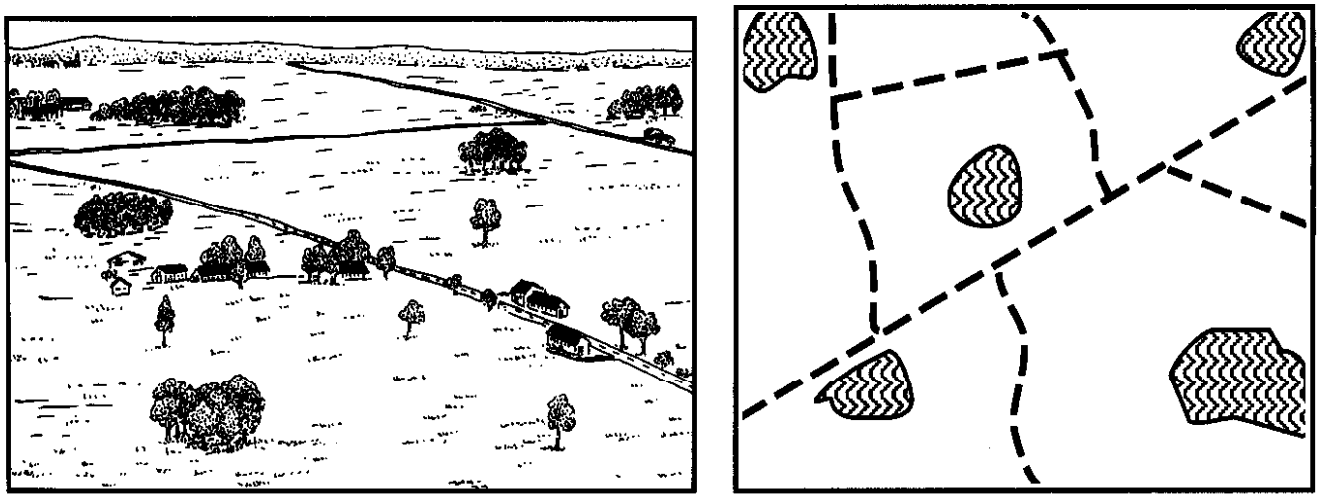
Effects of habitat fragmentation on restoration prospects

Species introduction and management of biodiversity in restoration projects

SER Summer School Restoration Ecology 2009
University of Münster - 29 June – 3 July



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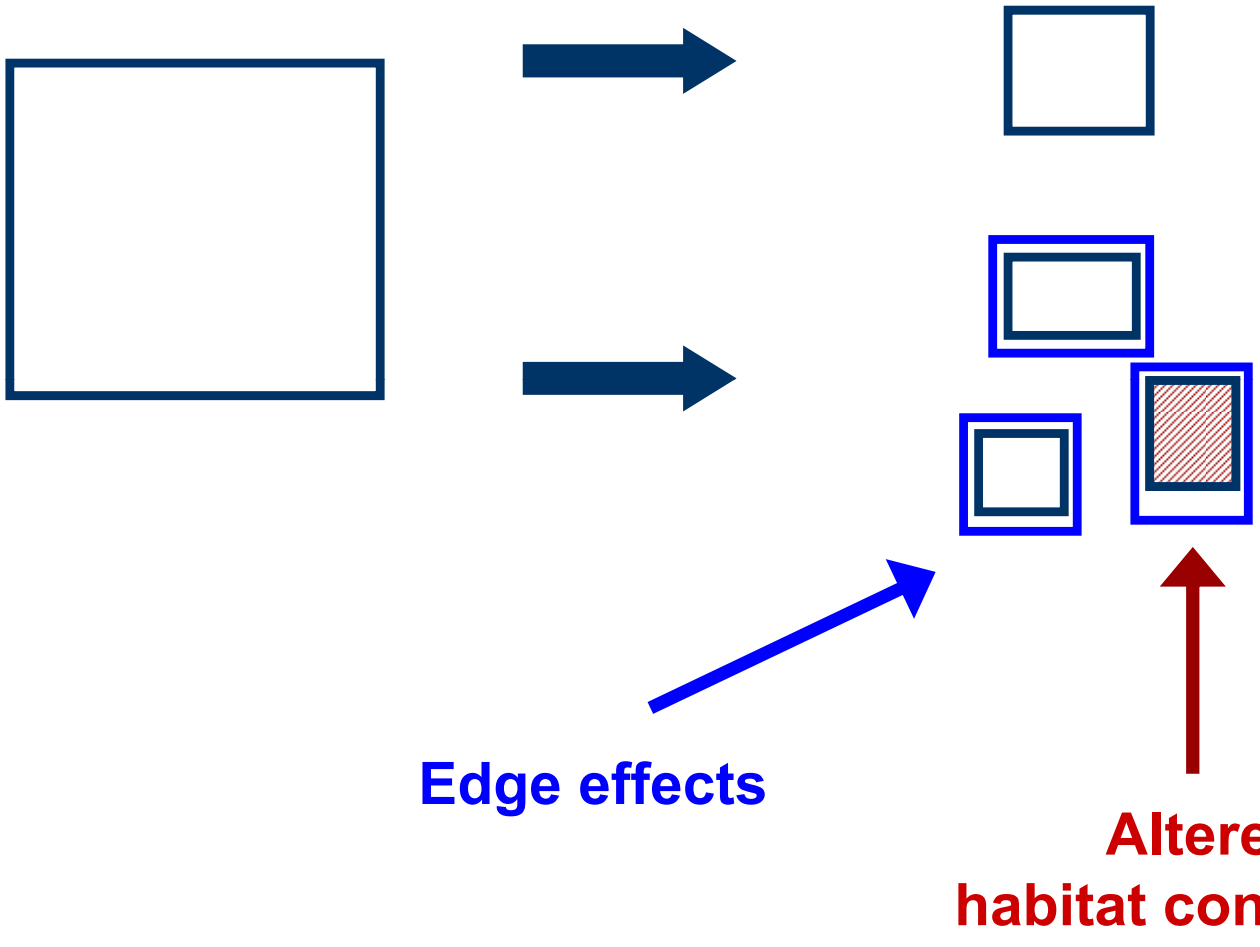
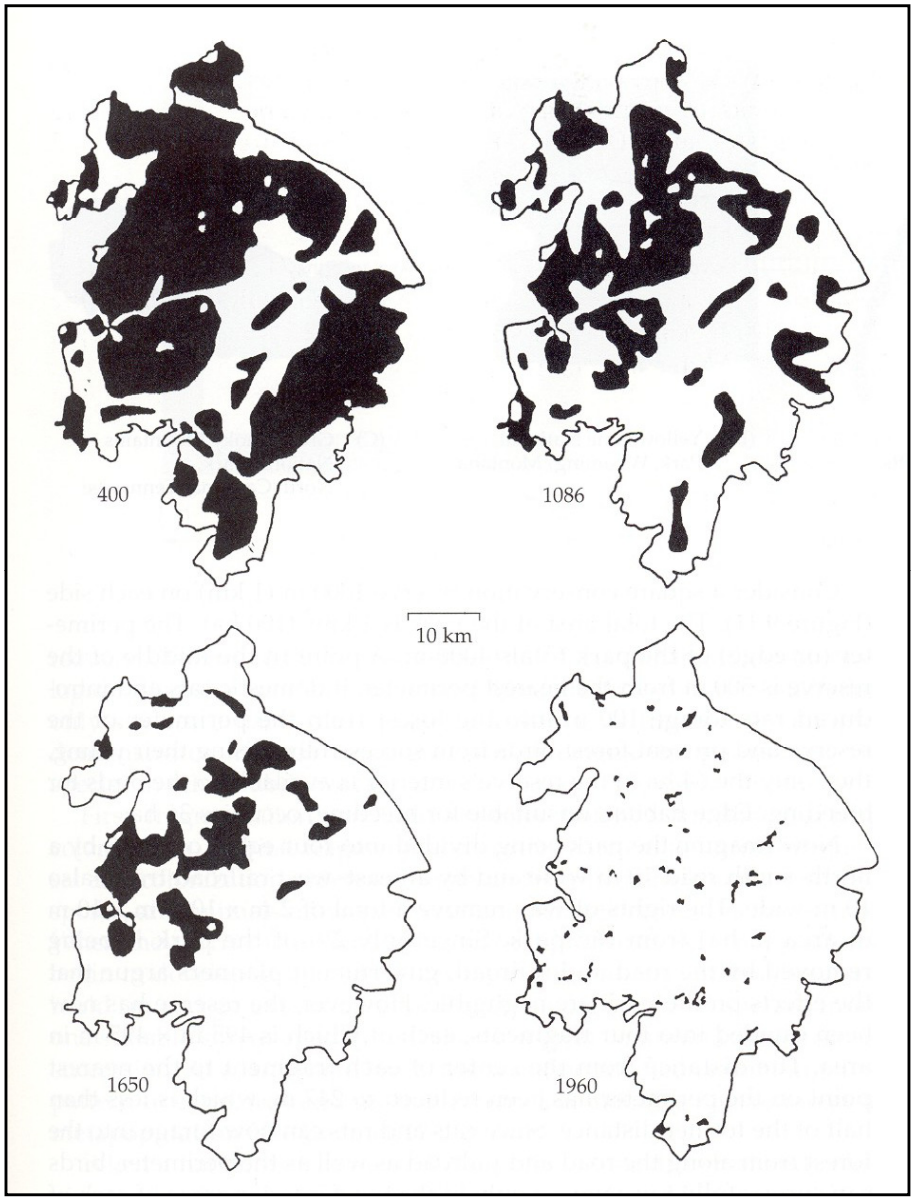
Outline

- Basics about habitat fragmentation
- Habitat fragmentation in forests:
  - Species incidence and forest size
  - Reproductive fitness and population size
- Habitat fragmentation in river valleys:
  - Reproductive fitness and population size *vs* soil environment
  - Importance of explanatory variables differs between years
- Habitat fragmentation in heathlands:
  - Again: Reproductive fitness and population size *vs* soils
  - Fitness and long-term changes in population size
- Habitat fragmentation in grasslands - do the species come back?
- Resumé


Decrease in habitat size
Increase in isolation
Edge effects
Altered habitat conditions

Deforestation in a tropical forest



Change in forest cover in Warwickshire county, from Primack (1998)

