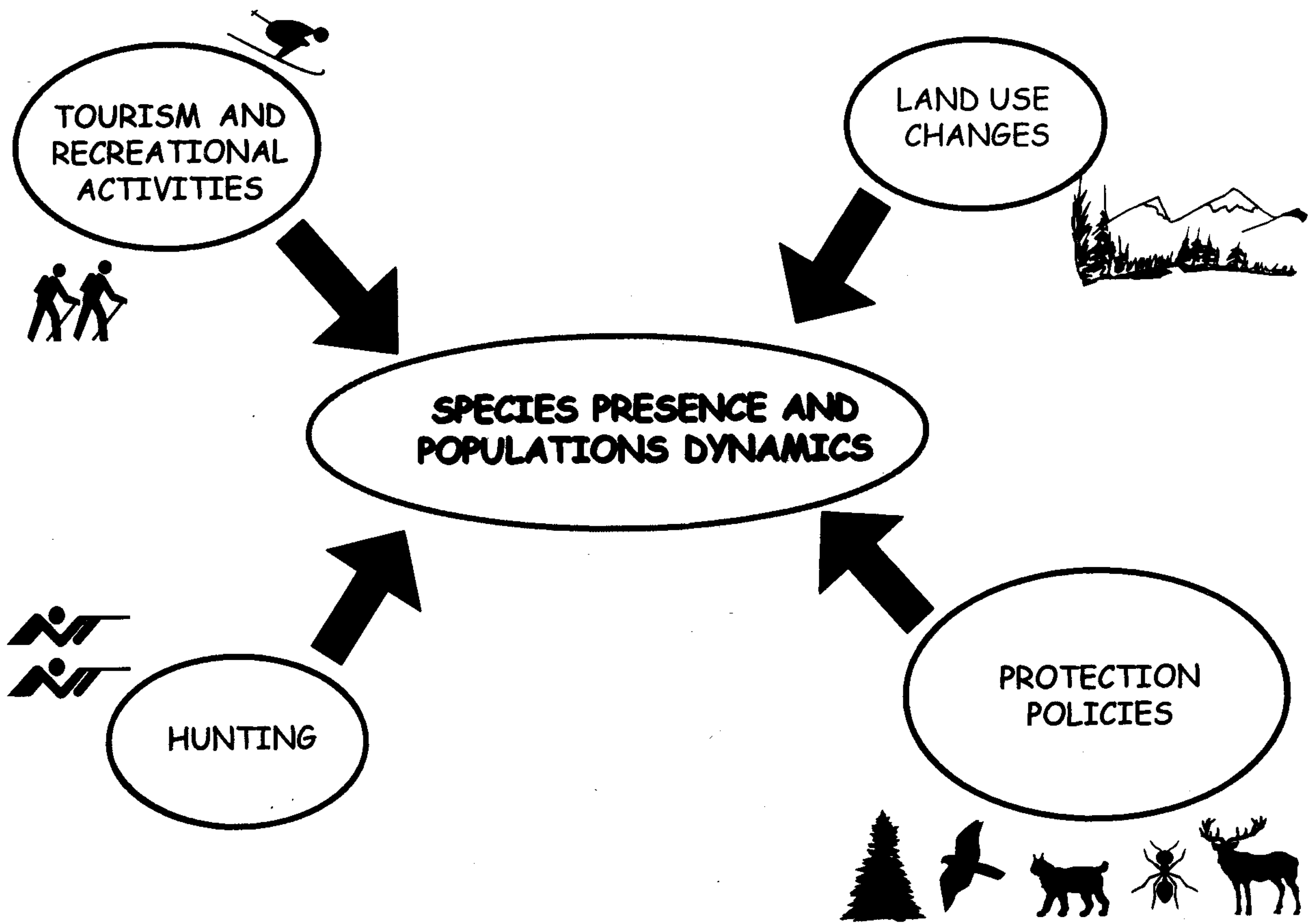
Harvesting Policies and Conservation

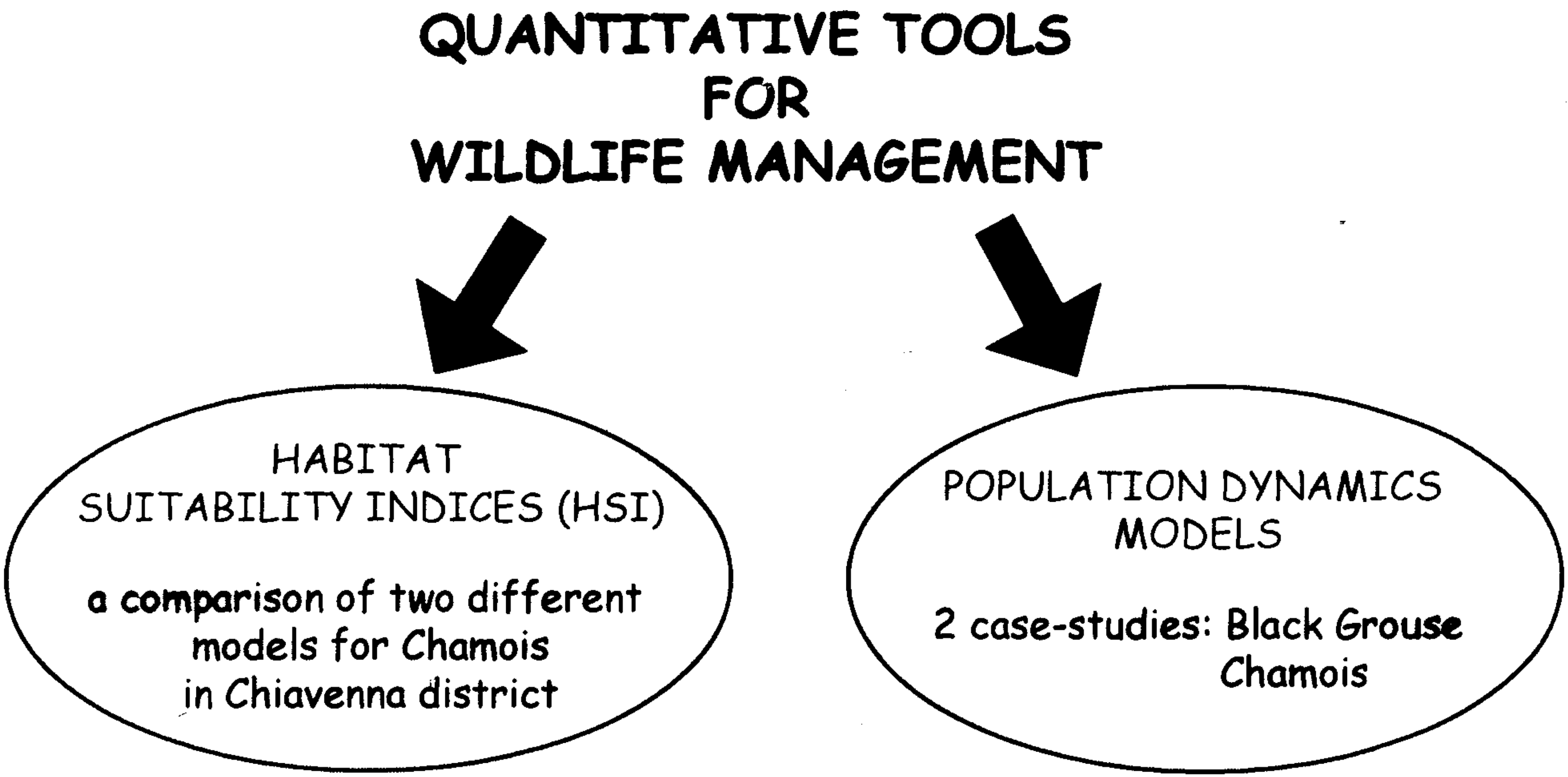
G. De Leo

Univ. degli Studi di Parma

M. Gatto

Politecnico di Milano

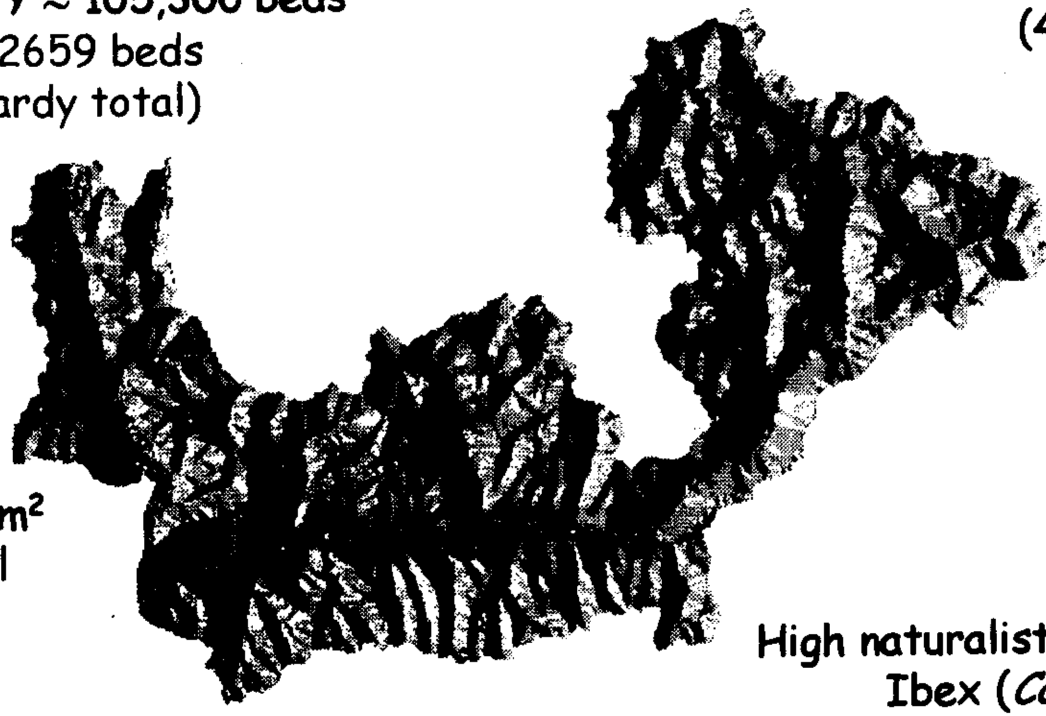

TOURISM AND RECREATIONAL ACTIVITIES
LAND USE CHANGES
SPECIES PRESENCE AND POPULATIONS DYNAMICS
HUNTING
PROTECTION POLICIES


QUANTITATIVE TOOLS
FOR
WILDLIFE MANAGEMENT
HABITAT
SUITABILITY INDICES (HSI)
a comparison of two different
models for Chamois
in Chiavenna district
POPULATION DYNAMICS
MODELS
2 case-studies: Black Grouse
Chamois

SONDRIO PROVINCE

INHABITANTS ≈ 177,300
TOURISTIC CAPACITY ≈ 105,300 beds
56 HUTS with 2659 beds
(56% of Lombardy total)

2749 HUNTERS in 1997
(4771 in 1978)



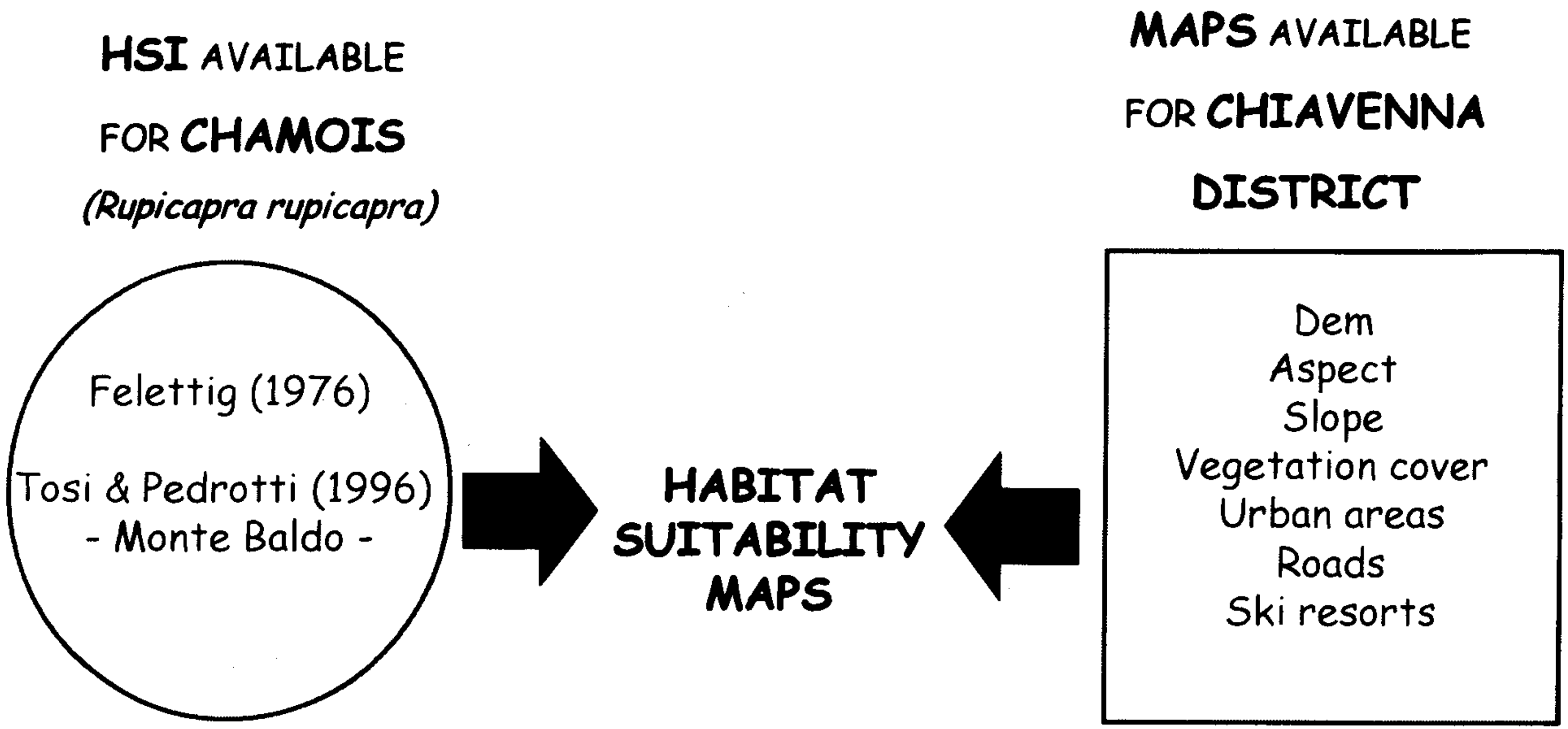
TOTAL AREA = 3212 Km^2
70 % above 1,500 a.s.l