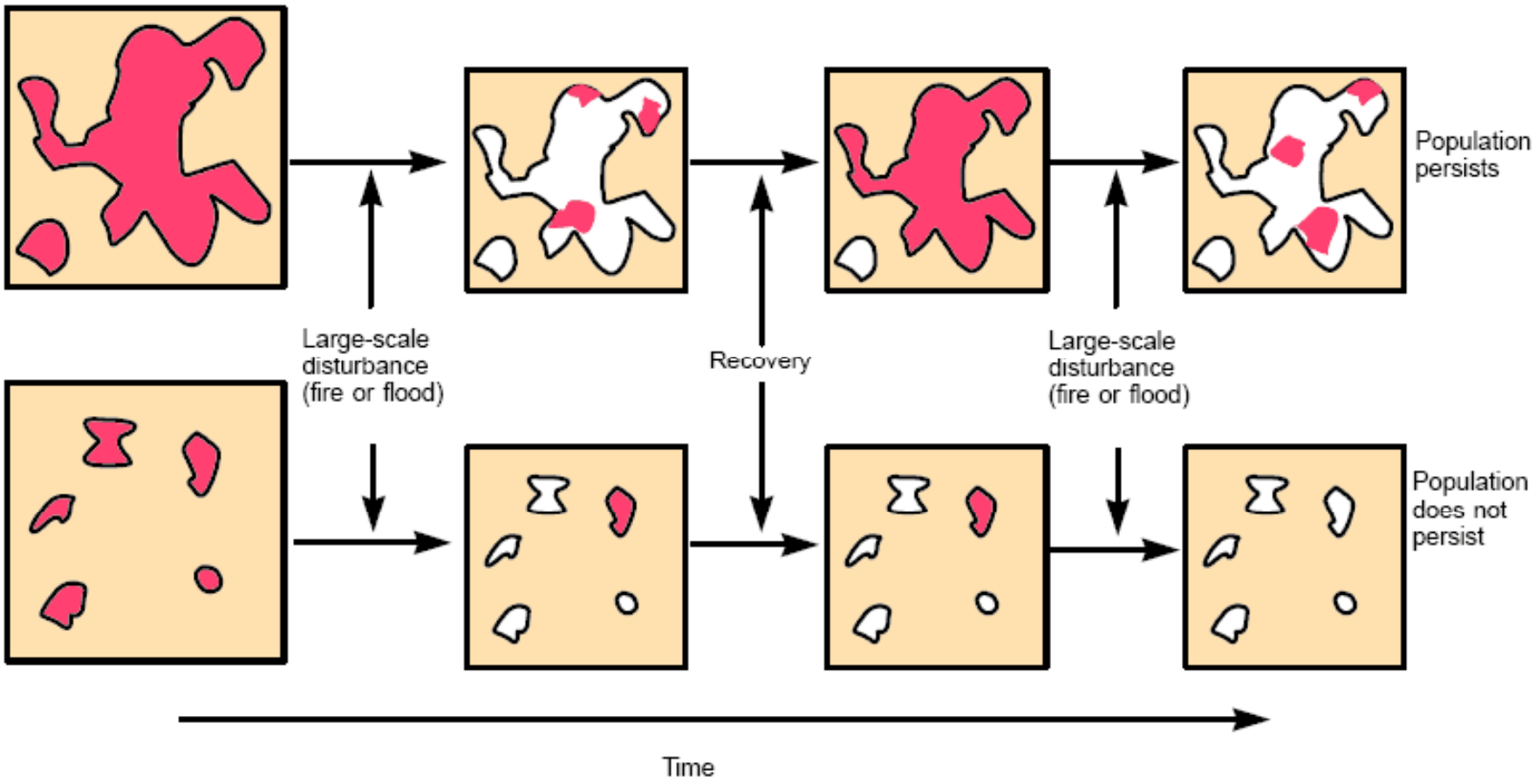
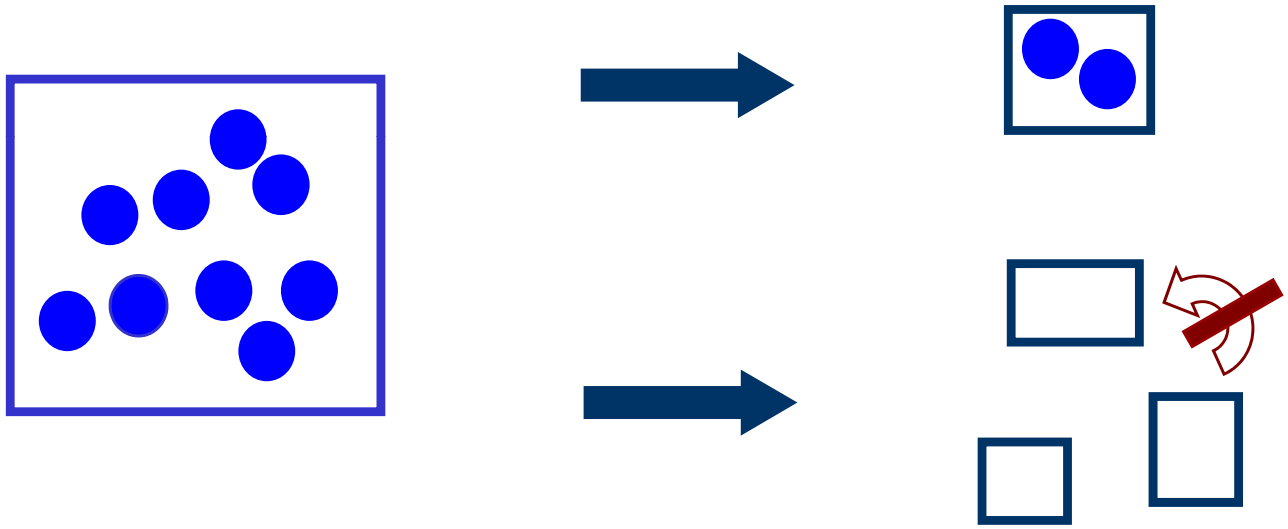


Figure 1.4.

Habitat fragmentation can result in the loss of a species due to natural disturbance. In this example larger, more connected habitat sustains the species over time, whereas smaller, more isolated habitat loses the species over time. (In this example, tan is non-habitat, red is occupied habitat, and white is unoccupied habitat.)

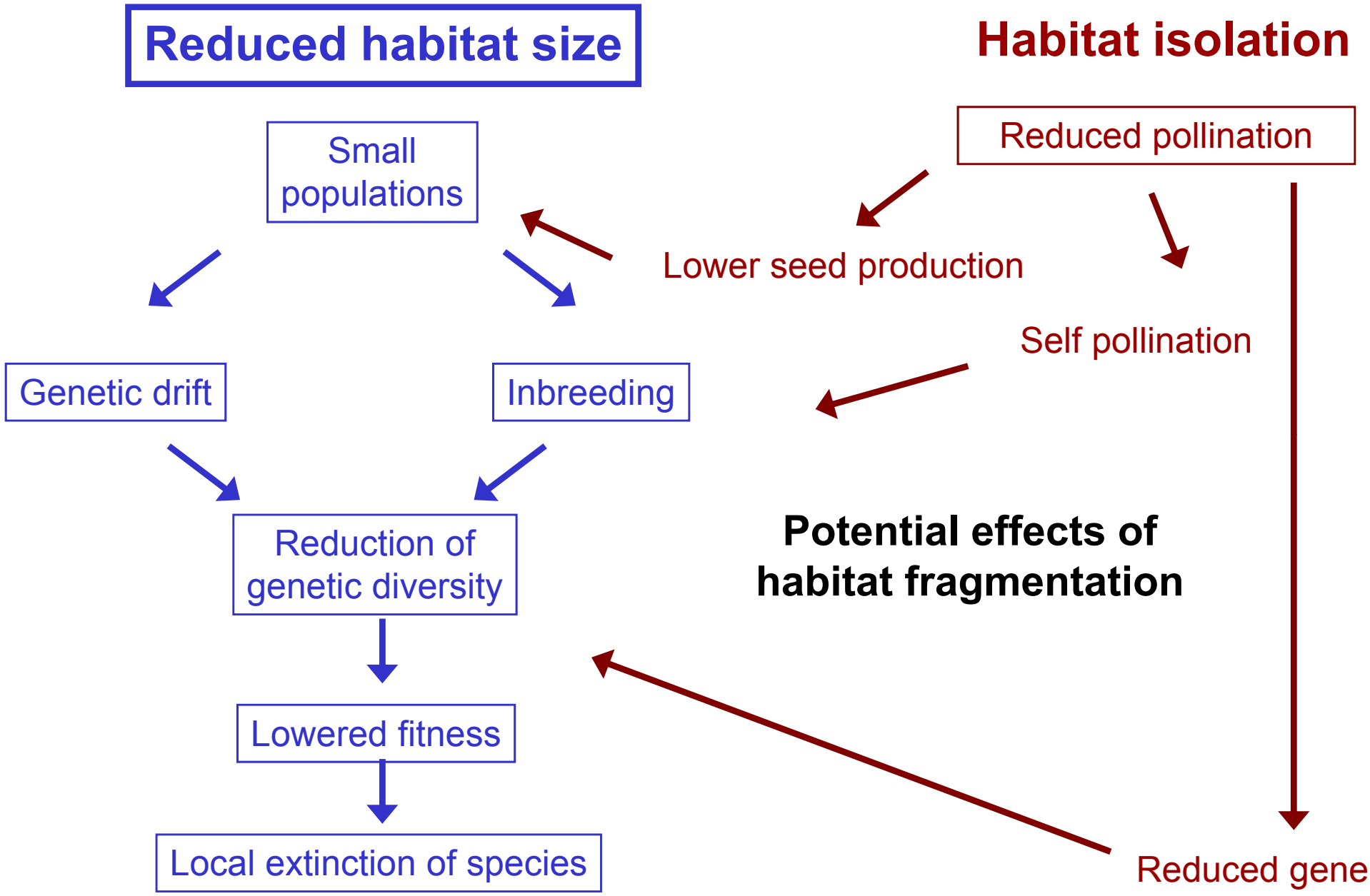
Effects of habitat fragmentation



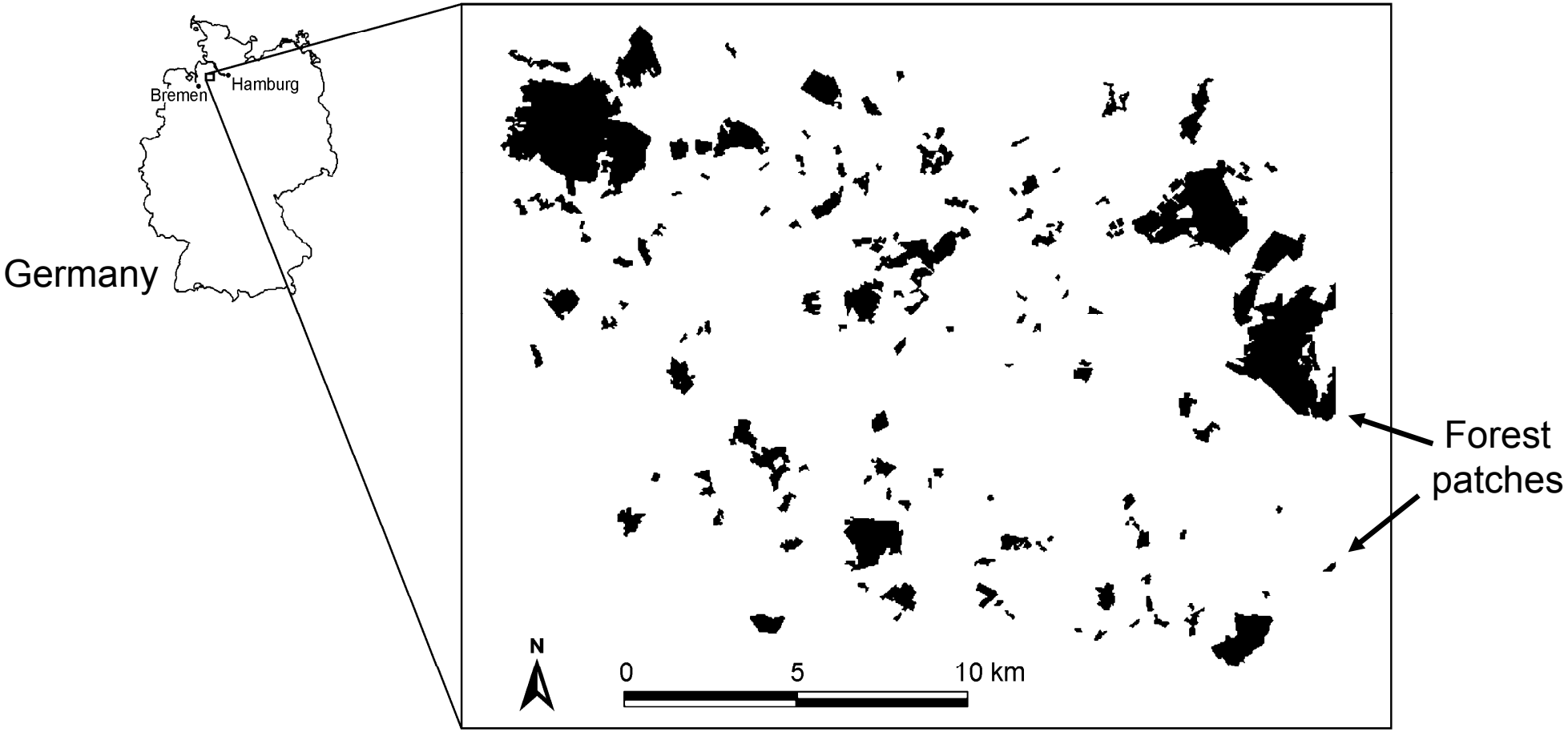
smaller populations

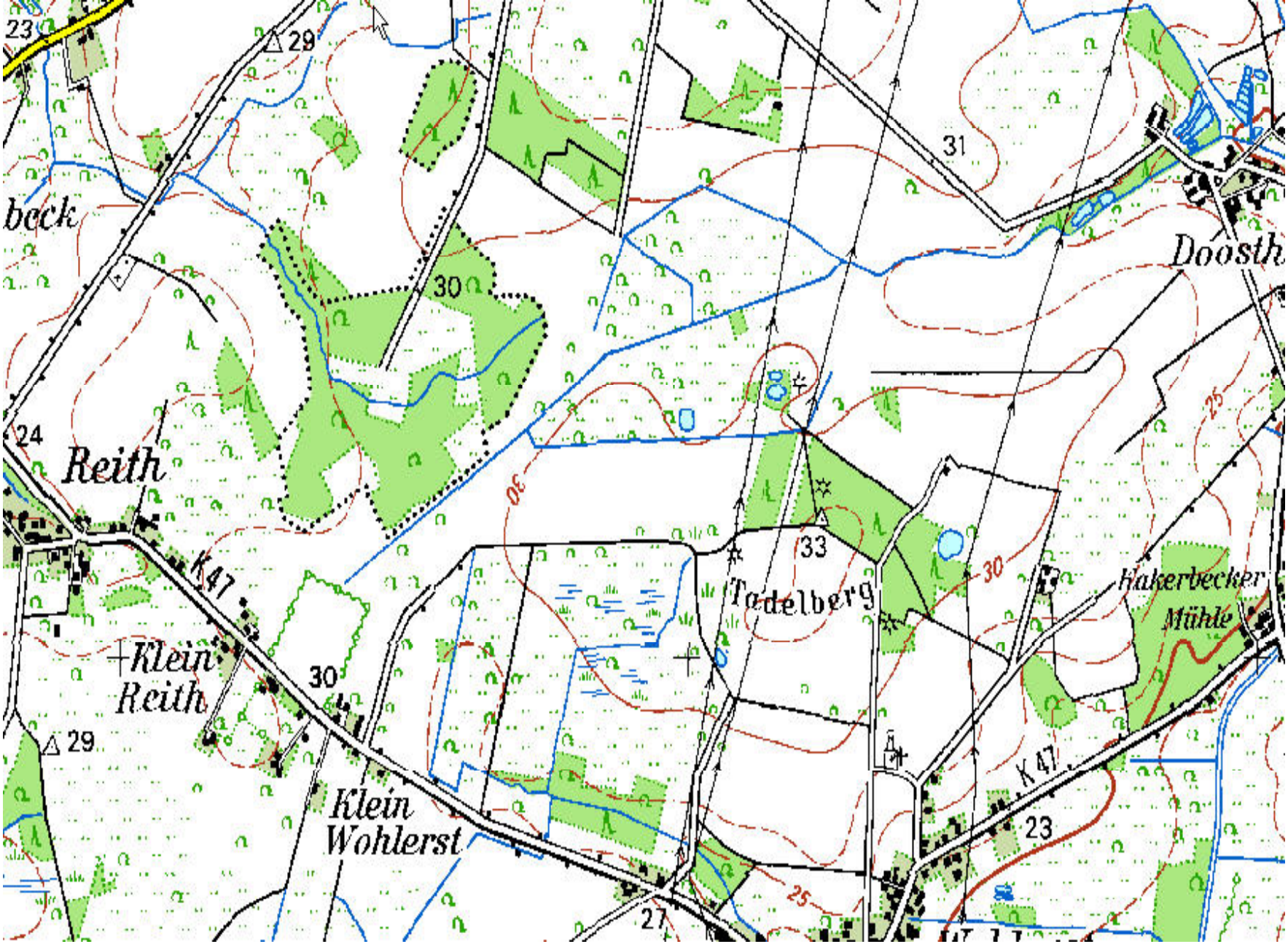
Interruption of dynamic processes

e.g. dispersal of seeds,
pollination by insects


Reduced habitat size
Habitat isolation
Small populations
Reduced pollination
Lower seed production
Self pollination
Genetic drift
Inbreeding
Reduction of genetic diversity
Potential effects of habitat fragmentation
Lowered fitness
Local extinction of species
Reduced gene exchange

Habitat fragmentation in forests




Reith
Klein Reith
Klein Wohlerst
Tadelberg
Hakerbecker Mühle
K47
K47
24
23
29
30
31
33
27
25
30

145 forest patches

- All deciduous forests in the study area
- Minimum size: 1 ha
- Predominantly *Fagus*- and *Quercus* forests on acid soils, *Quercus*-*Carpinus* forests and *Alnus*-*Fraxinus* forests

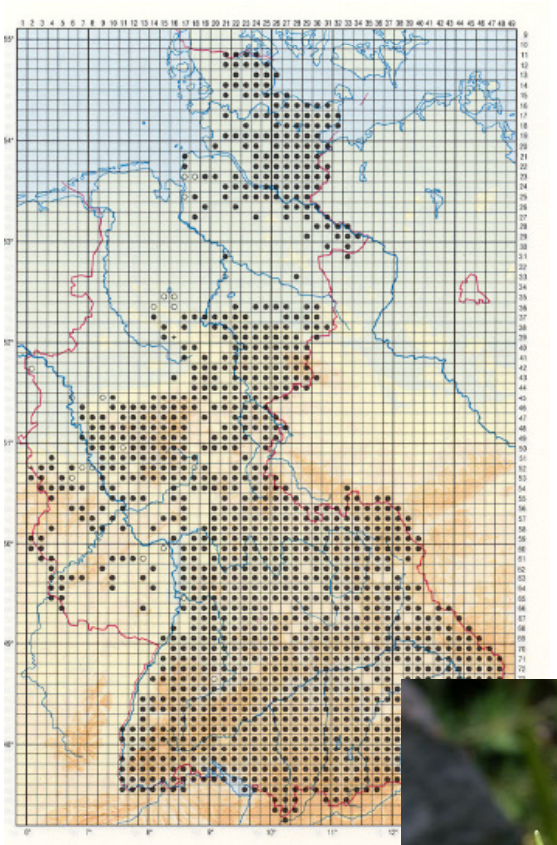
Effects on some herbaceous species

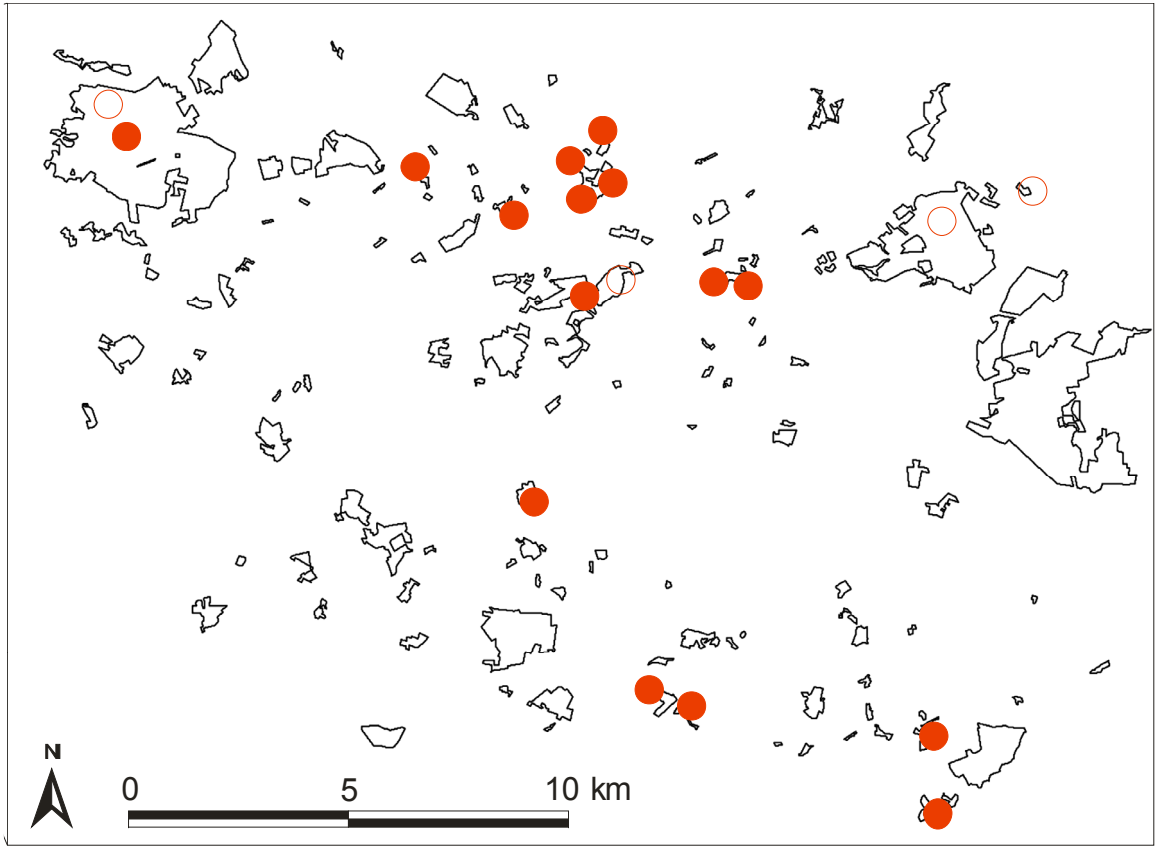
Species	Red list	Significantly affected by	
		Forest size	Isolation
Carex sylvatica		+	-
Epipactis helleborine		+	-
Brachypodium sylvaticum		+	
Chrysosplenium alternifolium	*	+	
Chrysosplenium oppositifolium	*	+	
Equisetum hyemale	*	+	
Gagea spathacea	*	+	
Galium odoratum		+	
Melica uniflora		+	
Phyteuma spicatum	*	+	
Platanthera chlorantha	*	+	

(Kolb & Diekmann 2004, J. Veg. Sci. 15: 199-208)

Species	Red list	Significantly affected by	
		Forest size	Isolation
Rumex sanguineus		+	
Stellaria nemorum		+	
Veronica montana	*	+	
Convallaria majalis			-
Luzula pilosa			-
Lysimachia nemorum	*		-
Sanicula europaea	*		-
Viola riviniana			-