PROTECTED AREAS
20% of total area

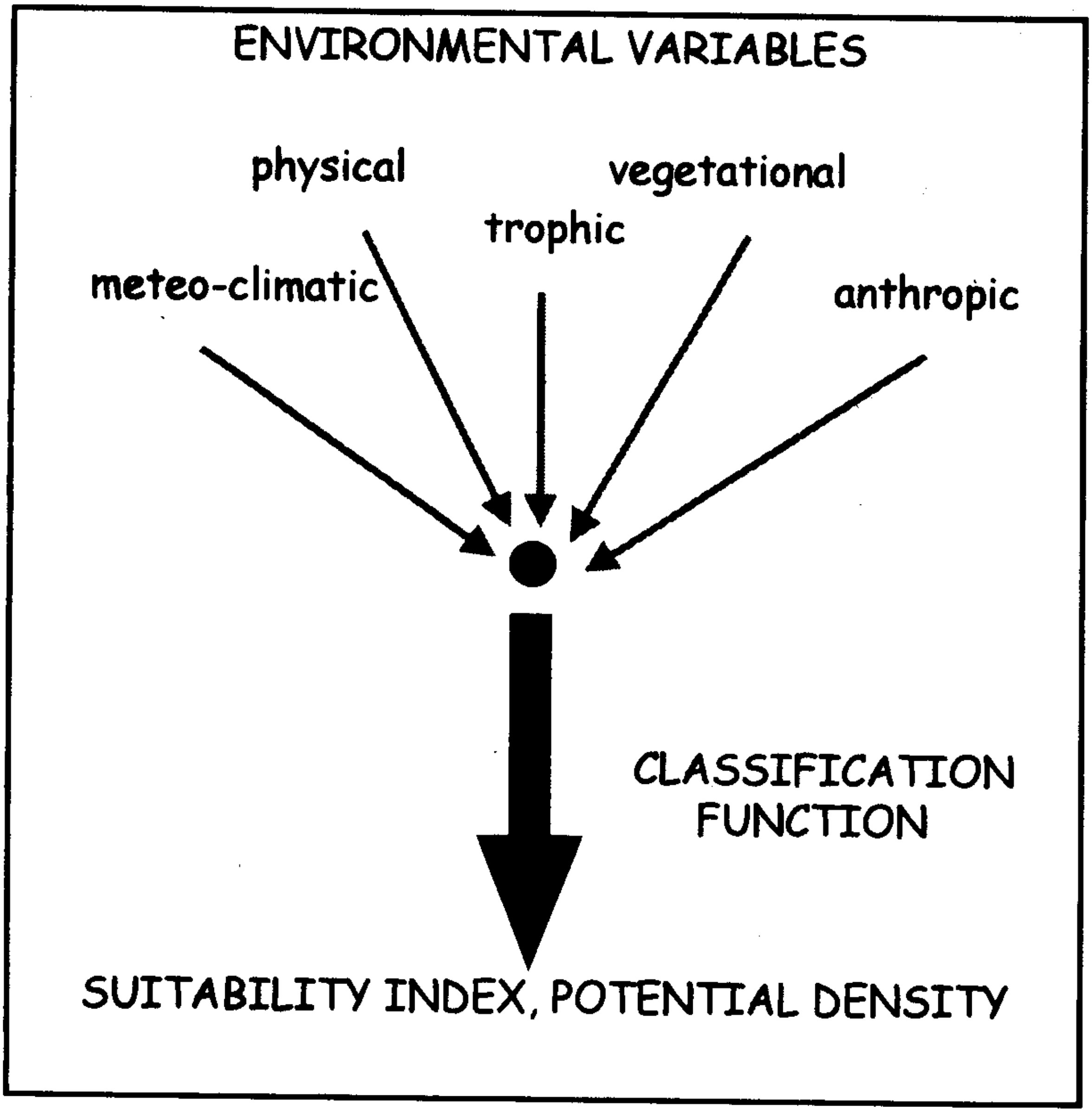
High naturalistic value species:
Ibex (*Capra ibex*)
Capercaillie (*Tetrao urogallus*)
Bearded vulture (*Gypaetus barbatus*)

USING VVF SOFTWARE

(Ranci Ortigosa, De Leo & Gatto, 1997)



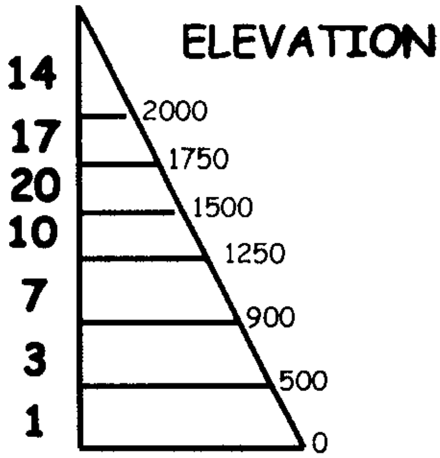
HABITAT SUITABILITY INDICES (HSI)

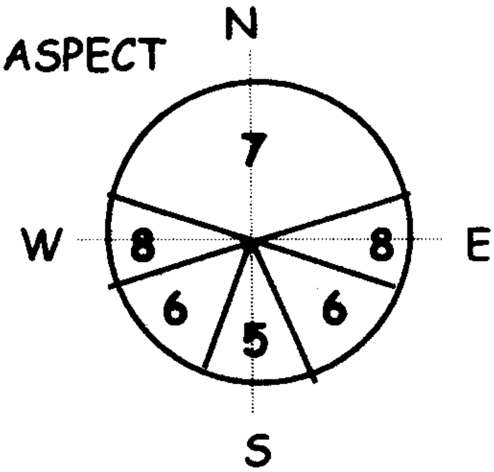


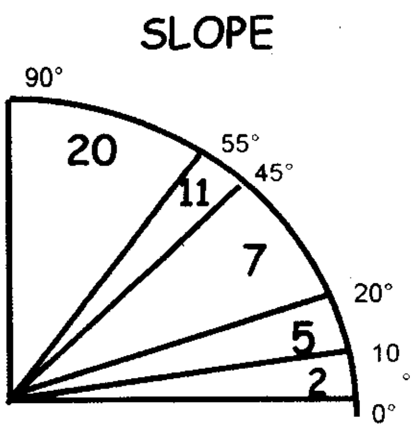
HSI for CHAMOIS

Monte Baldo

(Tosi & Pedrotti, 1996)







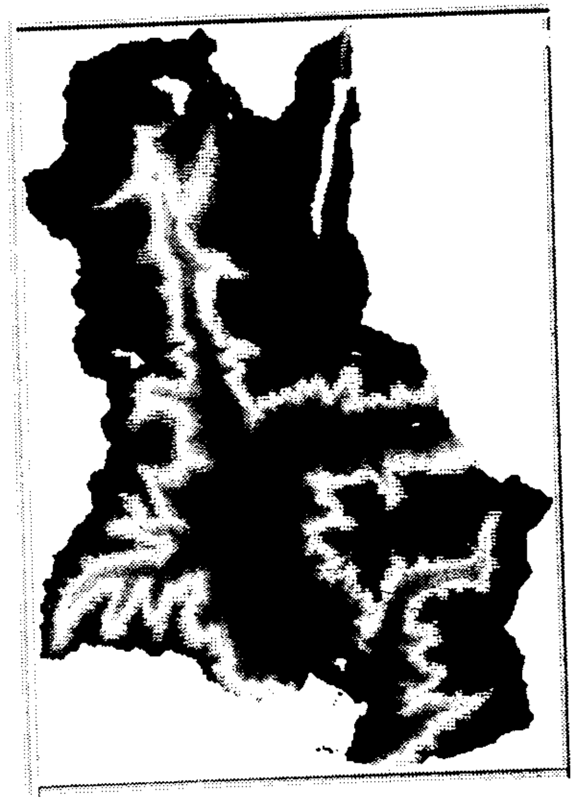
VEGETATION

Vegetazione rupestre e roccia nuda	18
Macereto	16
Prateria discontinua	20
Prateria continua	17
Mughete	14
Ontaneti	16
Arbusteti (escluse mughete ed ontaneti)	7
Pascolo alberato	14
Pascolo in bosco	12
Prati e prati-pascoli	4
Boschi di conifere con abete rosso e larice	11
Faggete	8
Pinete a pino nero	4
Bosco di carpino e orniello (orno-ostrieto)	6
Bosco di roverella e leccio	2
Boschi di castagno	4
Paludi, aree antropiche, coltivi	0

$$HSI = SI_{elevation} + SI_{aspect} + SI_{slope} + SI_{vegetation}$$

MAPS of CHIAVENNA DISTRICT

DEM



Vegetation

Urban areas, roads, ski resorts

Scale: 

COMPARISON OF 2 HSI MODELS

Pedrotti & Tosi (1996)

Felettig (1976)

non adatto
adatto (1-4 capi 100/ha)
buono (>4 capi 100/ha)

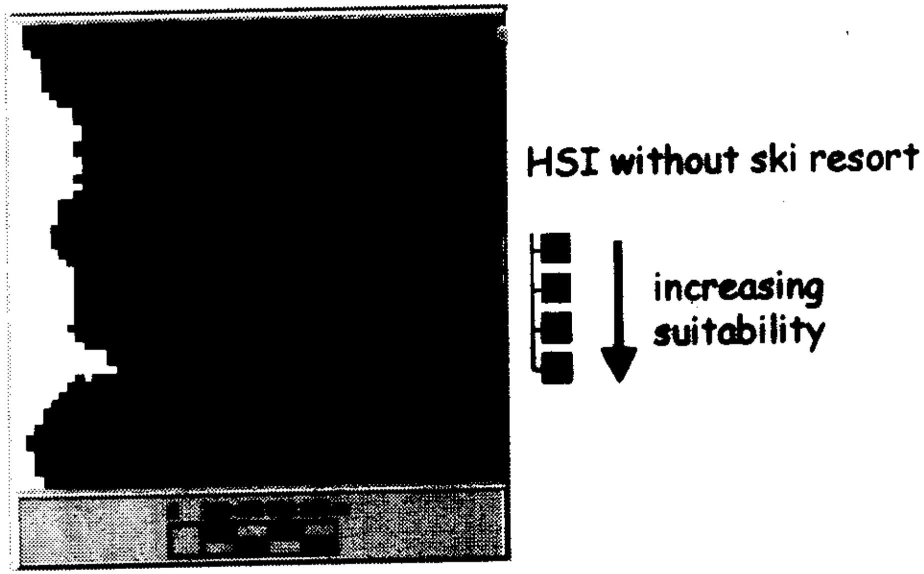
Map of differences

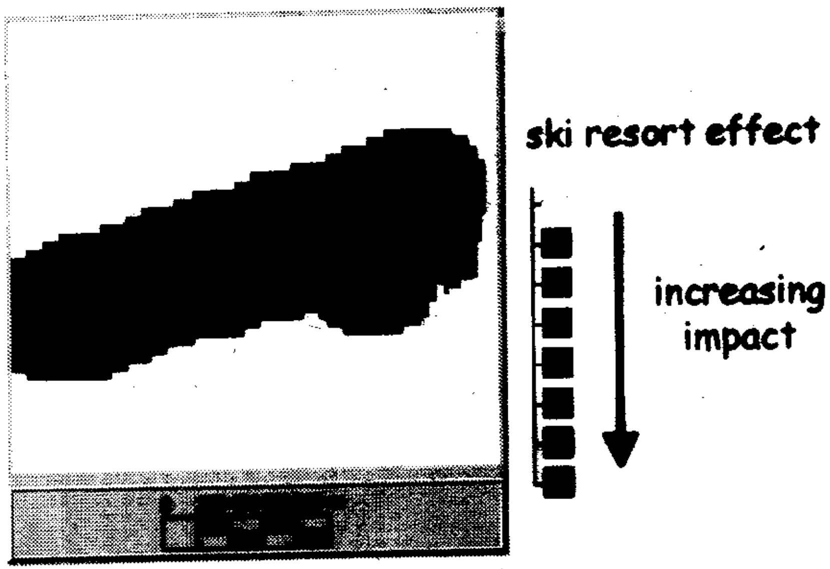
poco differente
molto differente

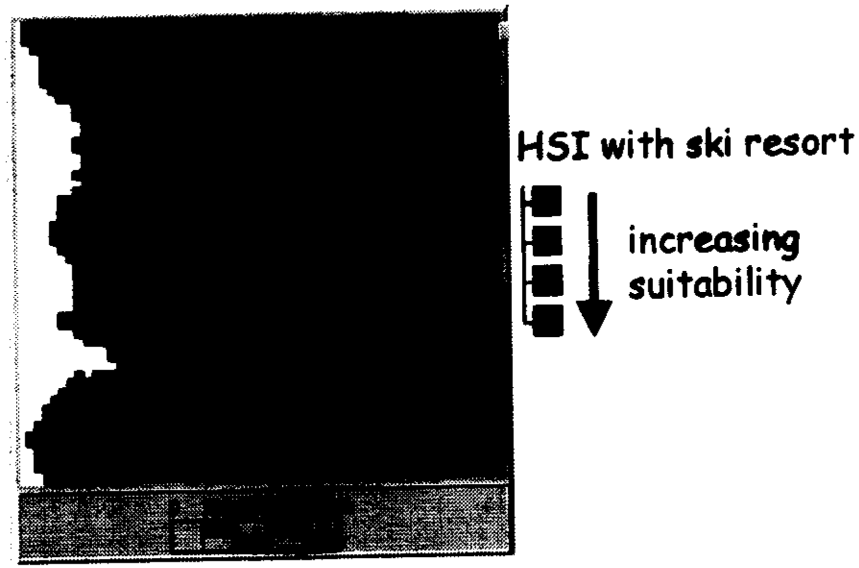
Potential abundance: 1983 chamois   1927 chamois

Abundance in 1997: 598 chamois

EFFECT OF HUMAN IMPACT: construction of a new ski resort



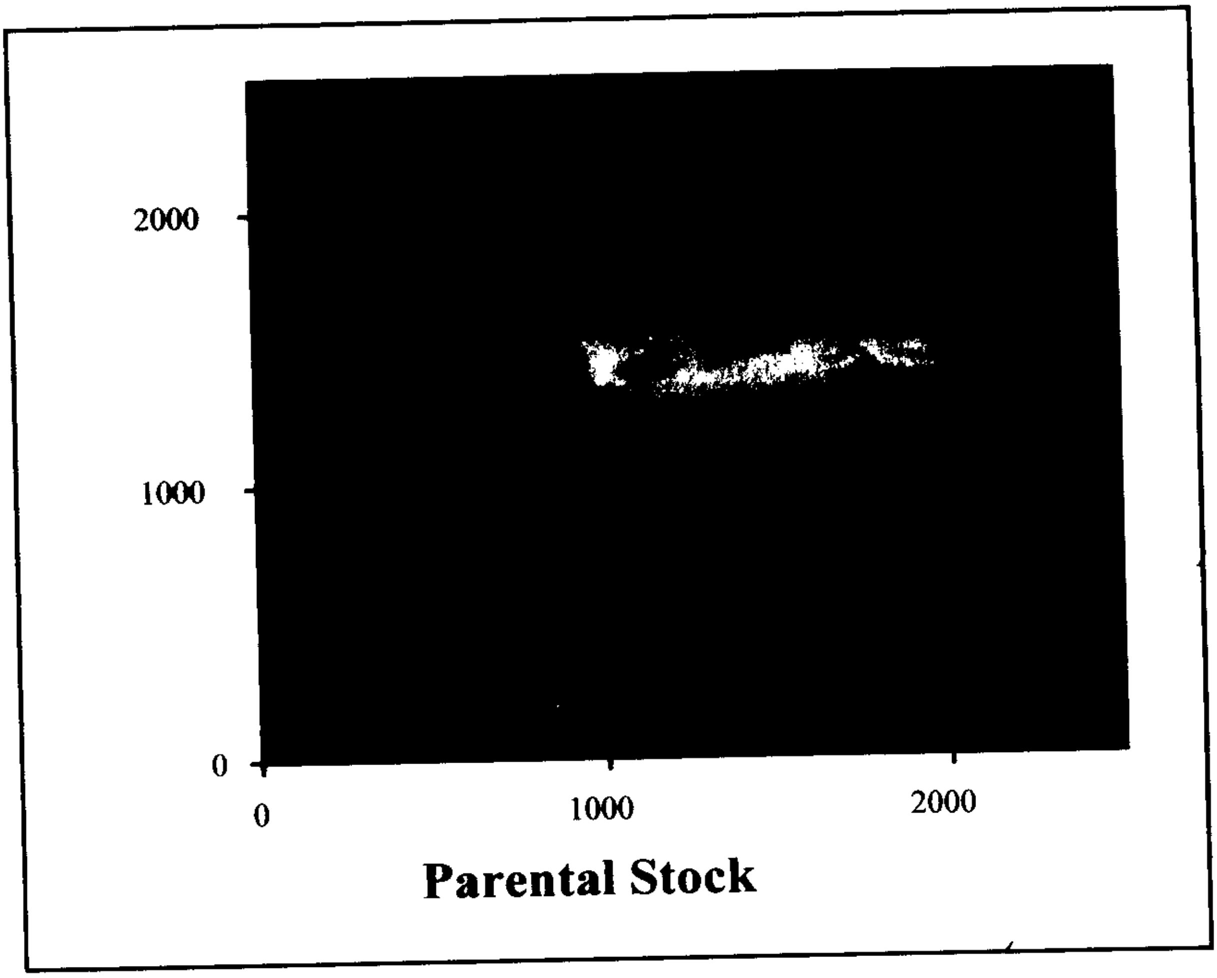




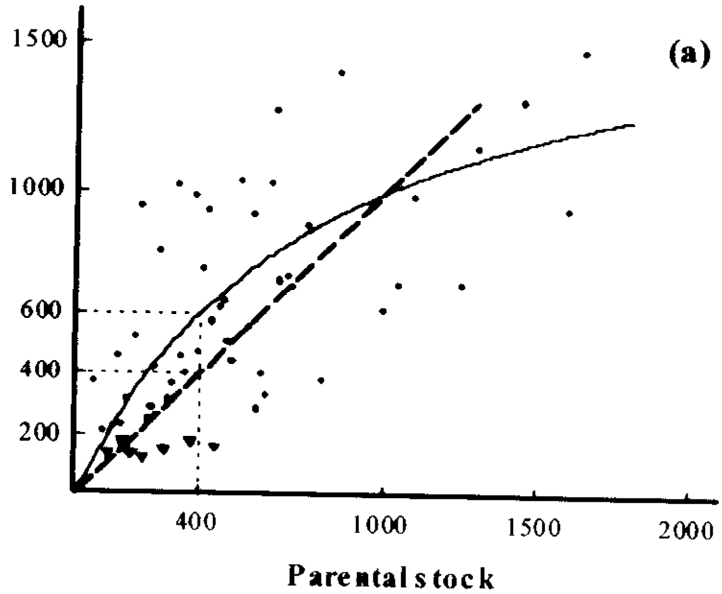
A definition of sustainability

- To maintain yield in the long run (MSY)
- To maintain the abundance of populations and the conservation of biodiveristy
- to maintain economic development without compromising existing resources with respect of future generations