Phyteuma spicatum

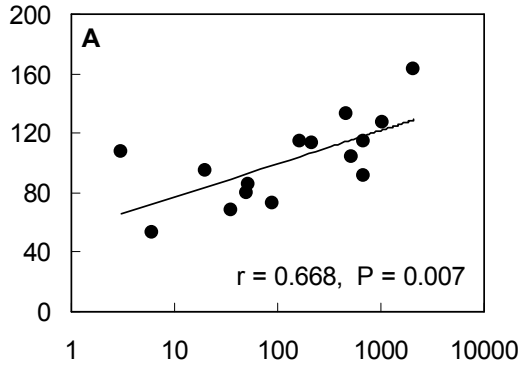


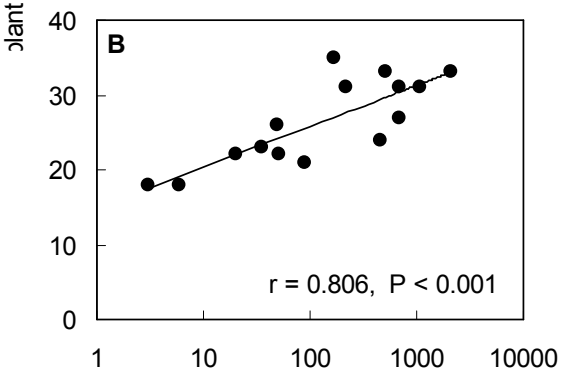


- 15 populations
- 3 - 2095 individuals
- Isolation: 400 - 4700 m

Field study

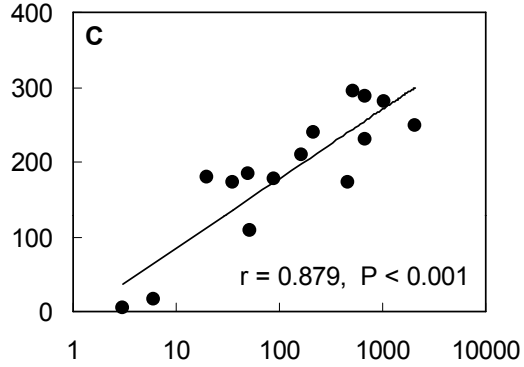
Leaf Area index

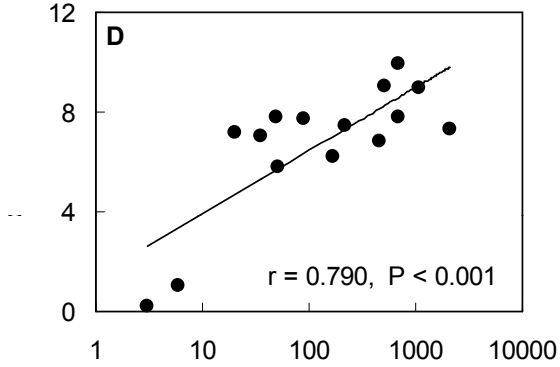




Seed capsules/ plant

No. of seeds/ plant

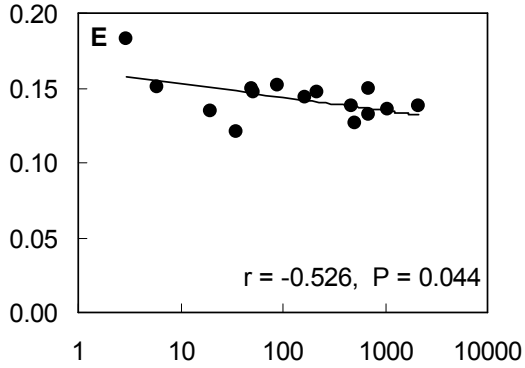


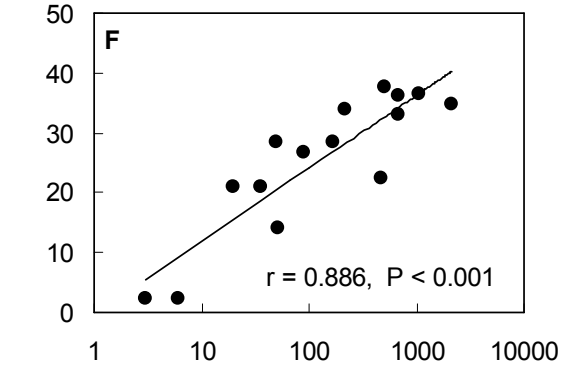


No. of seeds/ capsule

(Kolb 2005, J. Ecol. 93: 1226-1237)

Mean Seed weight [mg]

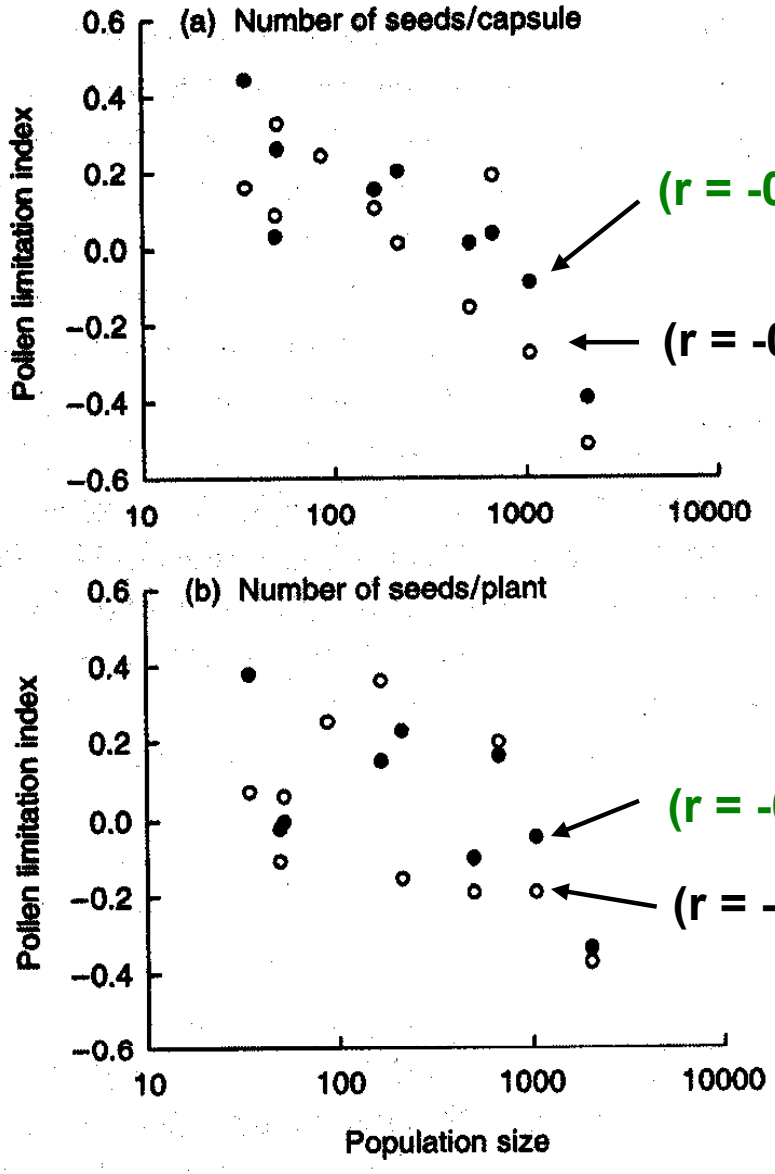




Repro- ductive output [mg]

log population size

log population size



(r = -0.835, p = 0.005)

(r = -0.600, p = 0.088)

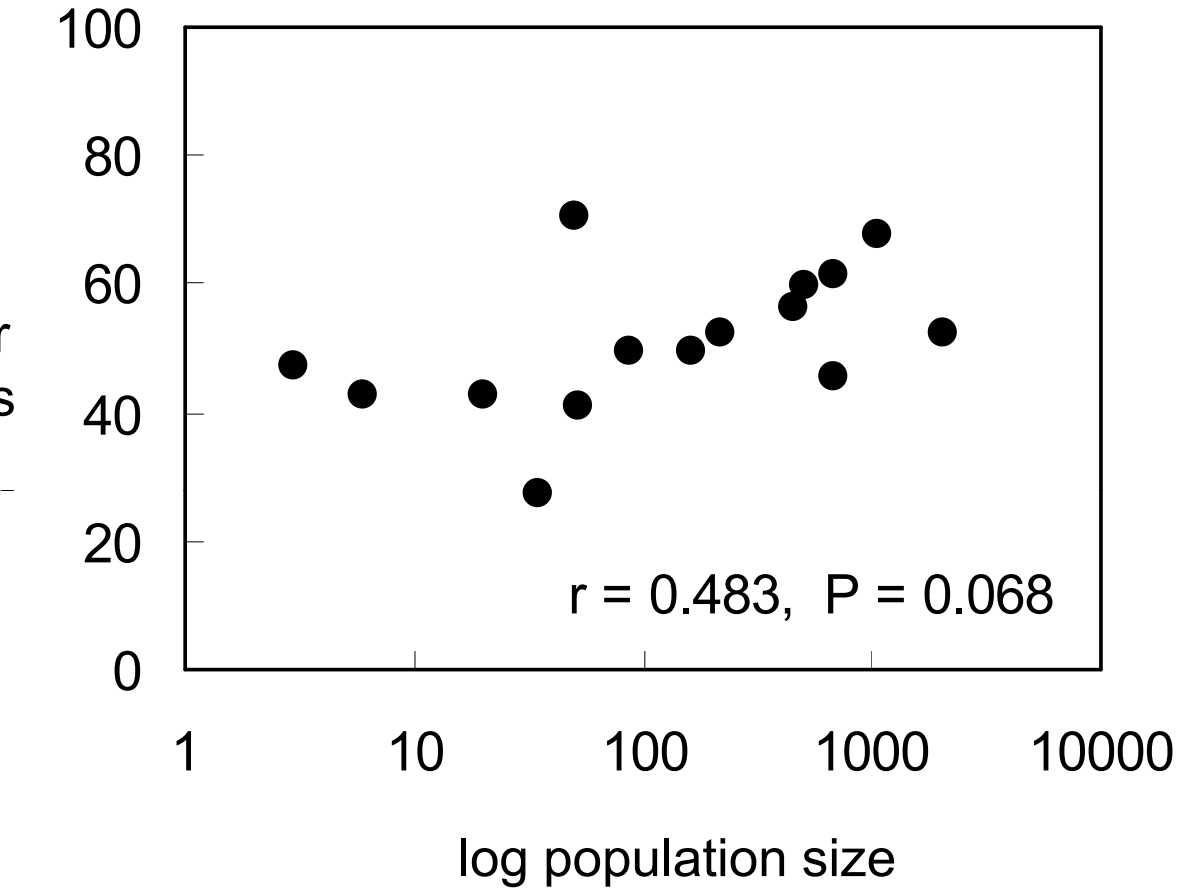
(r = -0.799, p = 0.006)

(r = -0.494, p = 0.146)

Pollination experiment:
Filled circles: Pollen from the same population
Open circles: Pollen from another population

Greenhouse

Seed from populations of different size were grown in the greenhouse, and their survival was measured.

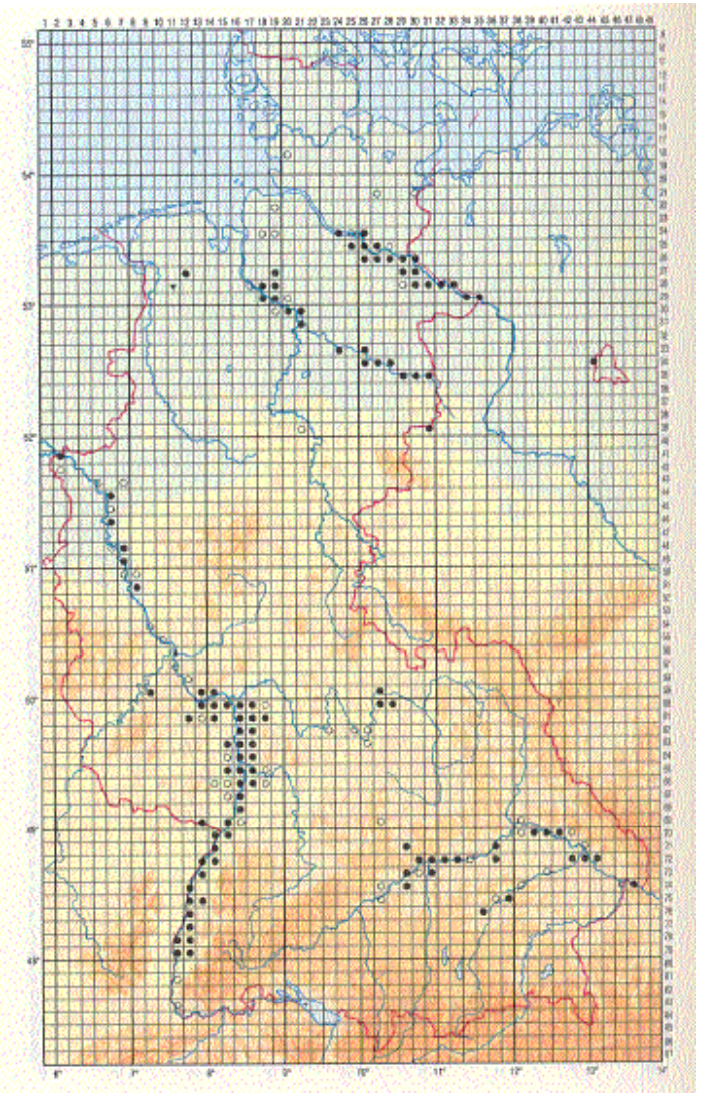


No effects of isolation and hardly any effects of habitat quality

Habitat fragmentation in river valleys

In Central Europe, the valleys of the large rivers have been heavily transformed by man: the rivers were straightened and diked, the valleys drained. Consequently, the area of wetland biotopes has strongly diminished. Many typical species of these river valleys, so-called river corridor plants, have become rare, being confined today to small and isolated populations.

Euphorbia palustris



Pseudolysimachion longifolium

Lathyrus palustris

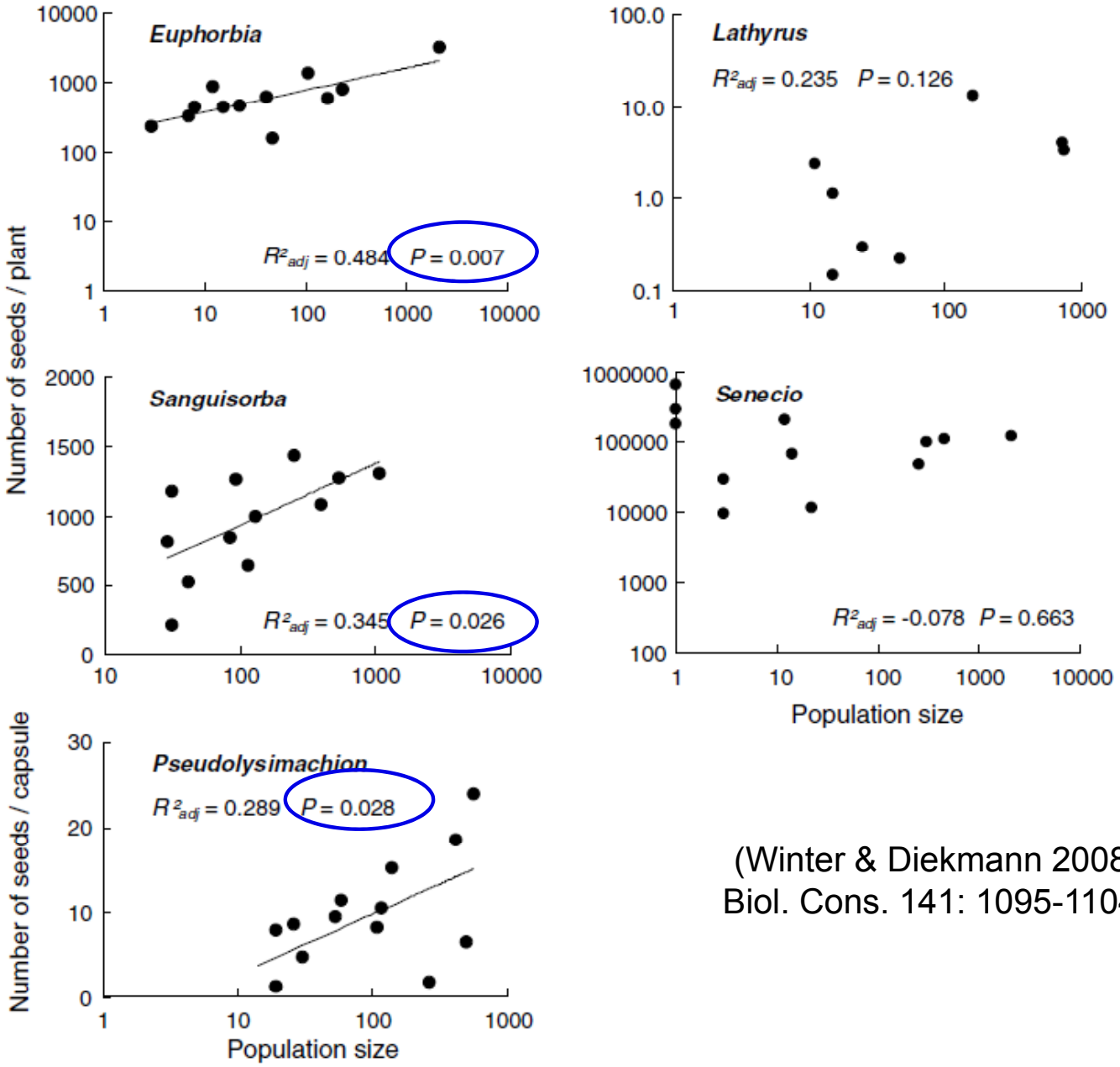
Sanguisorba officinalis

Senecio paludosus

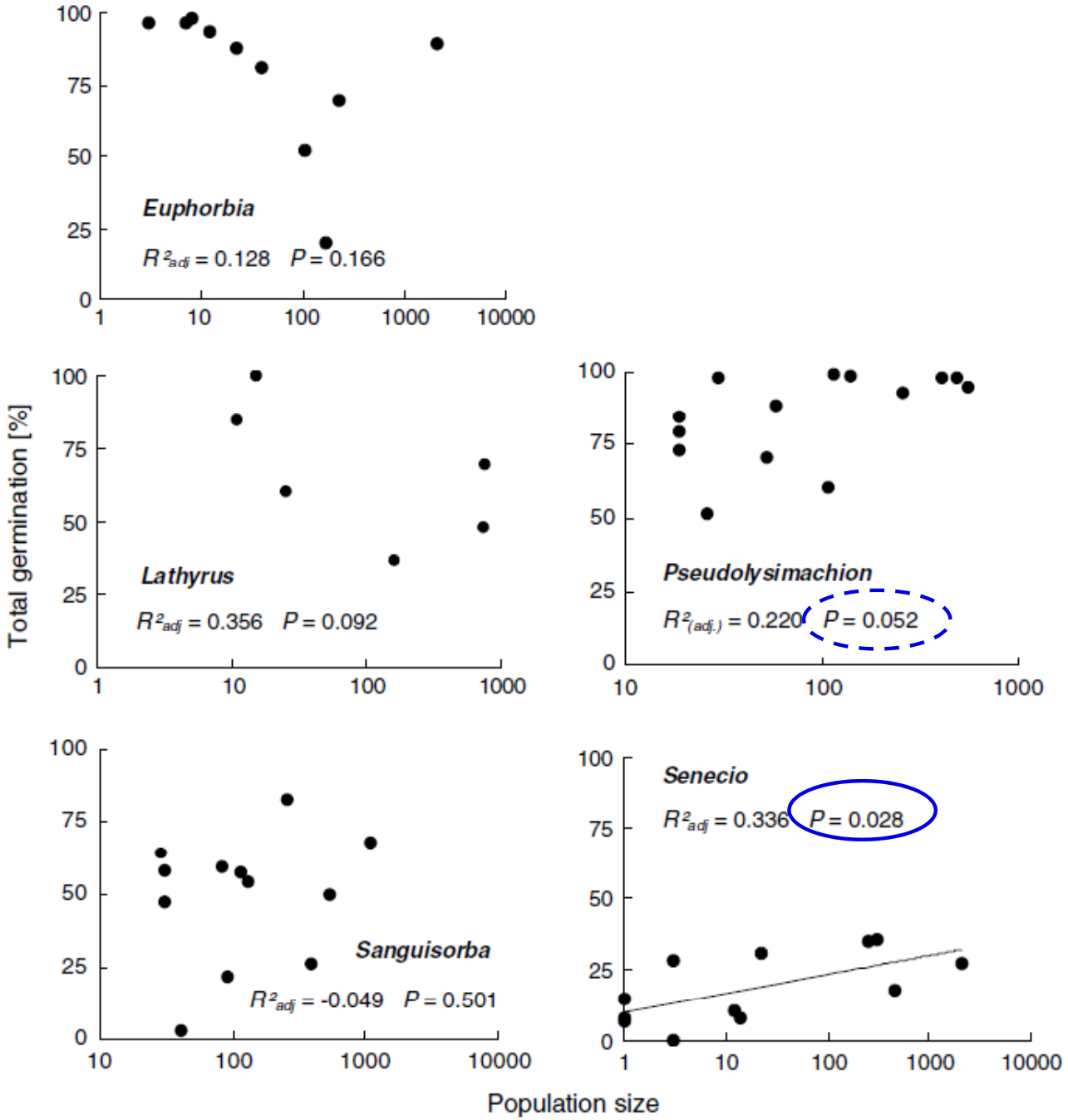
River valleys

Universität Bremen

ECOLOGY

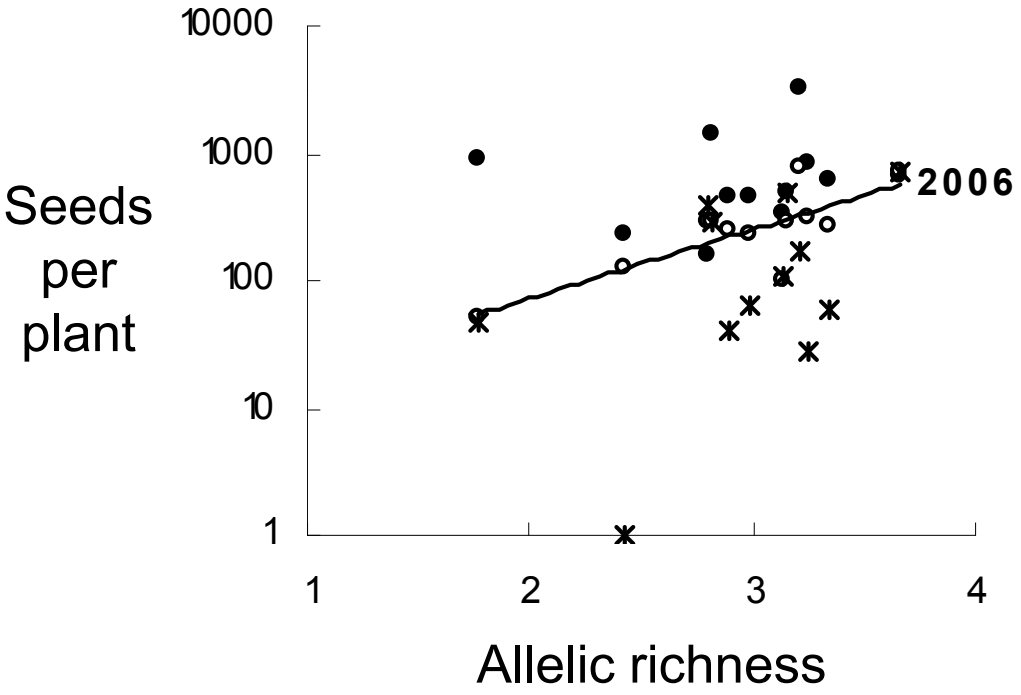


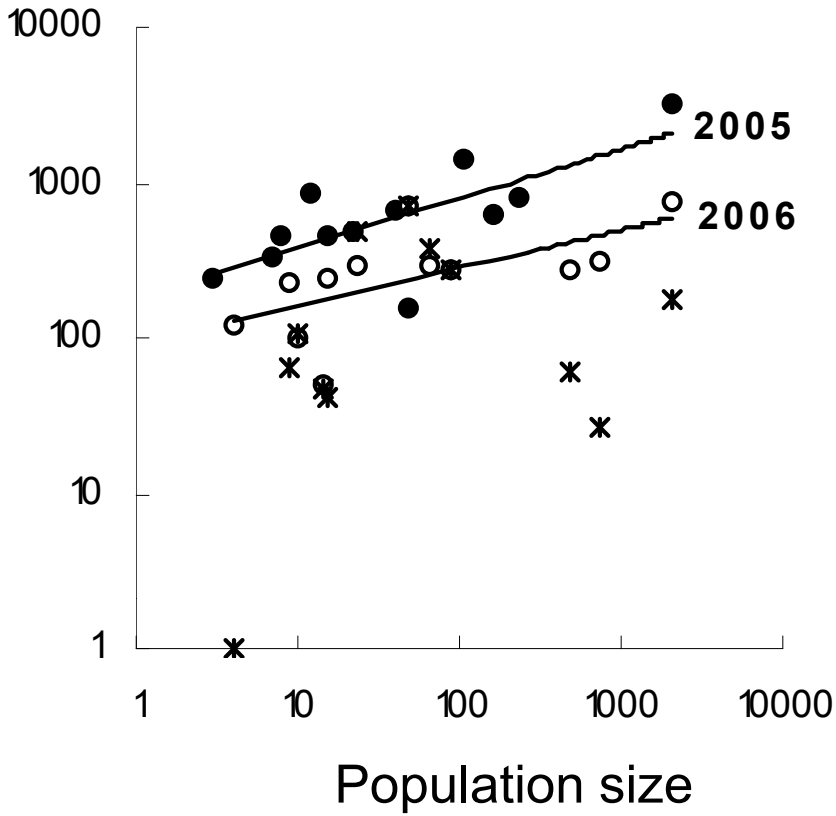
(Winter & Diekmann 2008,
Biol. Cons. 141: 1095-1104)