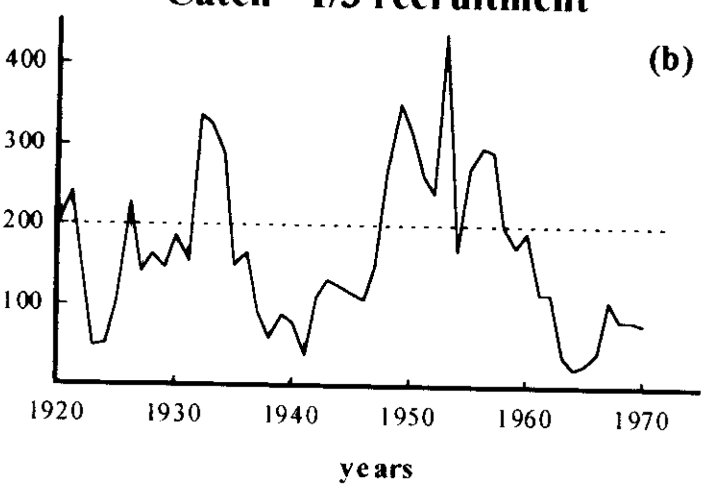
Sustainable Yield



Environmental Variability



Catch= 1/3 recruitment



Quota = 200 Extinction!!

Population Viability Analysis

PVA is a procedure to assess the likelihood that a population will become extinct within a certain time and under different management options.

Factors that can cause extinction

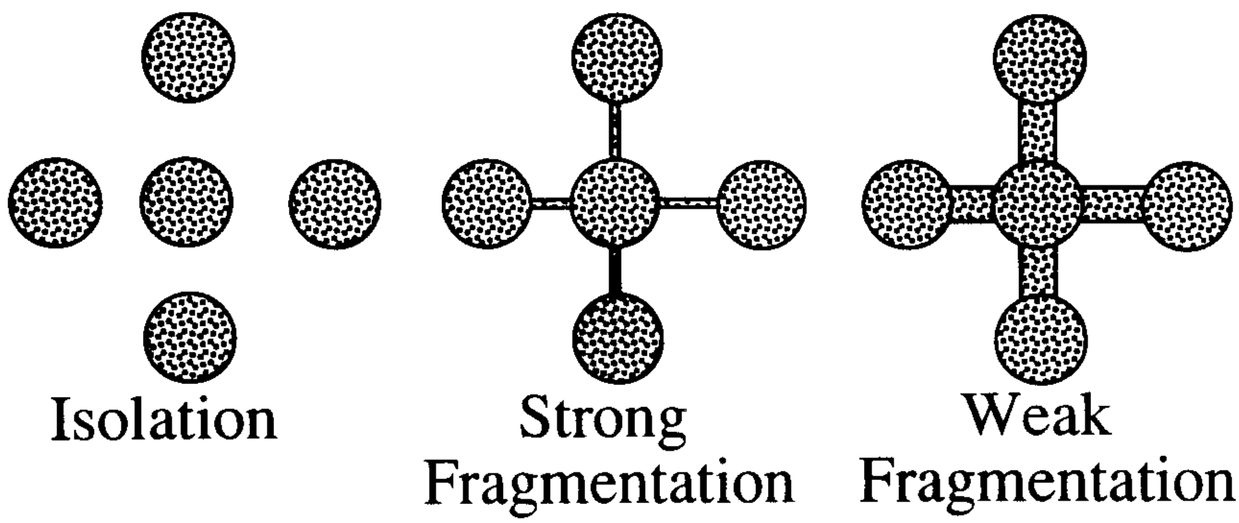
1. Endogenous
   - Random demographic changes
   - Social and/or behavioral dysfunction
   - Genetic drift and inbreeding

2. Exogenous
   - Chronic environmental factors such as habitat alteration, increased predation and competition, disease
   - Acute environmental stress or catastro-phes such as fires, floods, epidemics

In practice PVA is performed by running suitable simulation models of the population dynamics

KEY CONCEPTS IN PVA

- Probability of extinction within a certain time, median extinction time, distribution of extinction times
- Demographic stochasticity (the size of small populations must be treated as an integer number) vs. environmental stochasticity
- Quasi-extinction defined via a threshold below which the fate of the population is very uncertain due to inbreeding, Allee effect, demographic stochasticity, etc.
- Geographic structure in terms of metapopulations of differently connected local populations



Some key concepts of PVA

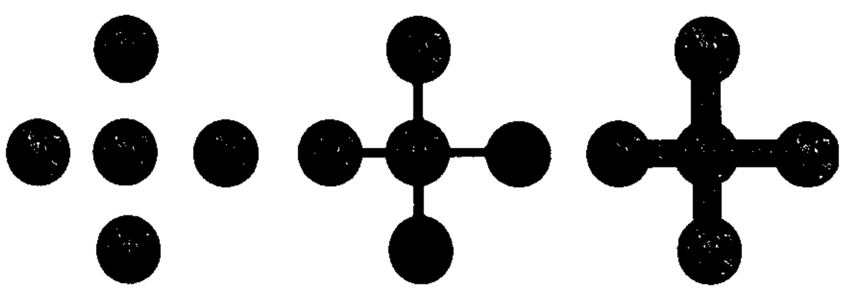
- **Environmental Variability and unpredictable exogenous factors**
  → stochastic demographic models

- **Demographic stochasticity, Allee effect, inbreeding… → individual based models;**
  → quasi-extinction threshold

- **Analysis of the risk of extinction (PVA) under different management scenarios:**
  - Probability of extinction within *T* years
  - median time of extinction
  - Prob. Den. Distr. of extinction time

- Existence of multiple objectives
  → multi-criteria optimization

- Geographic structure of the population,
  → metapopulations of differently connect local populations



A Population Viability Analysis of the grey partridge (*Perdix perdix*) in Europe

Giulio A. De Leo
Politecnico di Milano, Milano, Italy
Stefano Focardi
Istituto Nazionale per La Fauna Selvatica, Bologna, Italy
Marino Gatto
Politecnico di Milano, Milano, Italy
Isabella Cattadori
Centro di Ecologica Alpina, Monte Bondone (Trento), Italy

GLOBAL DENSITY TRENDS

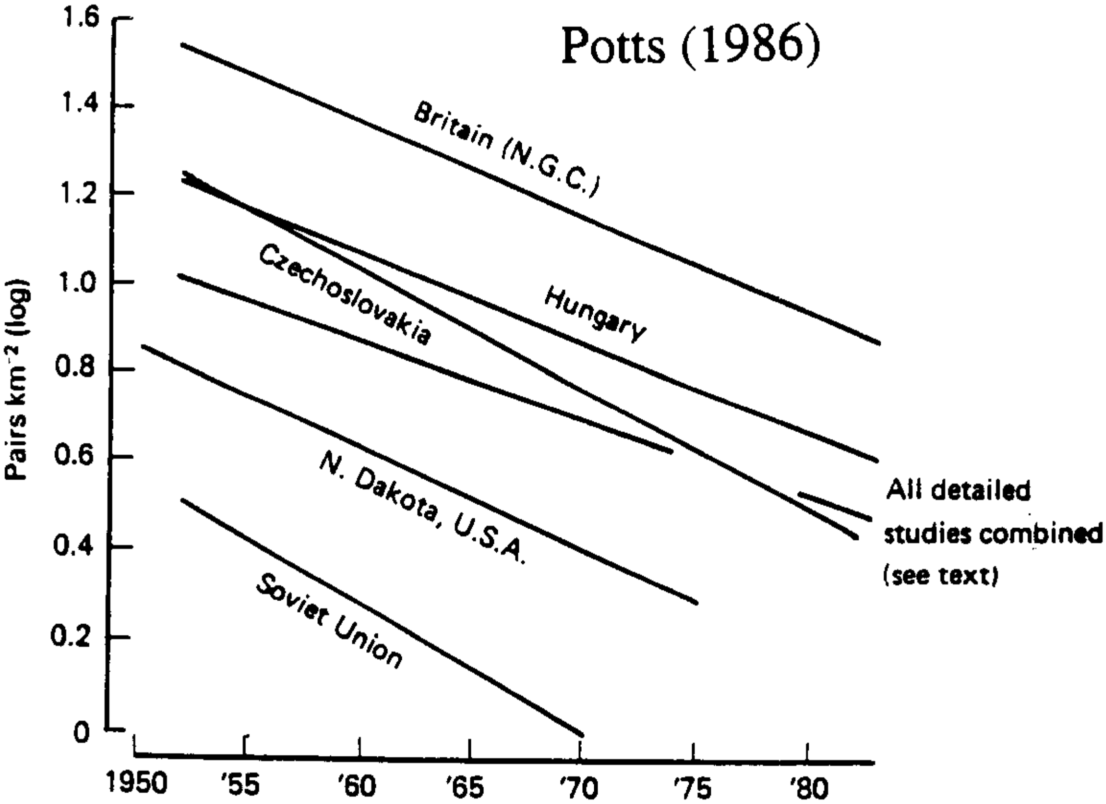
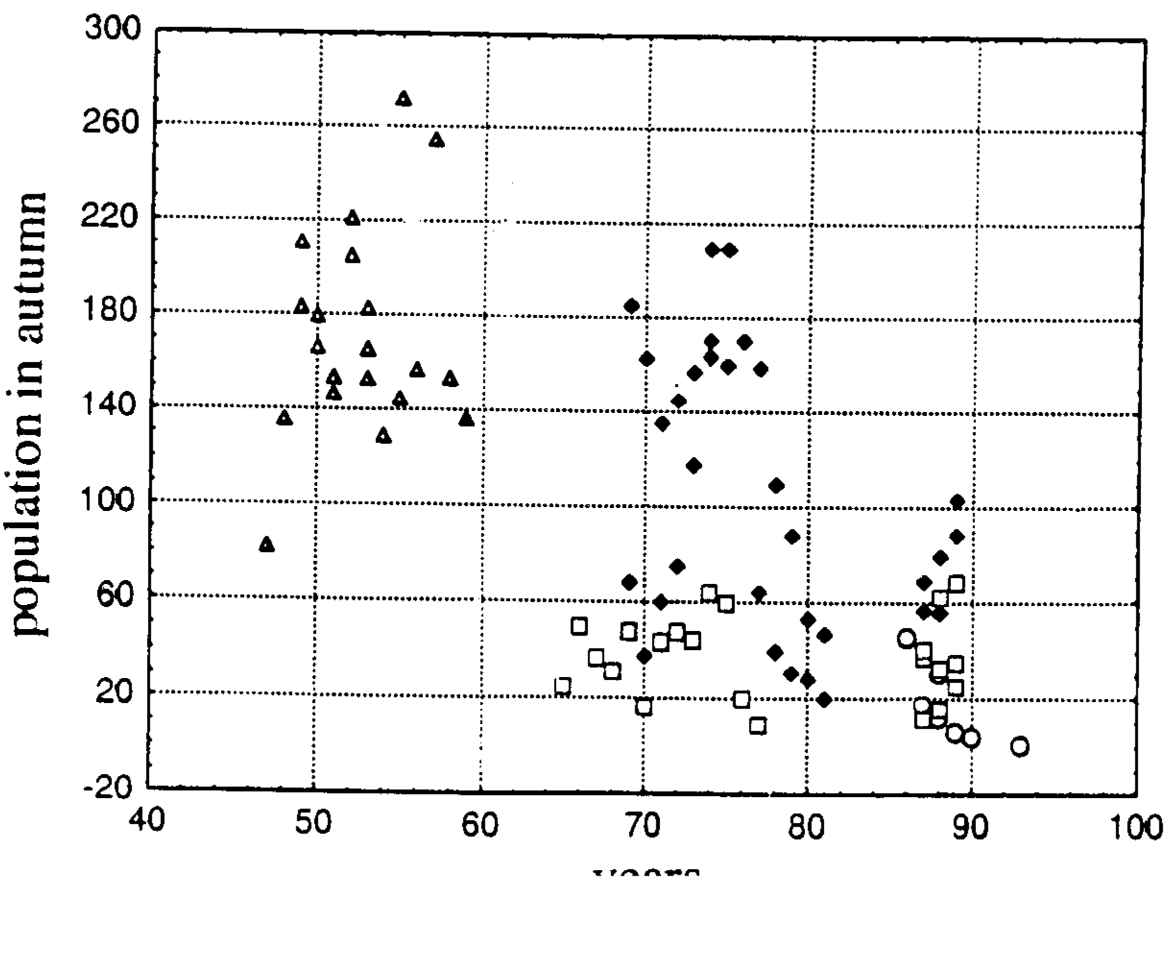


Fig. 2.5 The trend in density of breeding pairs km^{-2} over the period 1952 to 1985 for various regions of the world range.