Total germination [%]
Population size
Euphorbia
R^2_{adj} = 0.128 P = 0.166
Lathyrus
R^2_{adj} = 0.356 P = 0.092
Pseudolysimachion
$R^2_{(adj.)}$ = 0.220 P = 0.052
Sanguisorba
R^2_{adj} = -0.049 P = 0.501
Senecio
R^2_{adj} = 0.336 P = 0.028

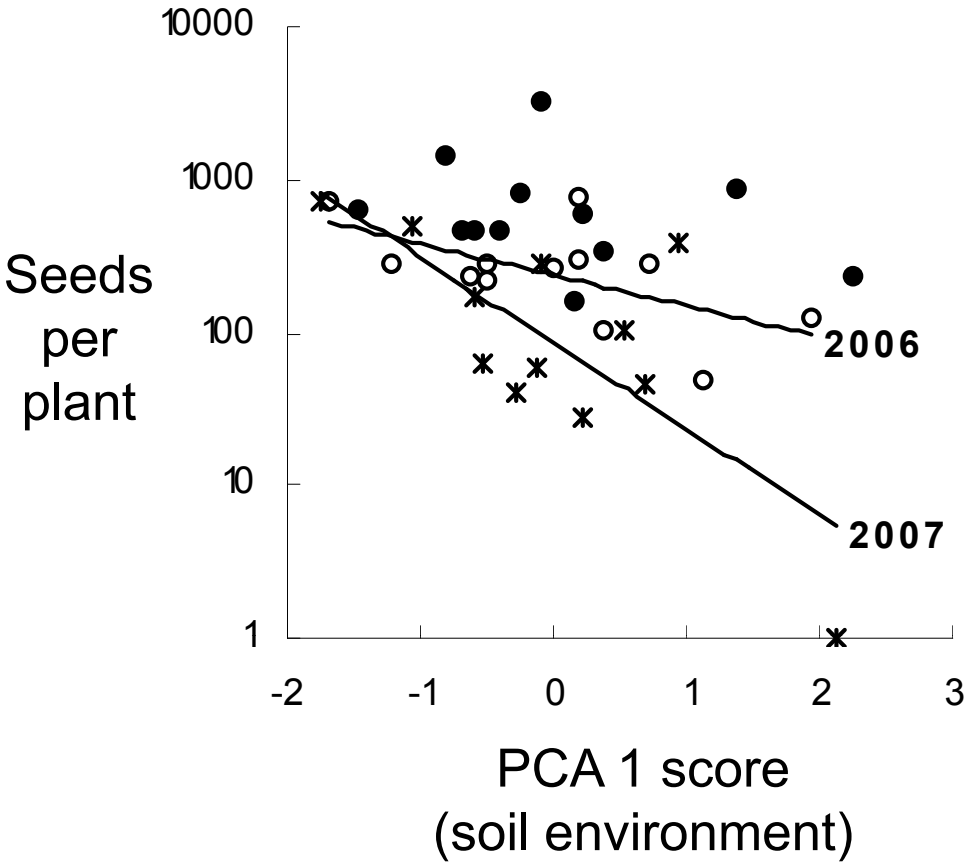
Variation (R^2) attributed exclusively to either population size and isolation, or soil variables (partial regression analysis)

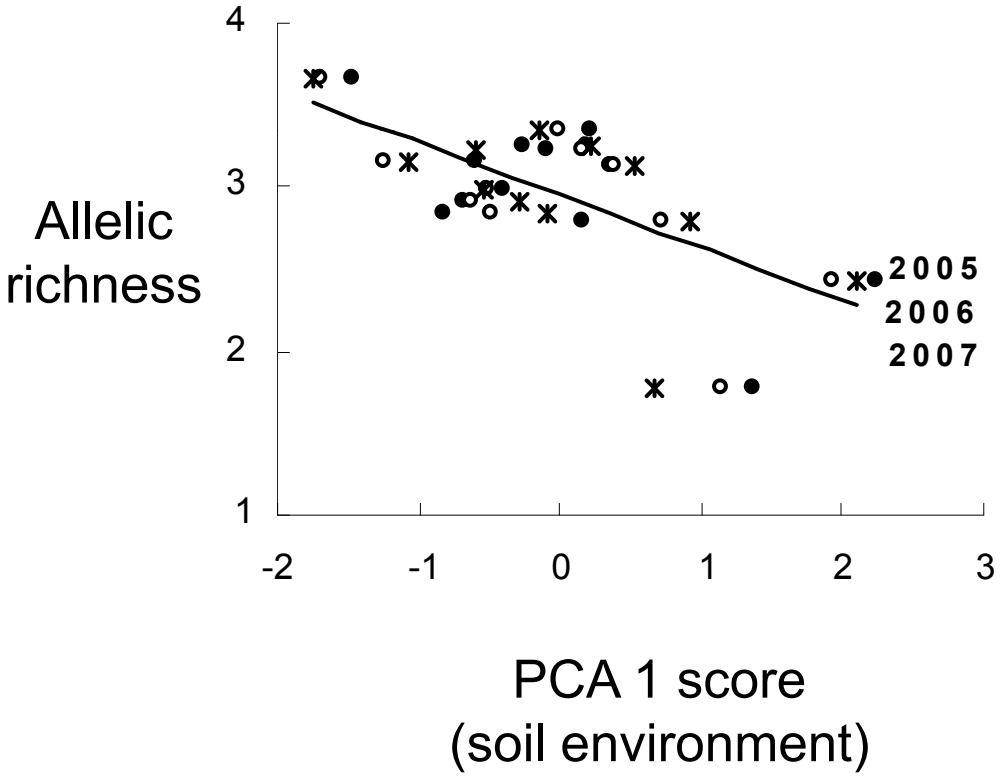
	Number of seeds		Total germination [%]	
	Pop size & isolation	Soil variables	Pop size & isolation	Soil variables
Euphorbia	**0.283**	0.064	**0.294**	0.219
Lathyrus	0.103	**0.233**	**0.297**	0.098
Pseudolysimachion	**0.341**	0.256	0.161	**0.318**
Sanguisorba	0.307	**0.603**	0.228	**0.381**
Senecio	0.058	**0.382**	**0.208**	0.129





(Winter & Diekmann, manuscript)

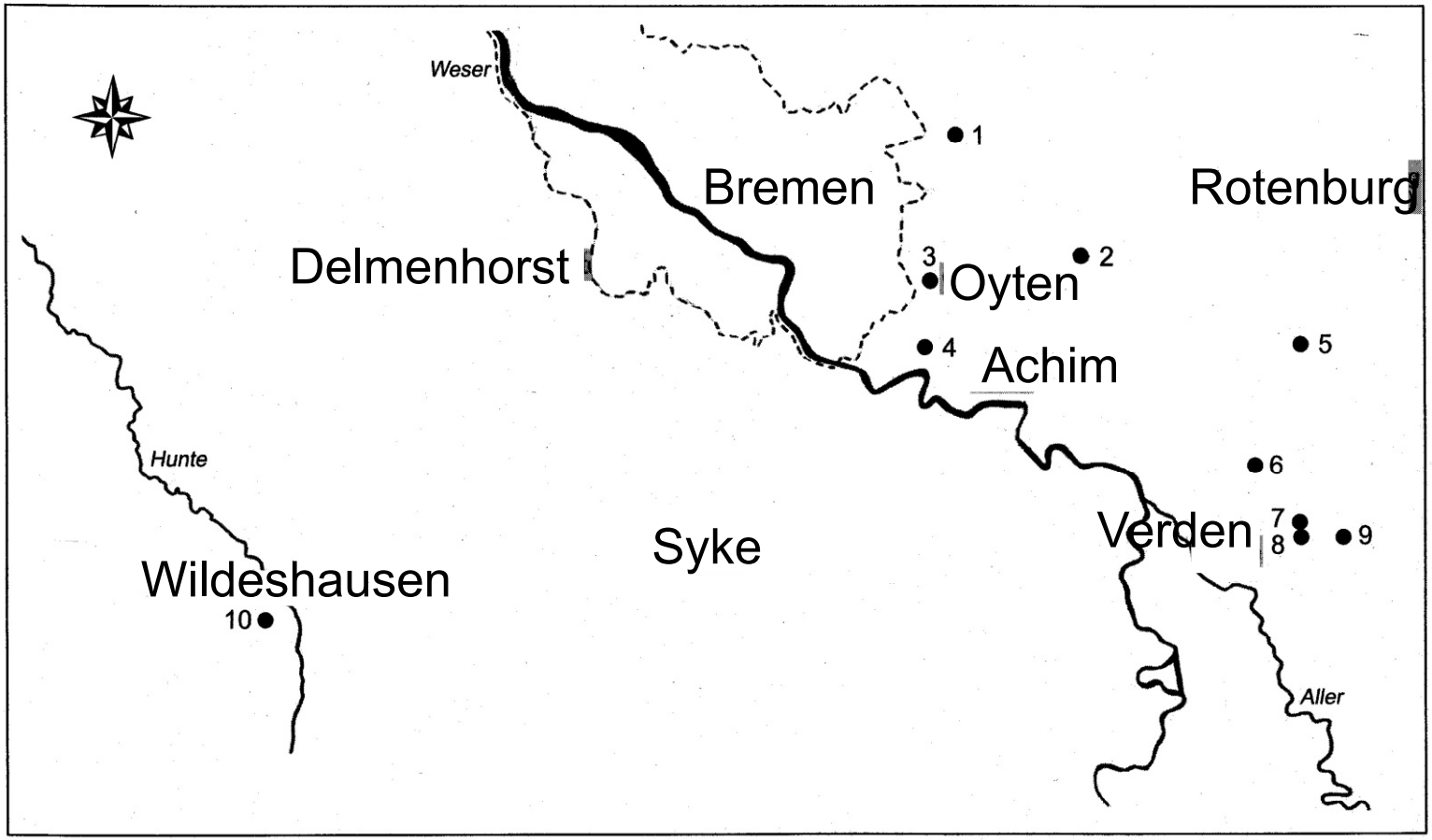

10000
1000
100
10
1
Seeds per plant
2006
2007
-2
-1
0
1
2
3
PCA 1 score
(soil environment)


4
3
2
1
Allelic richness
2005
2006
2007
-2
-1
0
1
2
3
PCA 1 score
(soil environment)