CAUSES OF DECLINE IN SUSSEX

Potts (1986) published the results of a long-term study conducted by the Game Conservancy in Sussex. The decline seems to be caused by

- **Increased chick mortality** due to the use of pesticides that kill prey which are absolutely necessary for survival during the first weeks after hatching
- **Lower predator control by the gamekeepers**
- **Reduced protection against predators due to removal of hedges**

INTRODUCTION

- Until 1960 the grey partdridge (*Perdix perdix*) was one of the most important quarry species in both U.K. and continetal Europe

- The population decline in the last 30 years was dramatic: it becomes extinct in a large part of its previous range and population density of remaining populations is very low

- The studies performed in southern England by the Game Conservancy (cf. Potts 1986) pointed out the effect of **modern agriculture**:

  Agrochemicals reduce chicks survival

  The importance of **predator control** by gamekeepers

  The effect of **removal of edges** on bird survival

  However there are some **counter-examples** from France and Italy

  1) Some populations remain viable in areas of intensive agriculture

  2) Populations living in traditional landscapes became extinct

Aim of the work

- **Demographic analysis**
  - **to describe population dynamics of the gray partridge by explicitly including *environmental variability***
  - **to identify density dependent phenomena and/or compensation mechanisms**
  - **to identify demograpic differences among European populations**

- **Management and harvesting**
  - **to analyze the effect and the effectiveness of different management policies**
  - **Assess some of the most credited hypothesis on the decline of the gray partridge**

Material and method

- Data from different populations
  - Italy
  - France
  - Poland
  - England

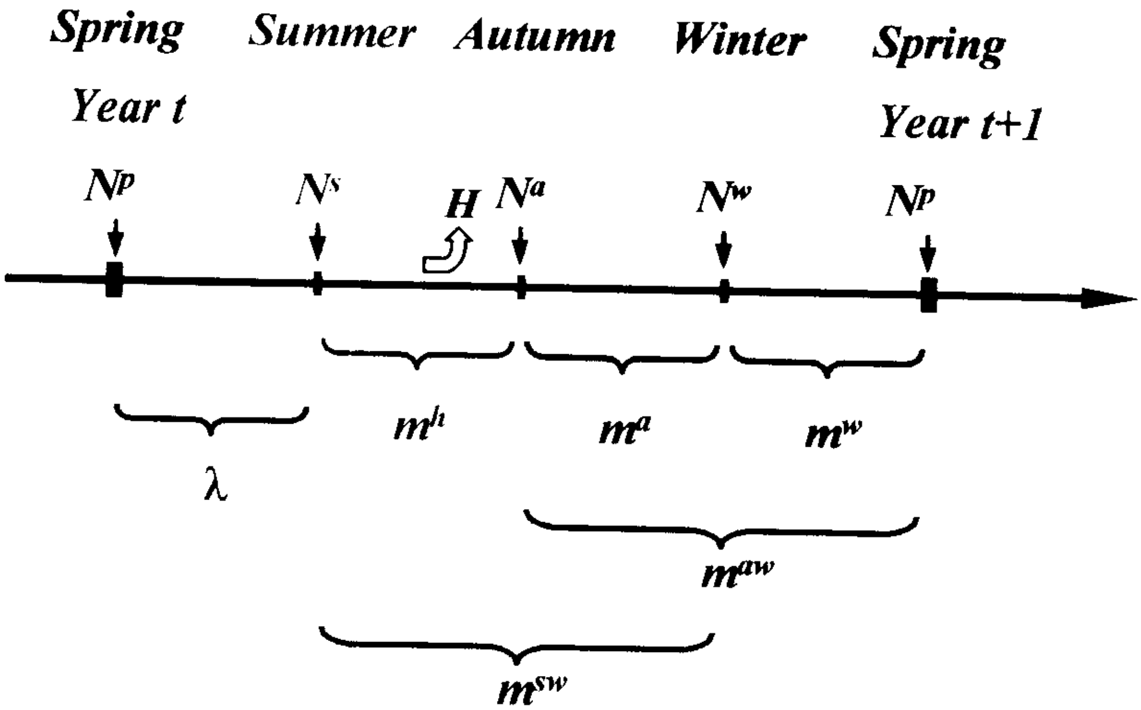
  between 1930 and 1990 (22 *papers*)

- Statistical analysis
  - summer period
  - autumn "
  - winter "
  - hunting season

- → Data has been pooled in two separate sets
  - Continental populations
  - British populations

- PVA under different scenarios

Main population variables and demographic rates



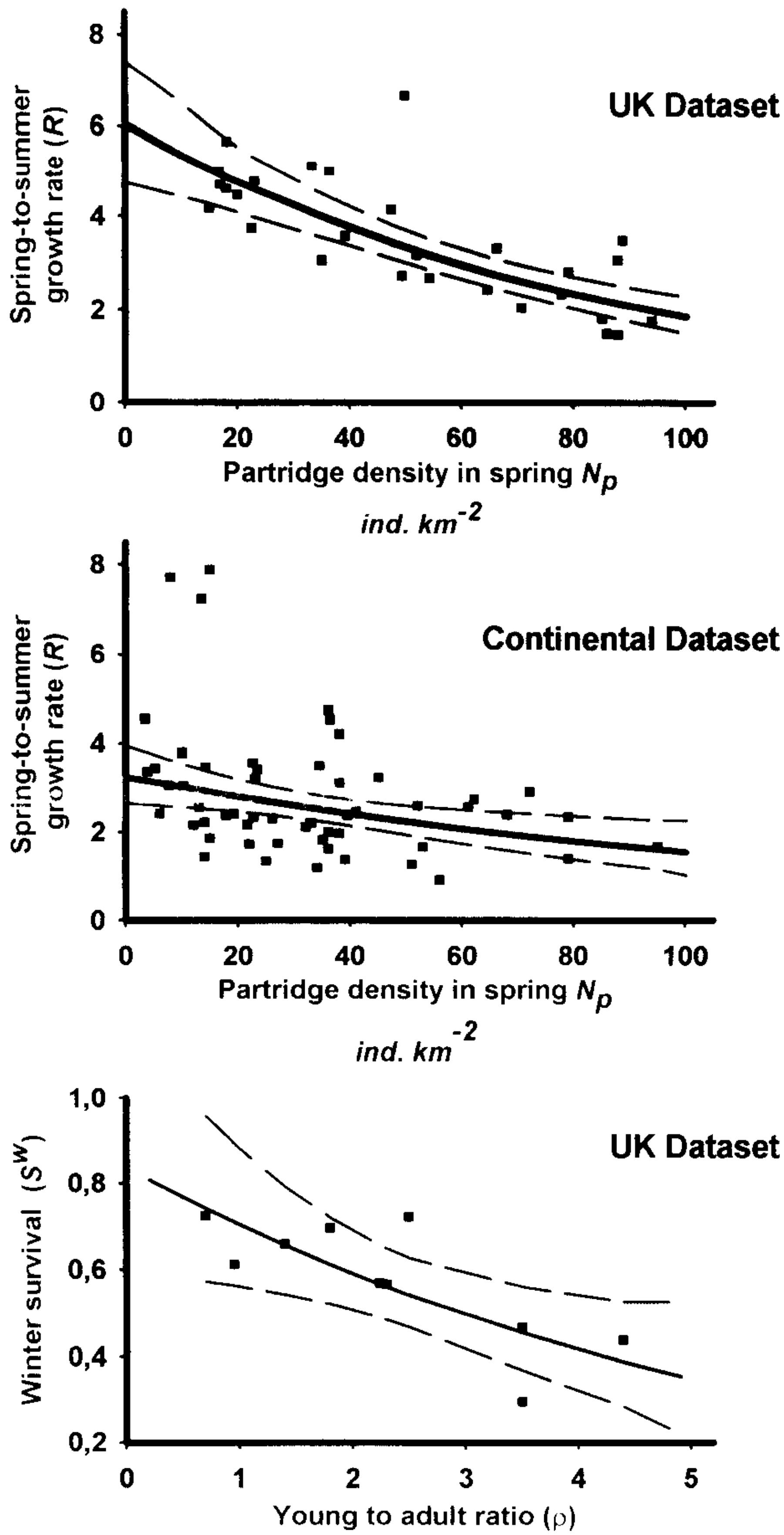
	Continental dataset (after 1965)		English dataset (before 1968)	
	Mean density ± St.Dev.	*# obs.*	*Mean density ± St.Dev.*	*# obs.*
N^p	26.3 ± 22.6	84	42.8 ± 29.3	39
N^s	77.0 ± 54.8	60	156.1 ± 68.1	28
N^a	69.4 ± 46.0	64	108.9 ± 47.3	21
N^w	7.2 ± 10.4	5	111.2 ± 19.9	16

	CONT. DATSET after 1965		UK DATASET before1968		
	Mean ± St. Dev.	# Obs.	Mean ± St. Dev.	# Obs.	Diff. UK – Continent
ρ	3.14 ± 159	41	2.73 ± 1.32	34	n.s.
λ	2.82 ± 1.45	56	3.56 ± 1.34	28	*
m^h	14.76 ± 21.28	51	25.29 ± 20.51	21	*
m^a	80.87 ± 27.56	5	11.15 ± 14.18	16	**
m^w	-	-	39.40 ± 12.33	15	-
m^{aw}	58.38 ± 21.27	49	50.77 ± 14.27	18	n.s.

n.s.: $p>0.05$, *: $0.01<p\leq0.05$, **: $p\leq0.001$

REGRESSION	Continent	UK
$ln\ \lambda$ *vs.* N^p	$-0.00735 \pm .0026$ ** (d.f.=49)	-0.0118 ± 0.002 ** (d.f.=26)
$ln\ \sigma^a$ *vs.* N^a	n.s.	-0.003 ± 0.0011 ** (d.f.=19)
$ln\ \sigma^{aw}$ *vs.* N^a	-0.002 ± 0.001* (d.f.=55)	n.s.
$ln\ \sigma^w$ *vs.* N^w	no dati	n.s.
$ln\ \sigma^w$ *vs.* ρ	no dati	-0.175 ± 0.056 * (d.f.=8)
$ln\ \rho$ *vs.* λ (†)	n.s.	$a = 33.42 \pm 16.30$ * $b = 0.885 \pm 0.036$ ** (d.f.=20)

n.s.: $p>0.05$; *: $0.01<p\leq0.05$, **: $p\leq0.01$; †: regressione non-lineare



UK Dataset
Spring-to-summer growth rate (R)
Partridge density in spring Np
ind. km-2
Continental Dataset
Spring-to-summer growth rate (R)
Partridge density in spring Np
ind. km-2
UK Dataset
Winter survival (Sw)
Young to adult ratio (ρ)