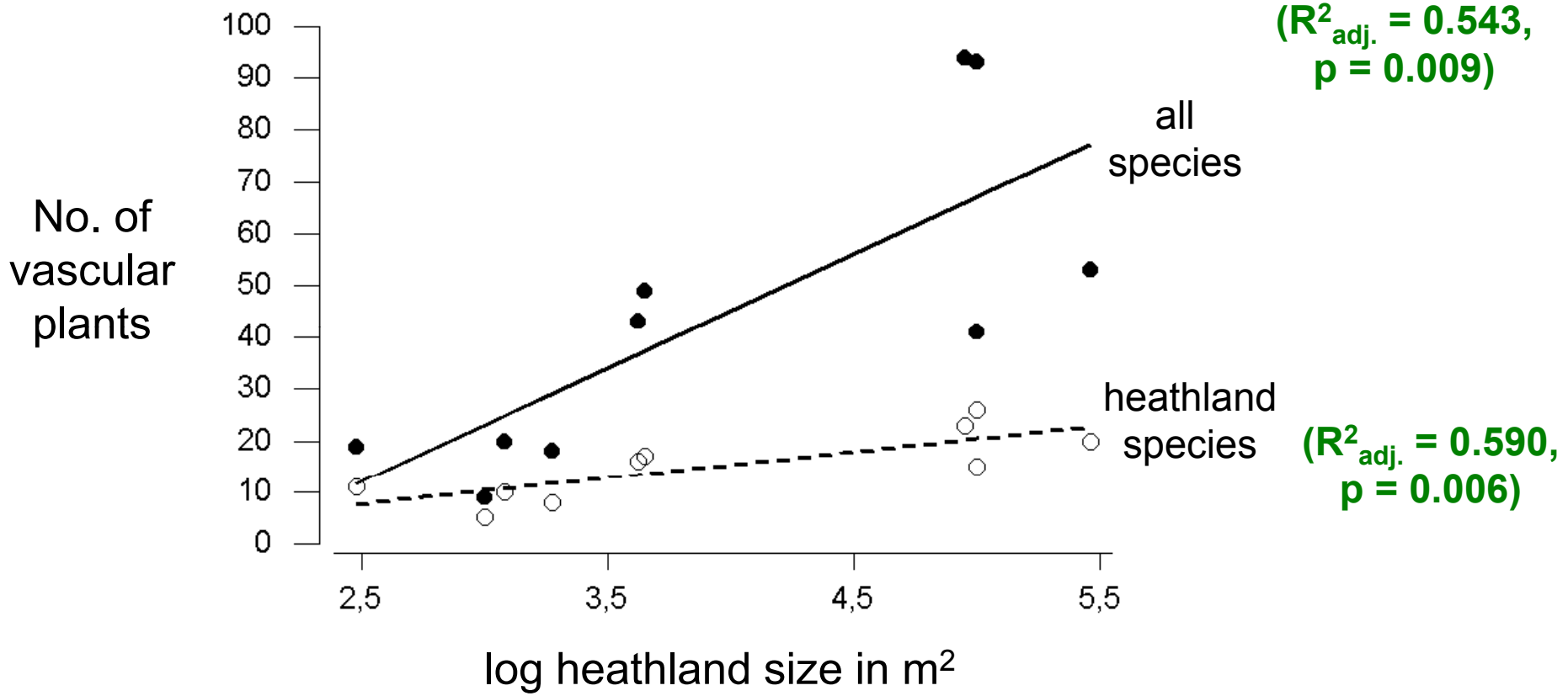
Habitat fragmentation in heathlands

- *Calluna* heathlands once were very common in the NW German lowlands, but have vanished almost completely during the last century. Today, they are confined to few small and isolated patches.

Study of 10 isolated heathland remnants in the surrounding of Bremen
(part of a student project)

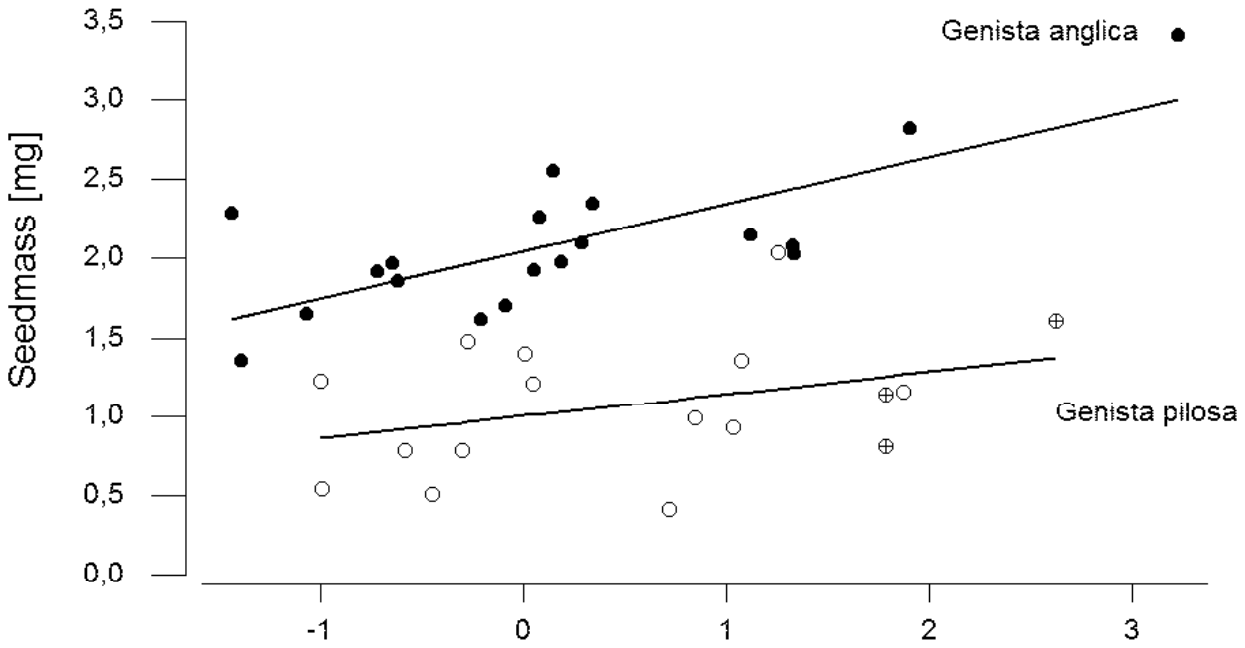


(Dieckhoff *et al.* 2006, Abh. Naturwiss. Vereins Bremen 46/1: 87-100)

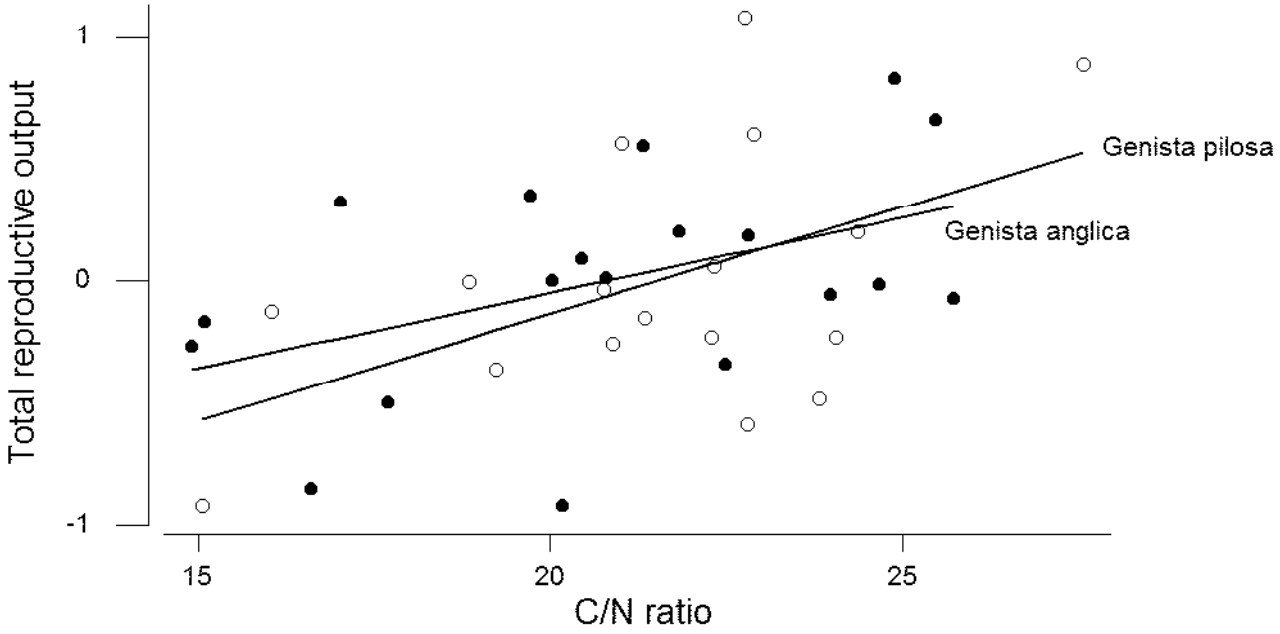


Relationship between species richness and heathland size

- Study of the effects of habitat fragmentation and the environment on the fitness of populations

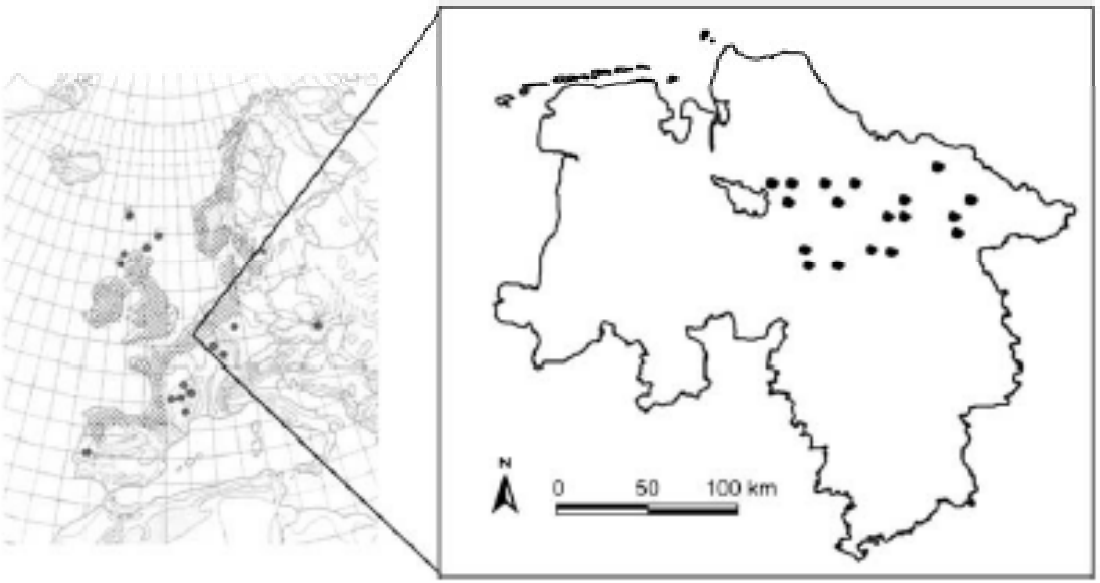


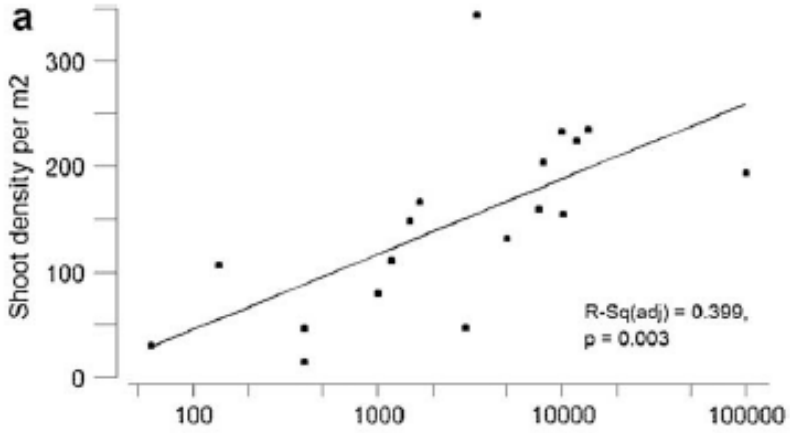
(Tsaliki & Diekmann, manuscript)