Demographic model

$$N_t^s = \lambda_t N_t^p$$

Spring-summer survival and recruitment

$$N_t^a = N_t^s - H$$

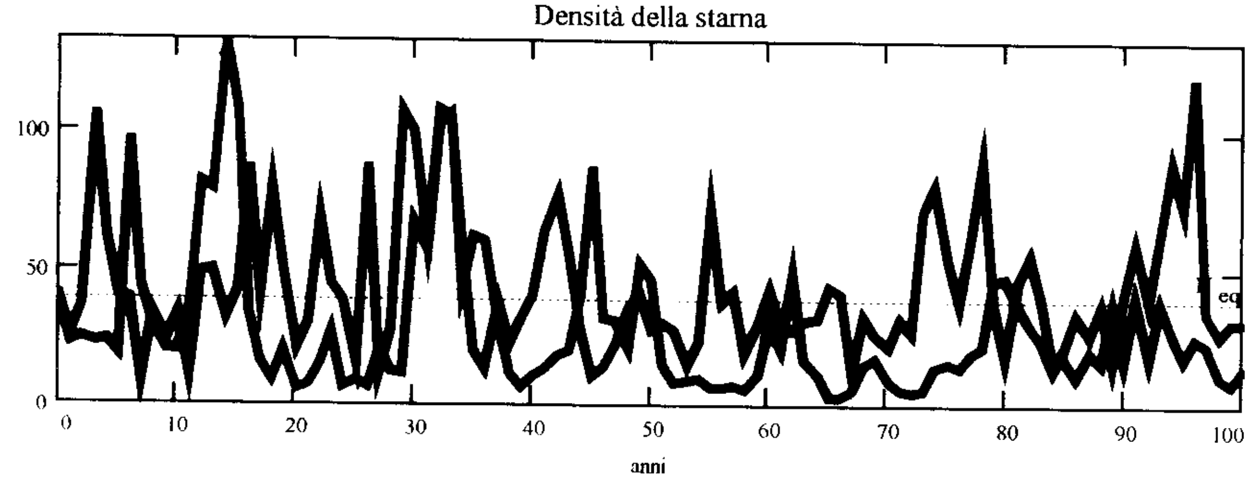
Autumn catch

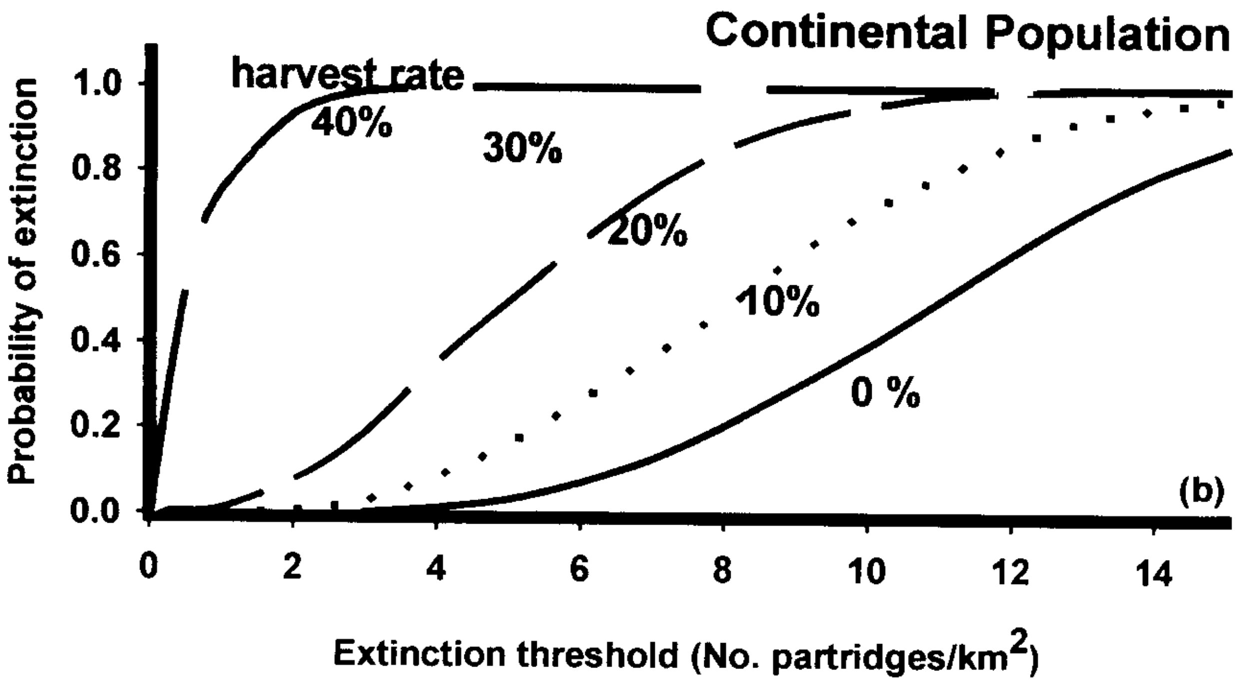
$$N_t^w = \sigma_t^a N_t^a$$

Autumn Survival

$$N_{t+1}^p = \sigma_t^w N_t^w$$

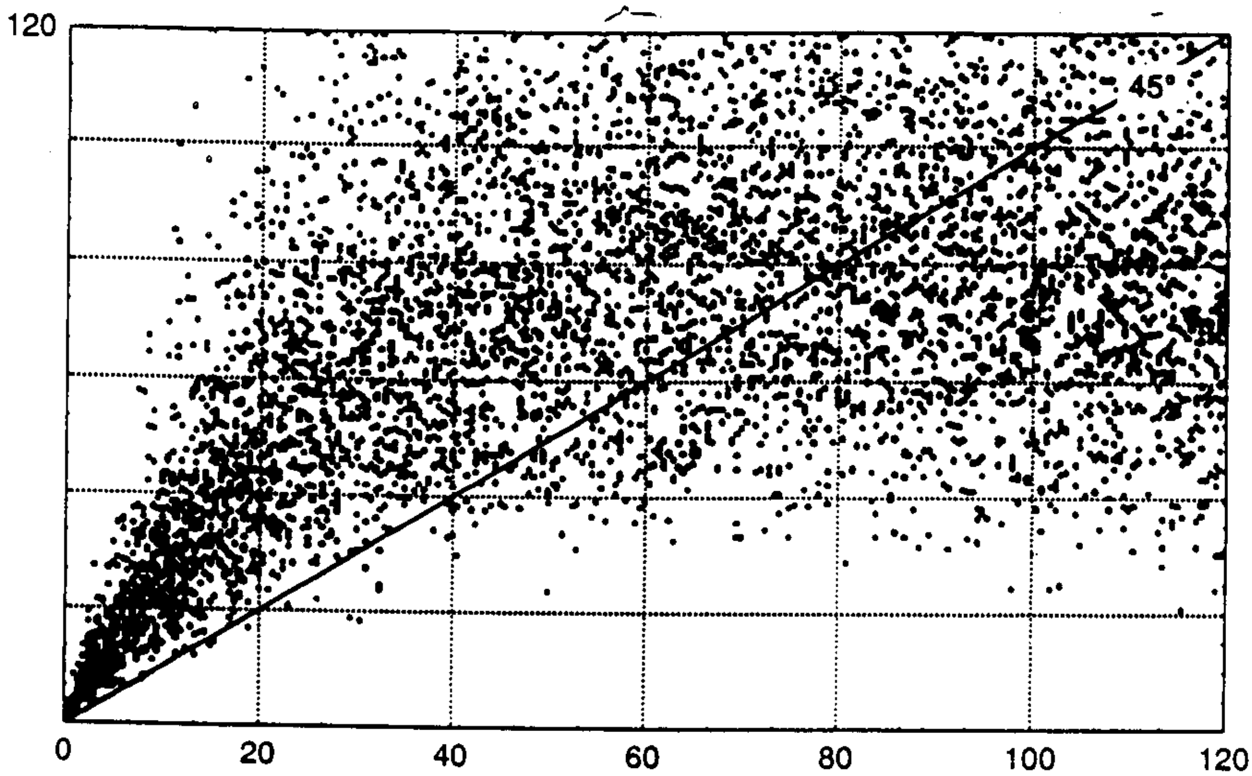
Winter Survival

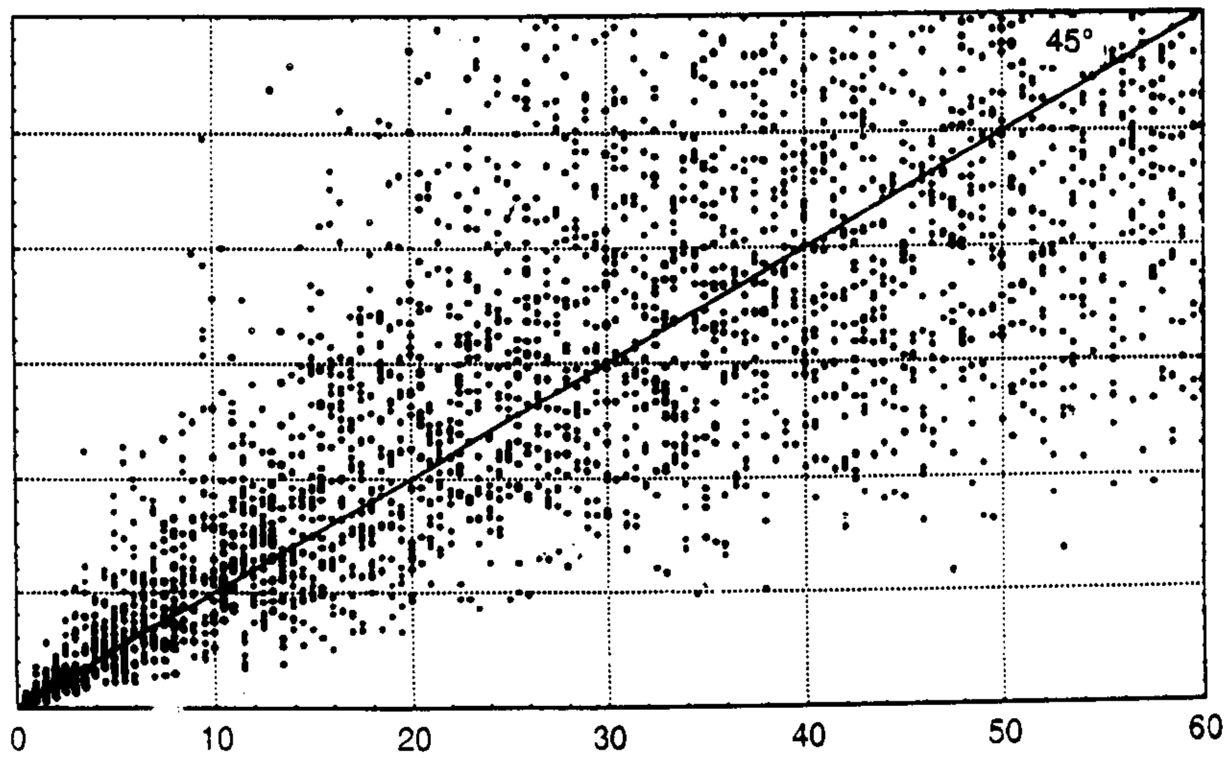


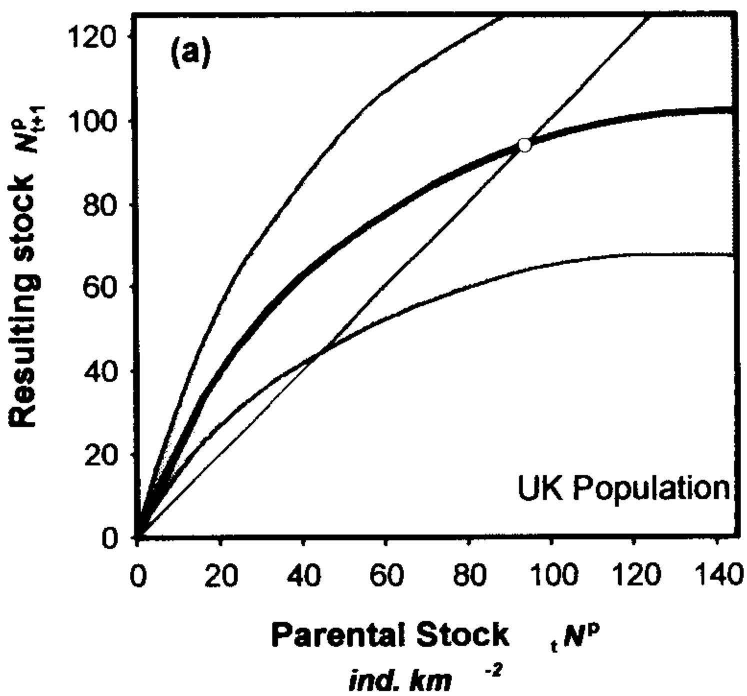


De Leo, Gatto, Focardi e Cattadori. A Population Viability Analysis of the Gray Partridge.
Sottoposto al ***Journal of Applied Ecology***.

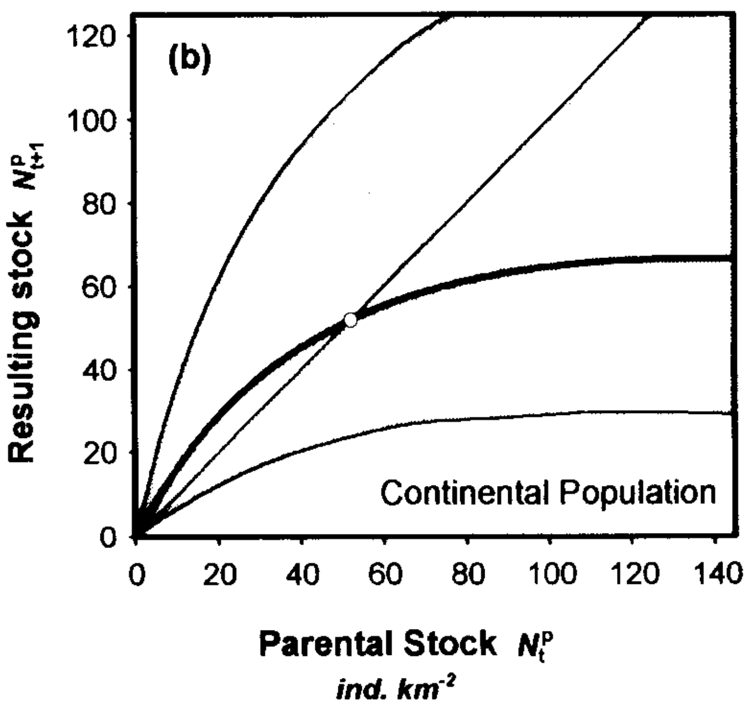
Stochastic models



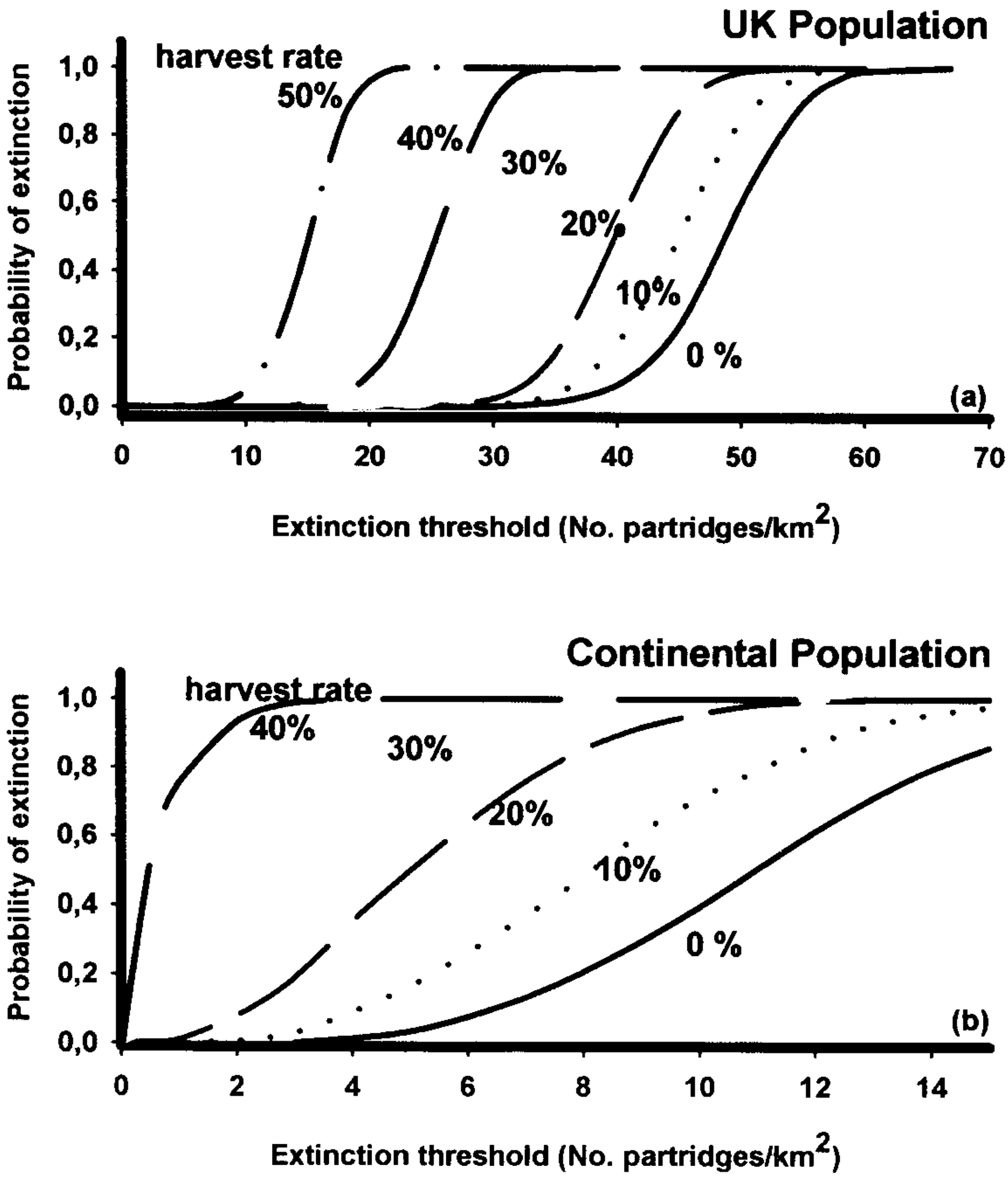




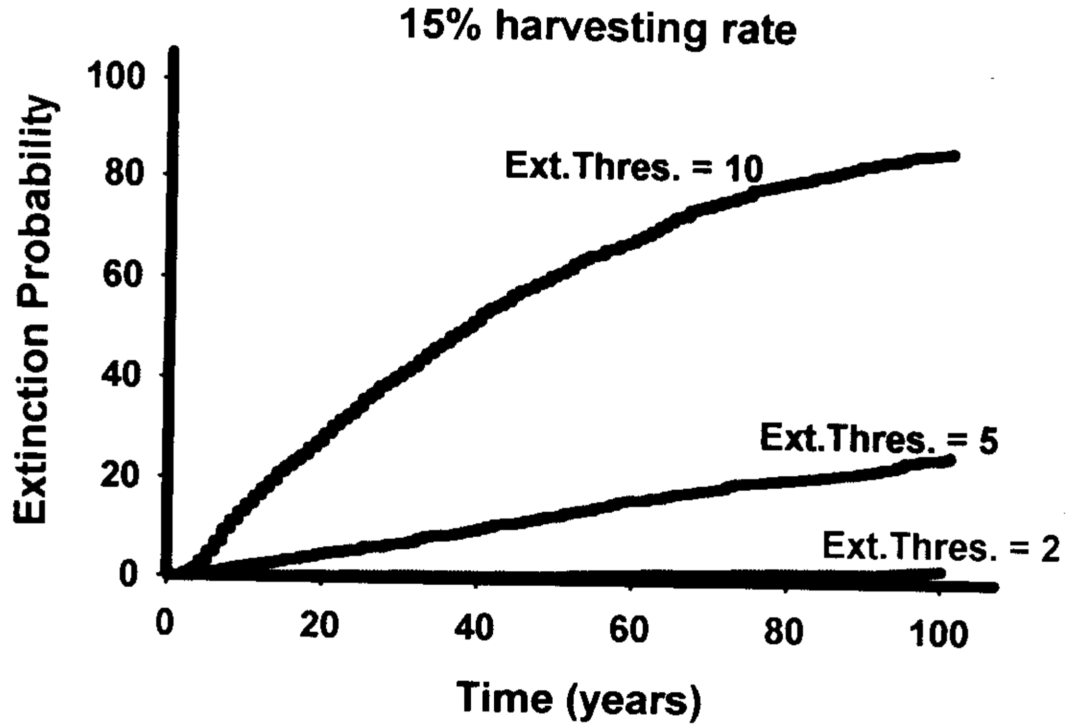
(a)
UK Population
Resulting stock N^p_{t+1}
Parental Stock $_tN^p$
ind. km $^{-2}$
0
20
40
60
80
100
120
140

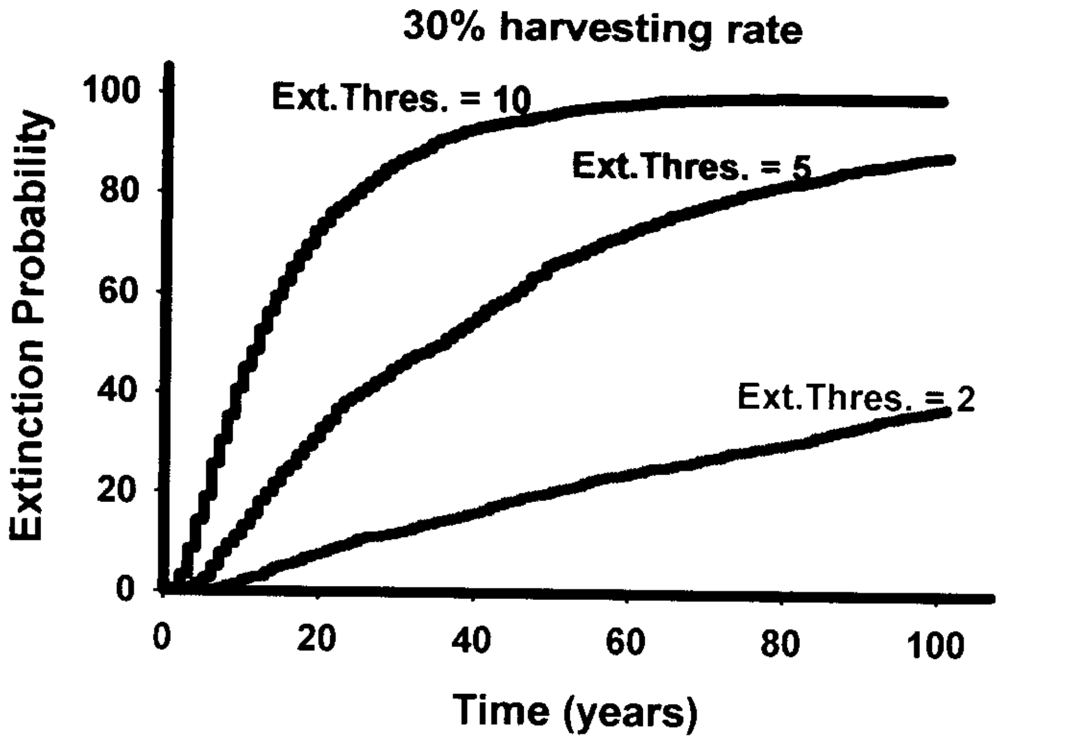


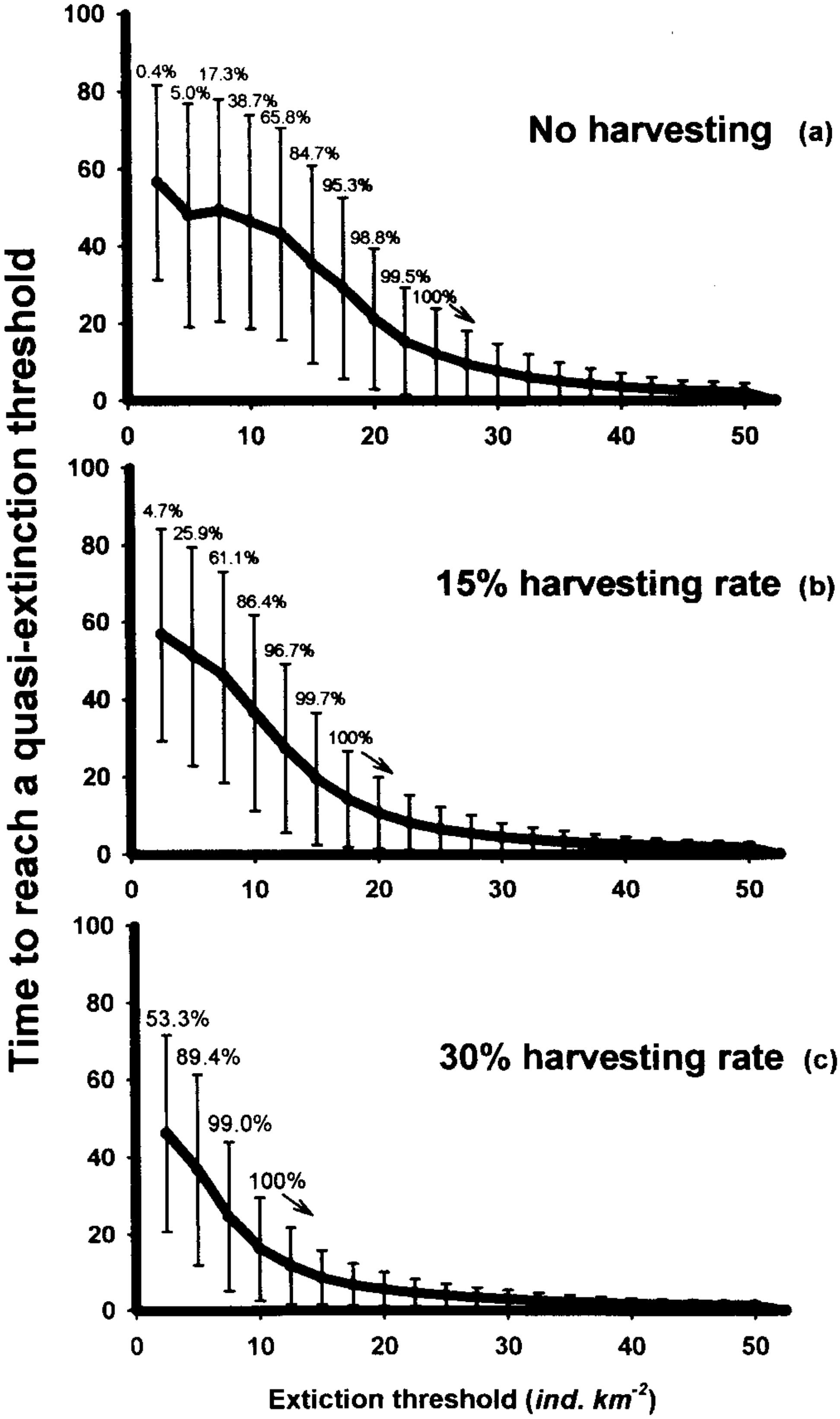
(b)
Continental Population
Resulting stock N^p_{t+1}
Parental Stock N^p_t
ind. km^{-2}
0
20
40
60
80
100
120
140



UK Population
harvest rate
50%
40%
30%
20%
10%
0 %
(a)
Probability of extinction
1,0
0,8
0,6
0,4
0,2
0,0
0
10
20
30
40
50
60
70
Extinction threshold (No. partridges/km2)
Continental Population
harvest rate
40%
30%
20%
10%
0 %
(b)
Probability of extinction
1,0
0,8
0,6
0,4
0,2
0,0
0
2
4
6
8
10
12
14
Extinction threshold (No. partridges/km2)


15% harvesting rate
Extinction Probability
Time (years)
Ext.Thres. = 10
Ext.Thres. = 5
Ext.Thres. = 2
0
20
40
60
80
100


30% harvesting rate
Extinction Probability
Time (years)
Ext.Thres. = 10
Ext.Thres. = 5
Ext.Thres. = 2
0
20
40
60
80
100


Time to reach a quasi-extinction threshold
No harvesting (a)
0.4%
5.0%
17.3%
38.7%
65.8%
84.7%
95.3%
98.8%
99.5%
100%
15% harvesting rate (b)
4.7%
25.9%
61.1%
86.4%
96.7%
99.7%
100%
30% harvesting rate (c)
53.3%
89.4%
99.0%
100%
0
20
40
60
80
100
0
10
20
30
40
50
Extiction threshold (ind. km-2)

DISCUSSION

- Traditional populations were much more resilient then present ones

- Large harvest was possible with traditional populations

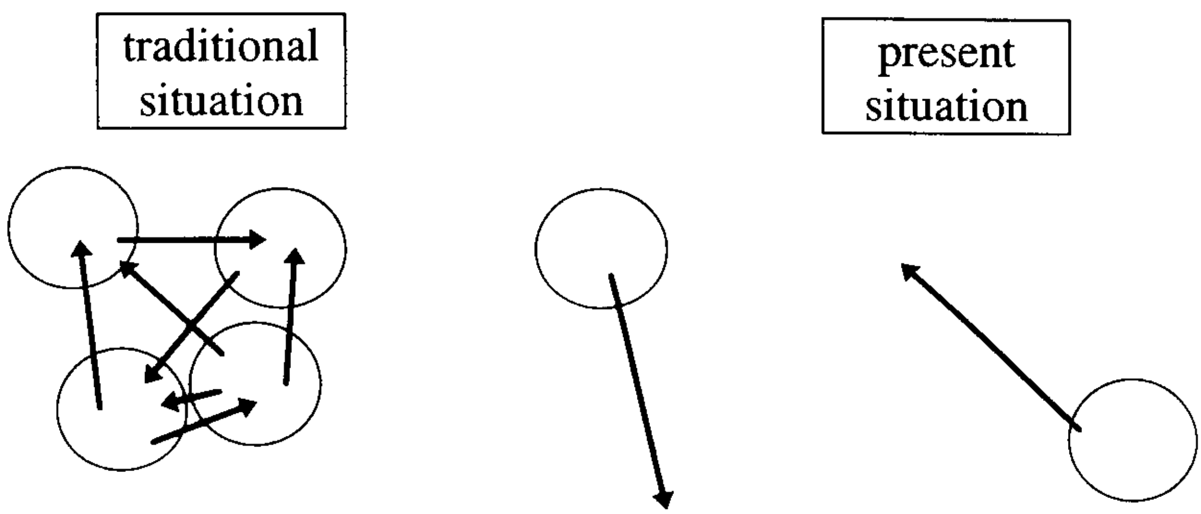
- No (even limited) harvest is possible with actual populations

- No compensation between harvest and autumn-winter mortality

- Autumn-winter mortality is:

  density dependent (Potts 1980)

  depends on the number of yearlings: larger the number of yearlings larger the dispersal outside the estate:



- Density-dependent increase rate *R* in spring-summer (Potts 1980, Rotella et al. 1996).

- There is **no a single bottleneck** in both continental and UK populations: deterioration of survival both in spring-summer and autumn-winter is necessary to explain decline.

  If in the continental model we replace in turn the demographic parameters (or functions, including density dependence) using the UK values the viability of continental populations increases very much

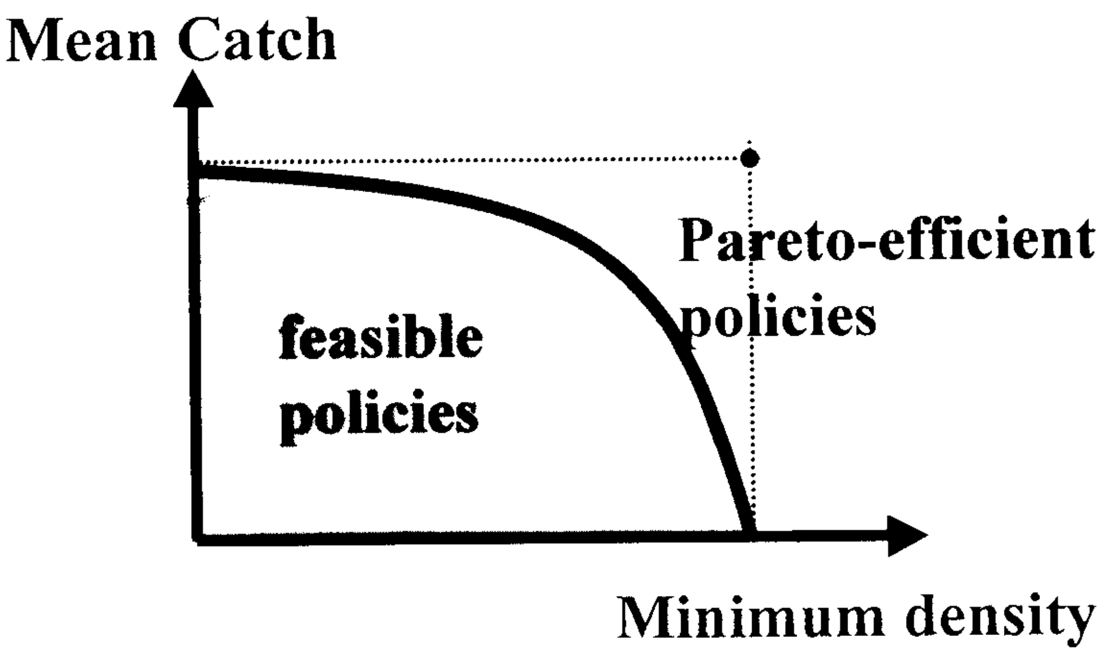
- Some information on the decline of UK populations:

  If in our UK model reduce *R* of the 50% (Potts and Aebischer 1994 report a 33% reduction due to herbicides) the equilibrium falls from 94 to 69 bird/km^2

  We argue that other factors cooperate to the crash of UK populations

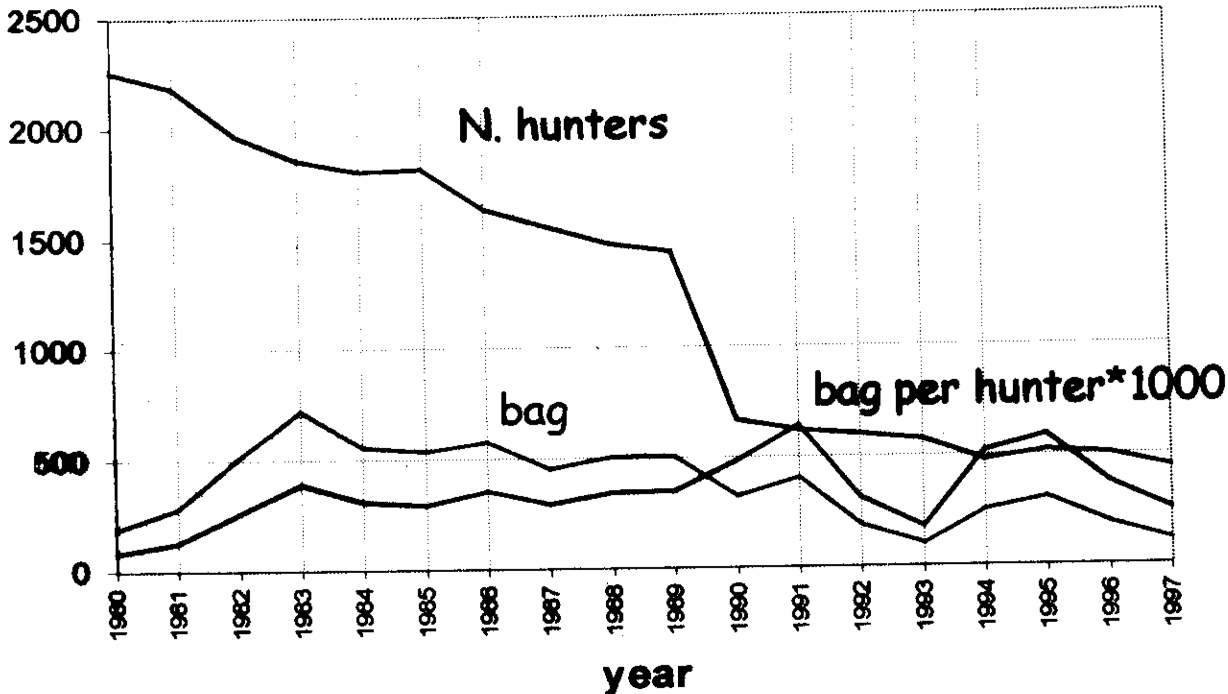
Paretian Policies

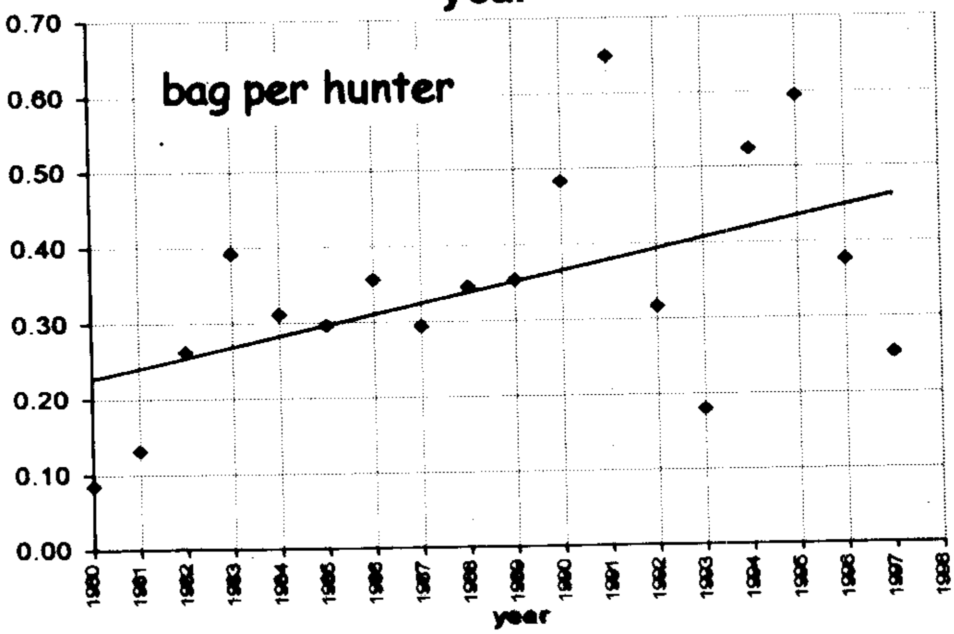
A policy is Paretian when it is not possible to improve the performance over any specific criterion without reducing the performance over at least another criterion



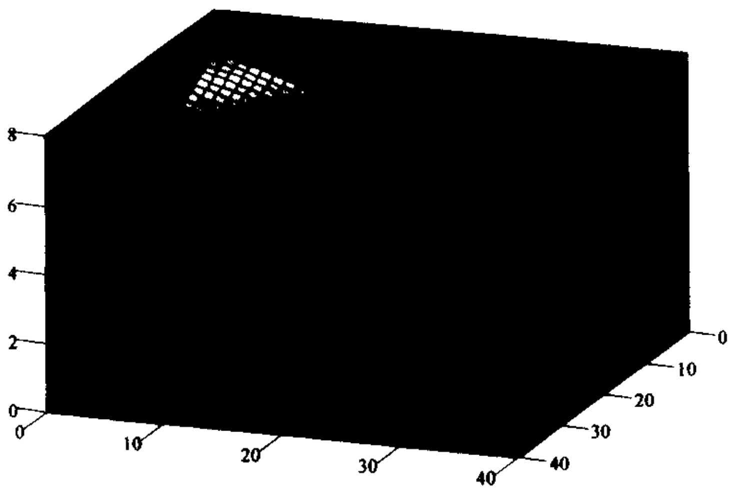
BLACK GROUSE *Tetrao tetrix*

SONDRIO PROVINCE 1980-97





Three criteria



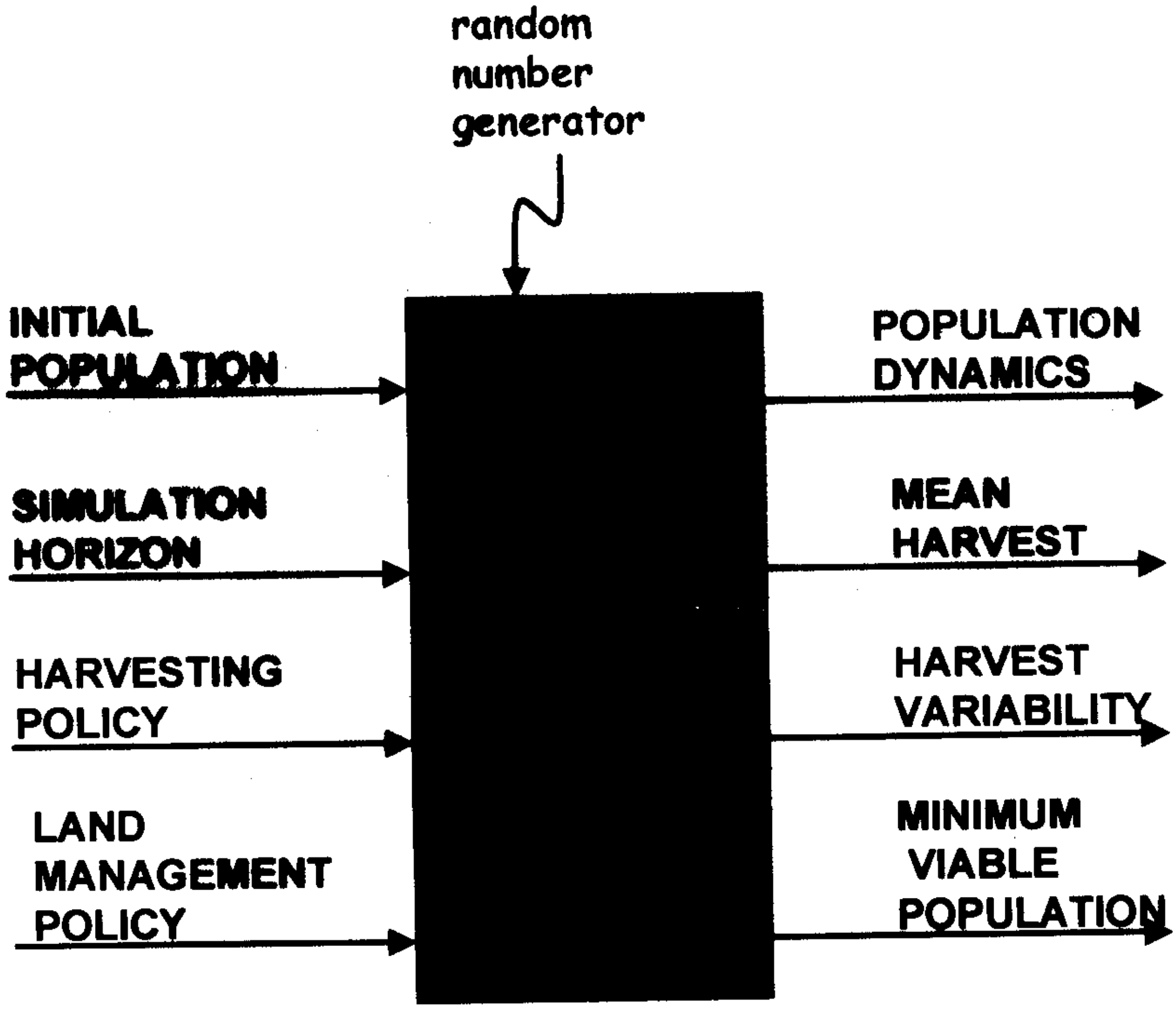
Goals:

- MAX MEAN CATCH
- MAX MINIMUM DENSITY
- MIN CATCH VARIABILITY

CONSTRAINS FOR MINIMUM SATISFACTION:

- MEAN CATCH $\geq$ 200 black grouses
- MINIMUM DENSITY $\geq$ 200 black grouses
- CATCH VARIBILITY $<$ 1.4

HOW TO USE THE MODEL FOR EVALUATING DIFFERENT MANAGEMENT POLICIES

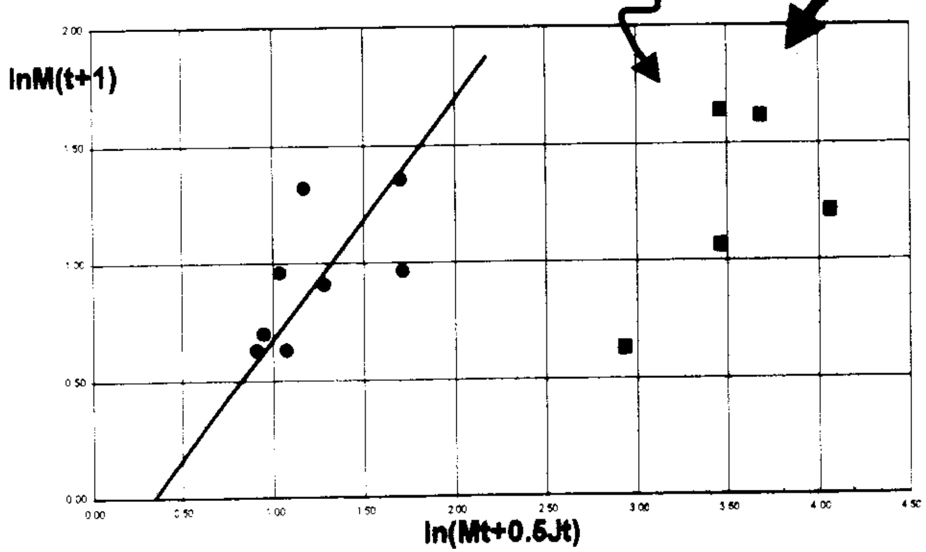


100 fifty-years simulations
were generated
for each policy

SURVIVAL THROUGH WINTER

$$M_{t+1} = \delta_t \, \sigma \, (M_t + J_t/2)$$

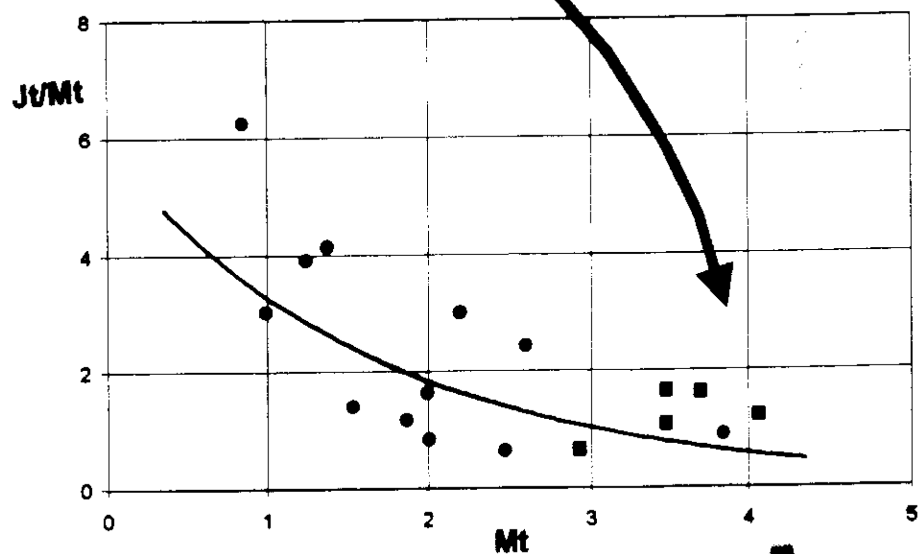
HARVESTING !



REPRODUCTION

$$J_t/M_t = \varepsilon_t \exp(a\text{-}bM_t)$$

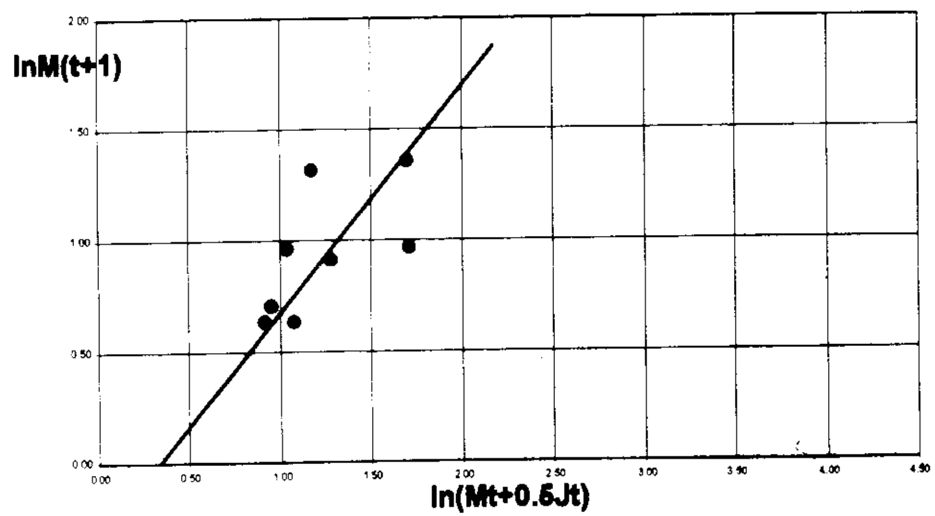
Val Viola (1992-98)



SURVIVAL THROUGH WINTER

$$M_{t+1} = \delta_t \, \sigma \, (M_t + J_t/2)$$

environmental noise (δ_t); 0.735 (σ); ADULT MALES /Km² (M_t); JUVENILES /Km² (J_t)

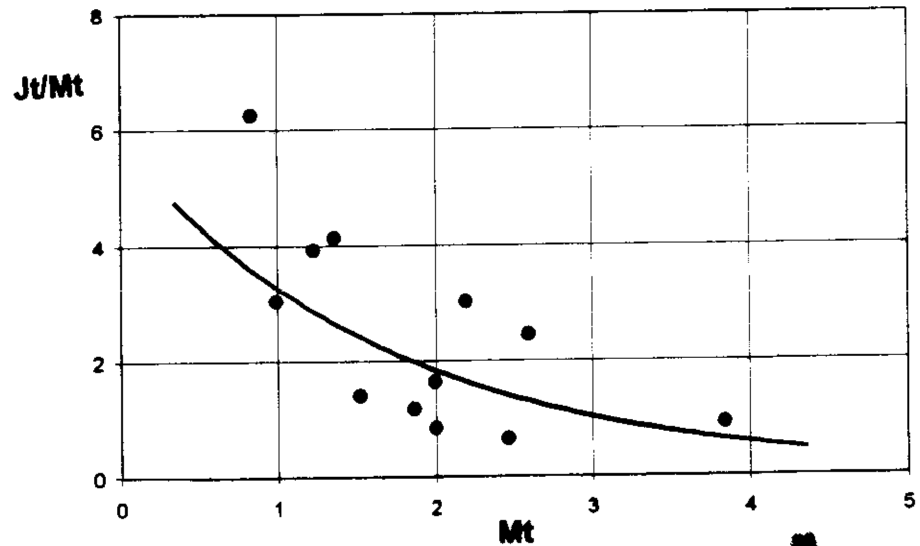


Data from areas without hunting

REPRODUCTION

$$J_t/M_t = \varepsilon_t \exp(a - bM_t)$$

environmental noise (ε_t); 1.757 (a); 0.5757 (b)

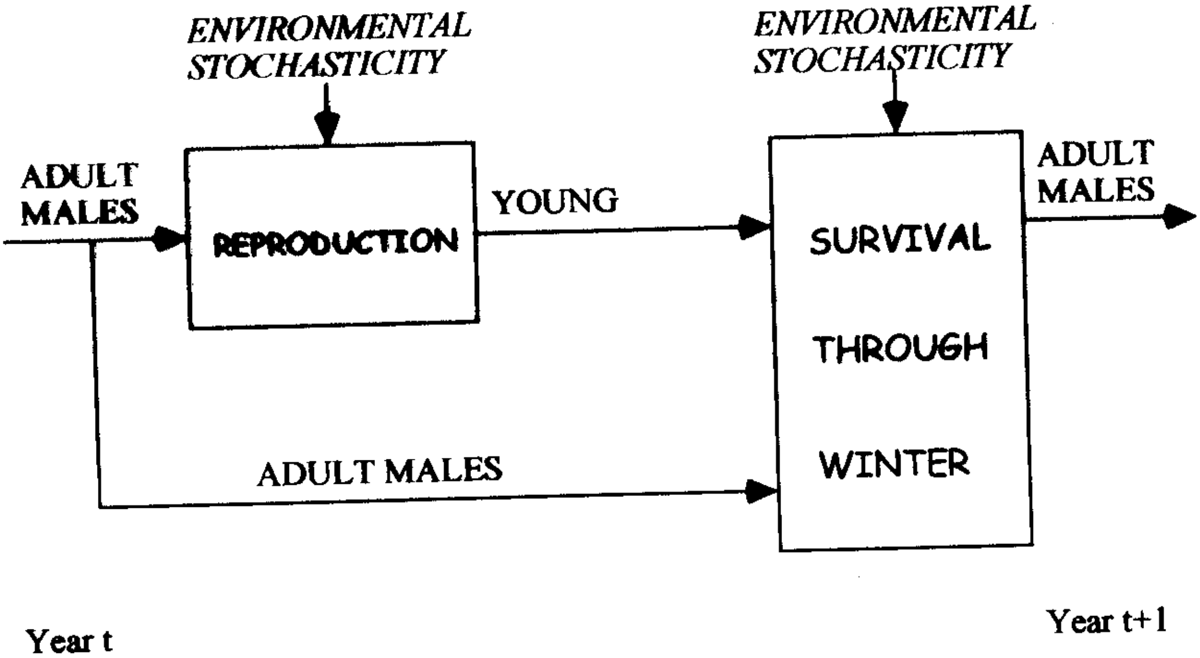


Data from all study areas

THE DEMOGRAPHIC MODEL
(Gatto, Montalbetti, Scherini & Tosi 1992)

AVAILABLE DATA:
6 STUDY AREAS in LOMBARDY

- Displaying **cocks**
  from Spring census **1983, 1984, 1985**
- **No.** of **broods and size of each brood**
  from Summer census **1983, 1984**



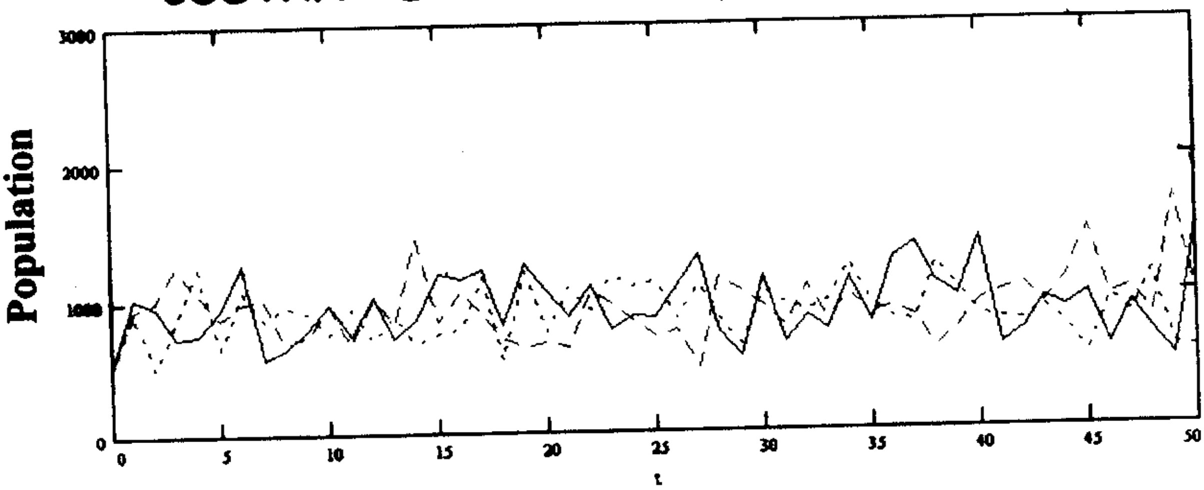
HARVESTING POLICIES

1. CONSTANT PERCENTAGE
   Annual harvest in fall is a **percentage** of males present in late summer

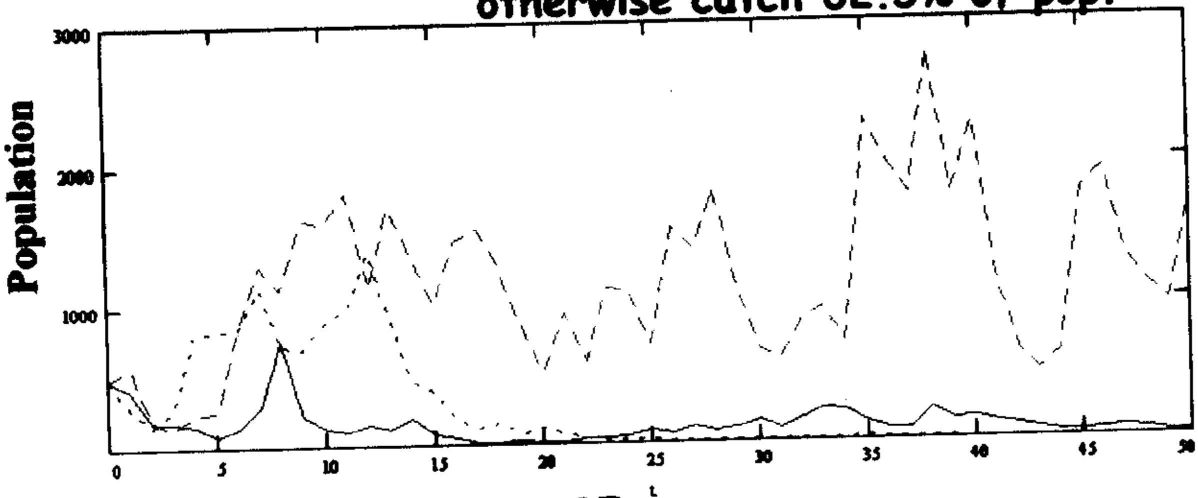
2. TOTAL QUOTAS
   Above a minimum population density harvest in fall is a **fixed quota**,
   below a minimum population density harvest in fall is a **percentage** of males present in late summer

3. CONSTANT ESCAPEMENT
   Harvest is determined before the hunting season so that a **constant number** of males is allowed **to escape** and reproduce in spring.
   If the number of available males is smaller than the allowed escapement, hunting is **not permitted**

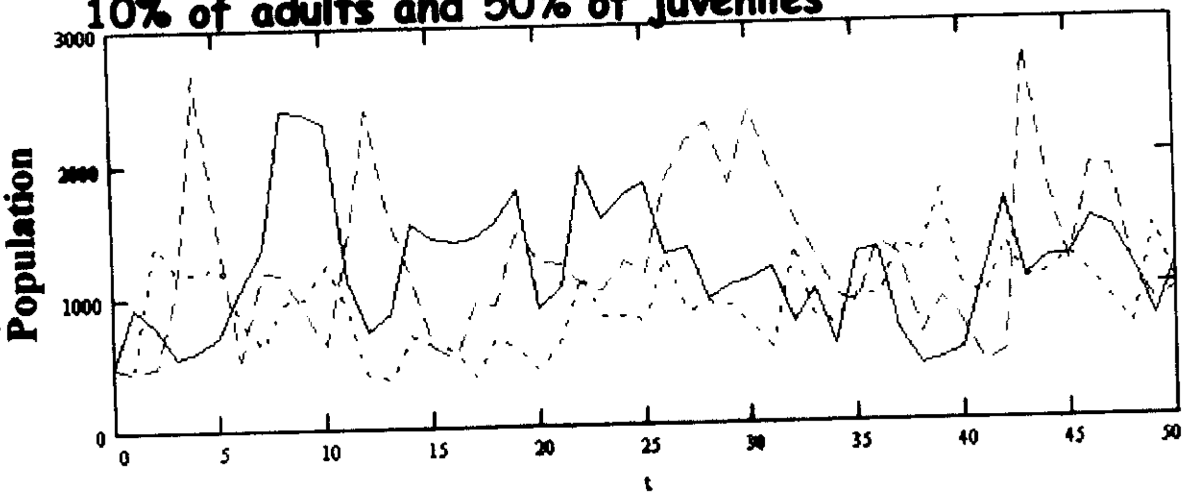
COSTANT ESCAPAMENT (1200 reproductive ind.)



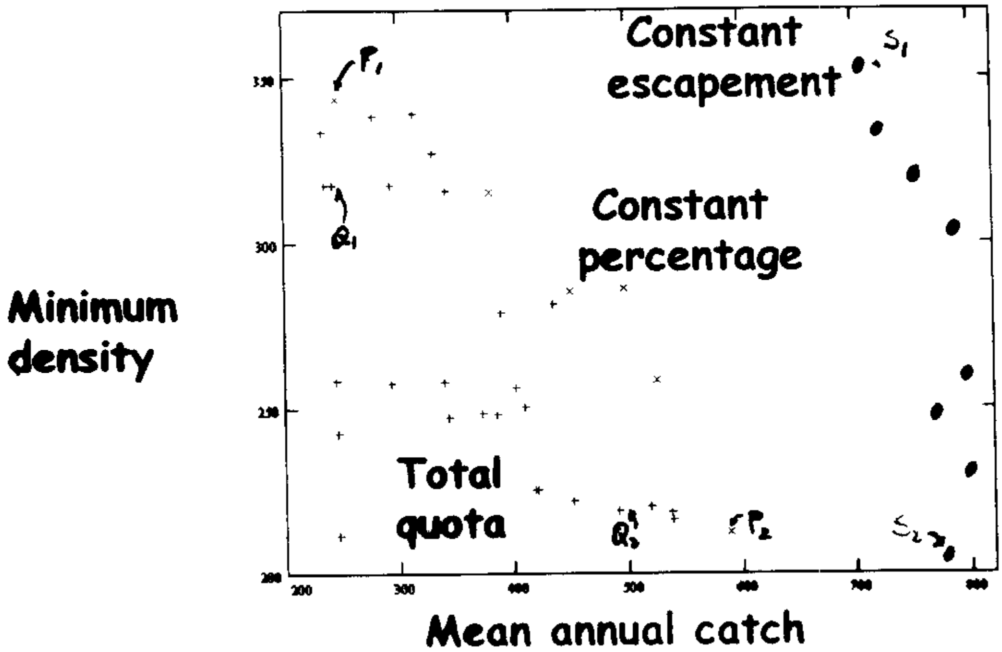
TOTAL QUOTAS: 500 ind. if population > 800, otherwise catch 62.5% of pop.

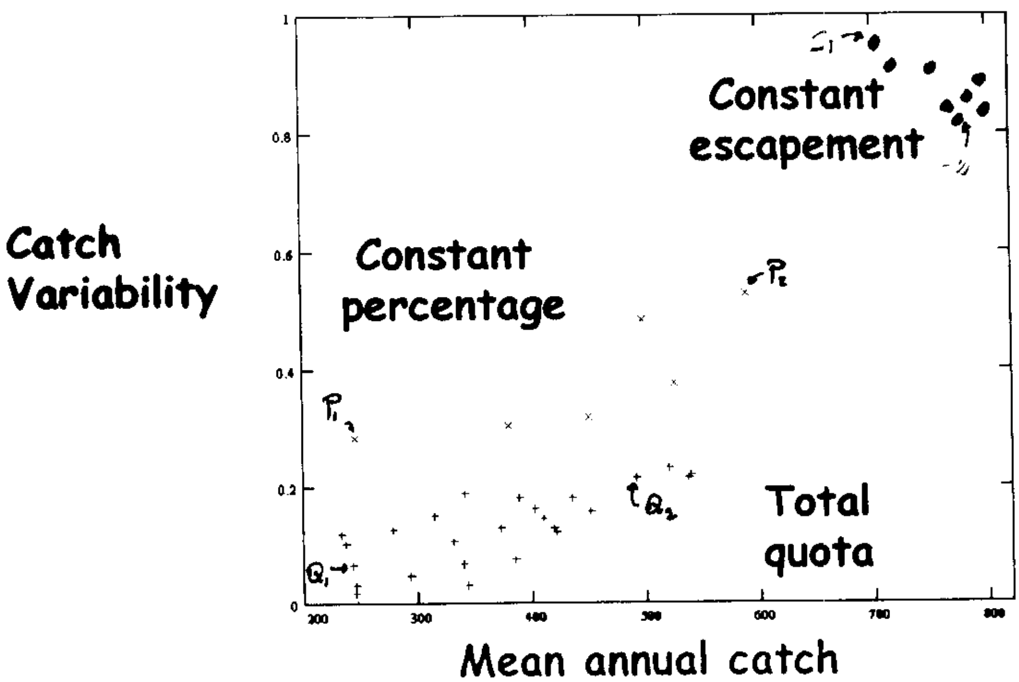


COSTANT PERCENTAGE: 10% of adults and 50% of juveniles



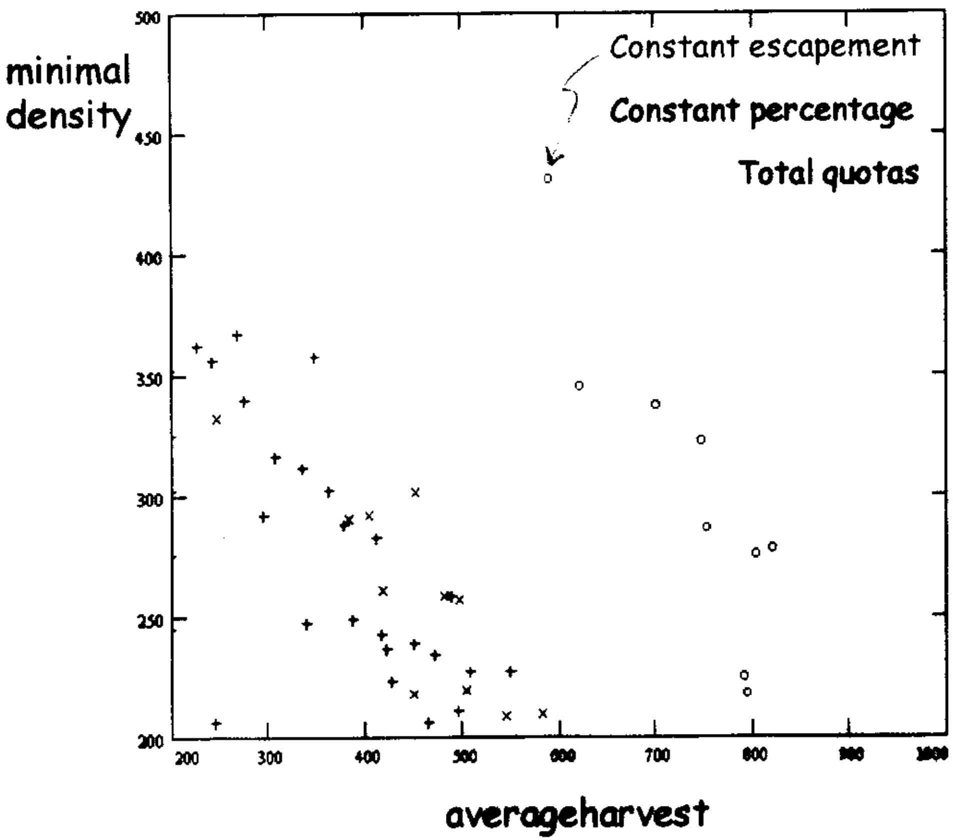
Risults for Sondrio

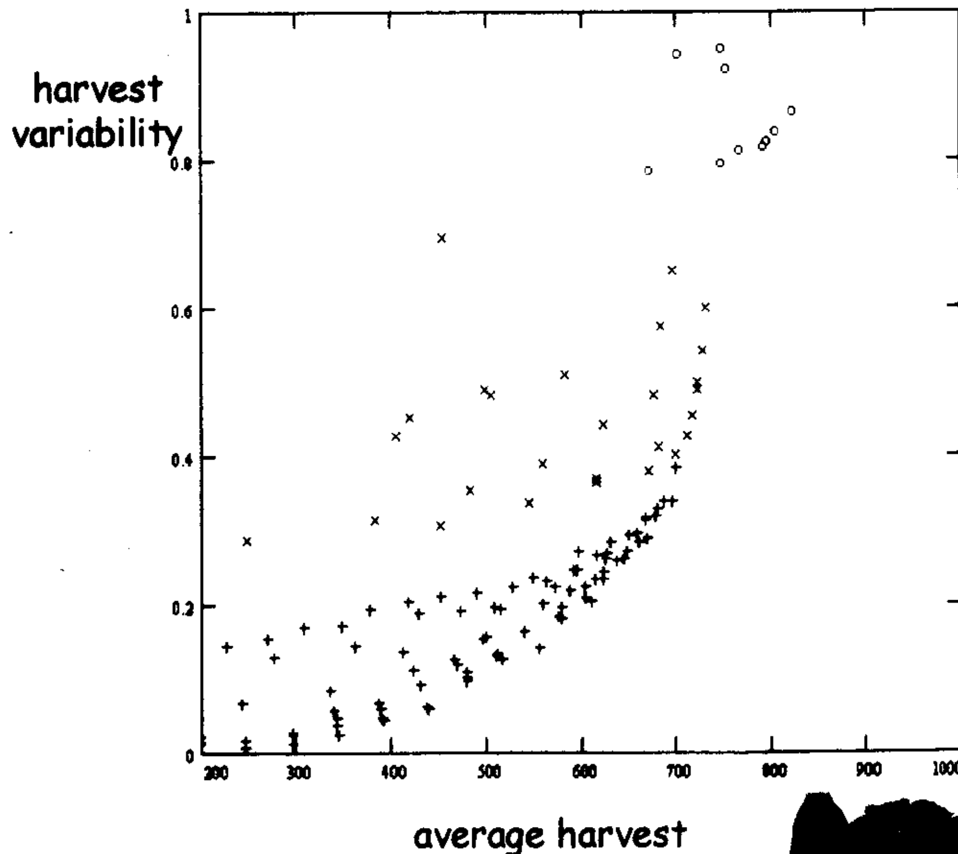




RESULTS FOR SONDRIO PROVINCE

OPTIMIZATION CRITERIA +	MINIMUM SATISFACTION TARGETS
MAX AVERAGE HARVEST	AVERAGE HARVEST ≥ 200 males
MAX MINIMAL DENSITY	MINIMAL DENSITY ≥ 200 males
MIN HARVEST VARIABILITY	HARVEST VARIABILITY < 1.4





CONCLUSION

- A **SPATIALLY EXPLICIT DESCRIPTION** OF THE **BIOTIC** AND **ABIOTIC** CHARACTERISTICS OF A GIVEN TERRITORY IS IMPORTANT FOR AN **EFFECTIVE MANAGEMENT OF WILDLIFE**

- AN **ACCURATE AND REGULAR** COLLECTION OF **DATA** BOTH THROUGH **CENSUS** AND WITH THE **ACTIVE COOPERATION OF HUNTERS** CAN LEAD TO THE SETUP OF **REALISTIC DEMOGRAPHIC MODELS** THAT INCORPORATE ENVIRONMENTAL FLUCTUATIONS

- **WILDLIFE MANAGEMENT POLICIES** CAN BE BASED ON **QUANTITATIVE METHODS** AND **EXPLICITLY ACCOUNT FOR THE VARIOUS GOALS** (SPECIES PROTECTION, LAND UTILIZATION FOR RECREATIONAL ACTIVITIES, HUNTING, ETC.) THAT A DECISION MAKER **MUST** REASONABLY CONSIDER

- THE **COOPERATION WITH SONDRIO PROVINCE** IS ALREADY BRINGING INTERESTING RESULTS IN THIS DIRECTION

CONCLUSIONS

- UK and continental Europe populations have different demographies
- Grey partridge is at high risk of extinction in continental Europe
- Continental Europe populations are not suitable for harvesting
- Larger preserve areas could effectively decrease the chance of extinction
- Our study is preliminary. More detailed management options such as setting up corridors connecting the preserves or reintroducing hedges necessitate a spatial and behavioral model to be evaluated