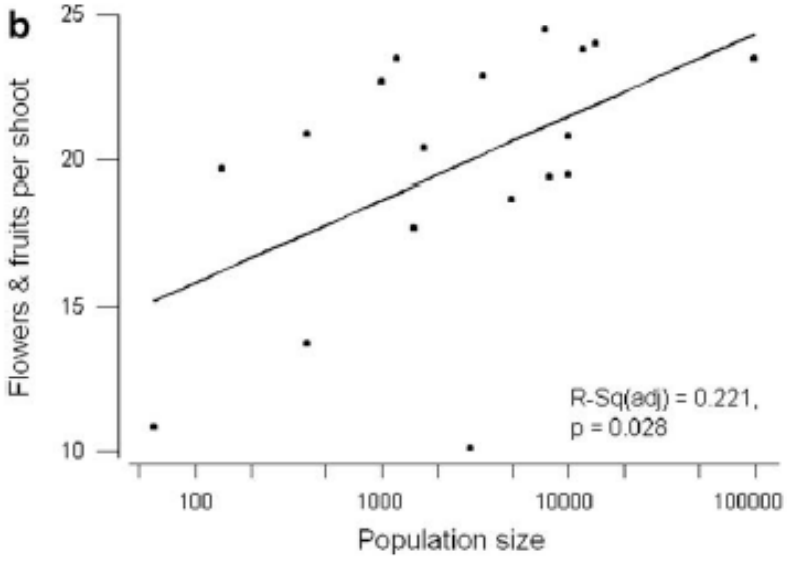

Total reproductive output
1
0
-1
15
20
25
C/N ratio
Genista pilosa
Genista anglica

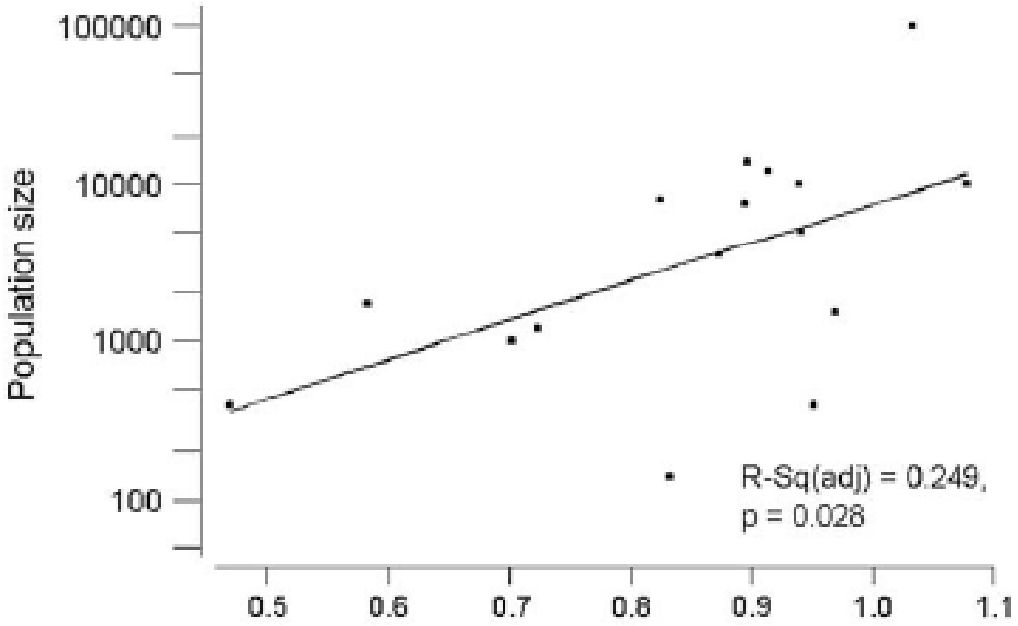
Narthecium ossifragum

(Tsaliki & Diekmann 2009, Acta Oecol. 35: 415-421)

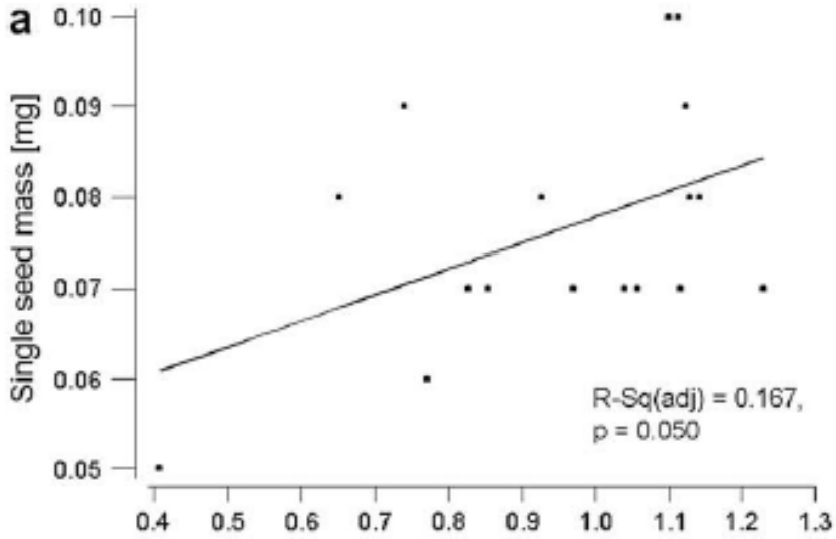


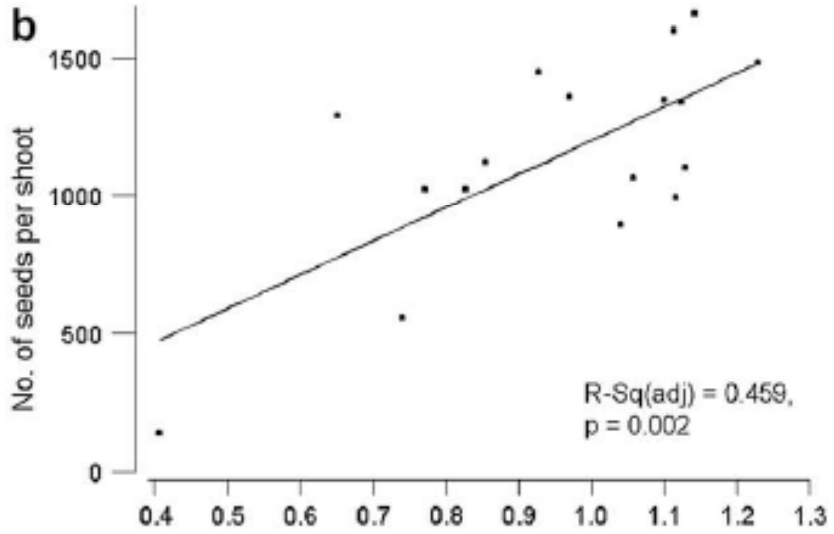




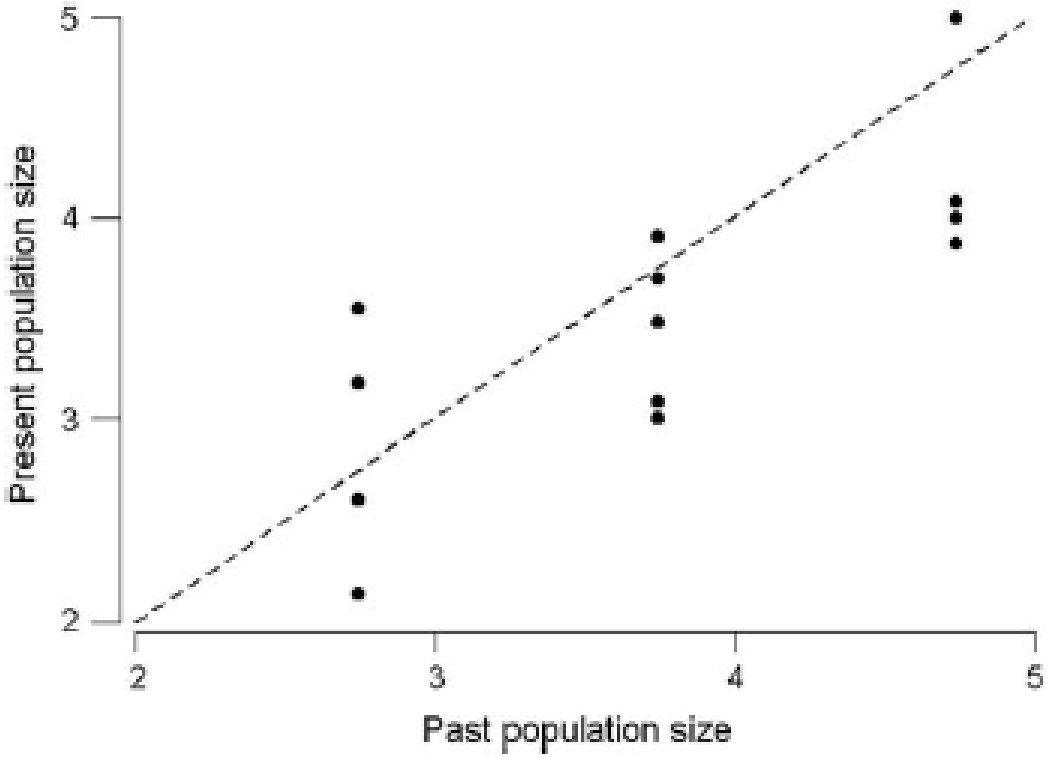


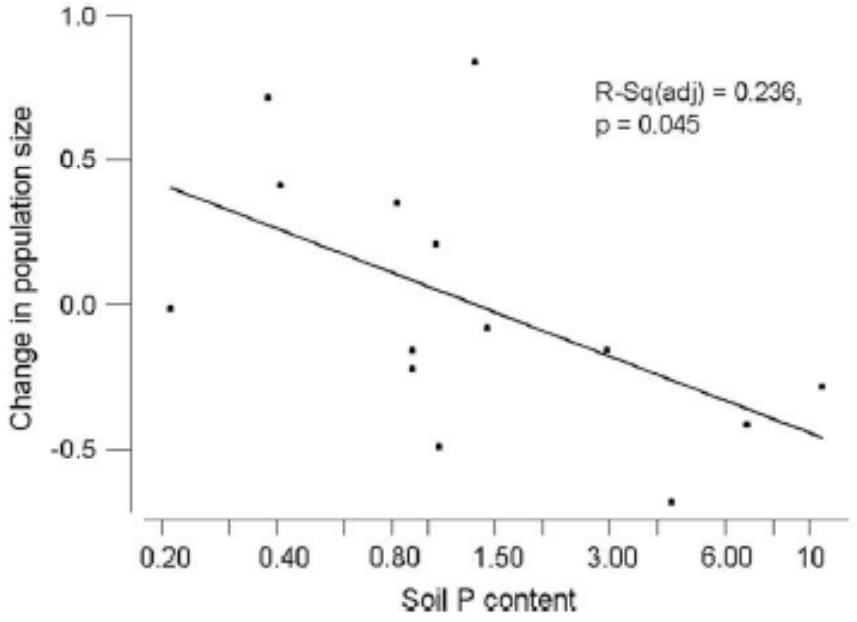
Relative light availability





Soil water content


Present population size
Past population size
5
4
3
2
2
3
4
5


Change in population size
Soil P content
R-Sq(adj) = 0.236,
p = 0.045
1.0
0.5
0.0
-0.5
0.20
0.40
0.80
1.50
3.00
6.00
10

Habitat fragmentation in grasslands

Data set of 3 x 109 sample plots of grassland vegetation in the Holtumer Moor area east of Bremen, NW Germany

Three inventories

Year(s) of inventory	Author(s)	Data collection	Plot size
1963/64	Dierschke, 1969	Vegetation relevés	Varying
1988	Dierschke & Wittig, 1991	Vegetation relevés	25 m^2
2006	Waldmann, 2007	Vegetation relevés & environmental data	25 m^2

	1963	1988	2006
Silene flos-cuculi	IV	I	+
Lotus pedunculatus	IV	+	+
Senecio aquaticus	III	r	r
Bromus racemosus	II	r	-
Carex nigra	IV	r	r
Carex acuta	II	r	+
Cynosurus cristatus	IV	+	-
Alopecurus pratensis	I	IV	V
Taraxacum officinale	III	IV	IV
Holcus lanatus	V	V	IV
Cardamine pratensis	V	III	III
Alopecurus geniculatus	+	II	I
Stellaria media	-	I	III
Urtica dioica	-	+	I

Changes in species constancy

Cumulative number of species:

1963: 146

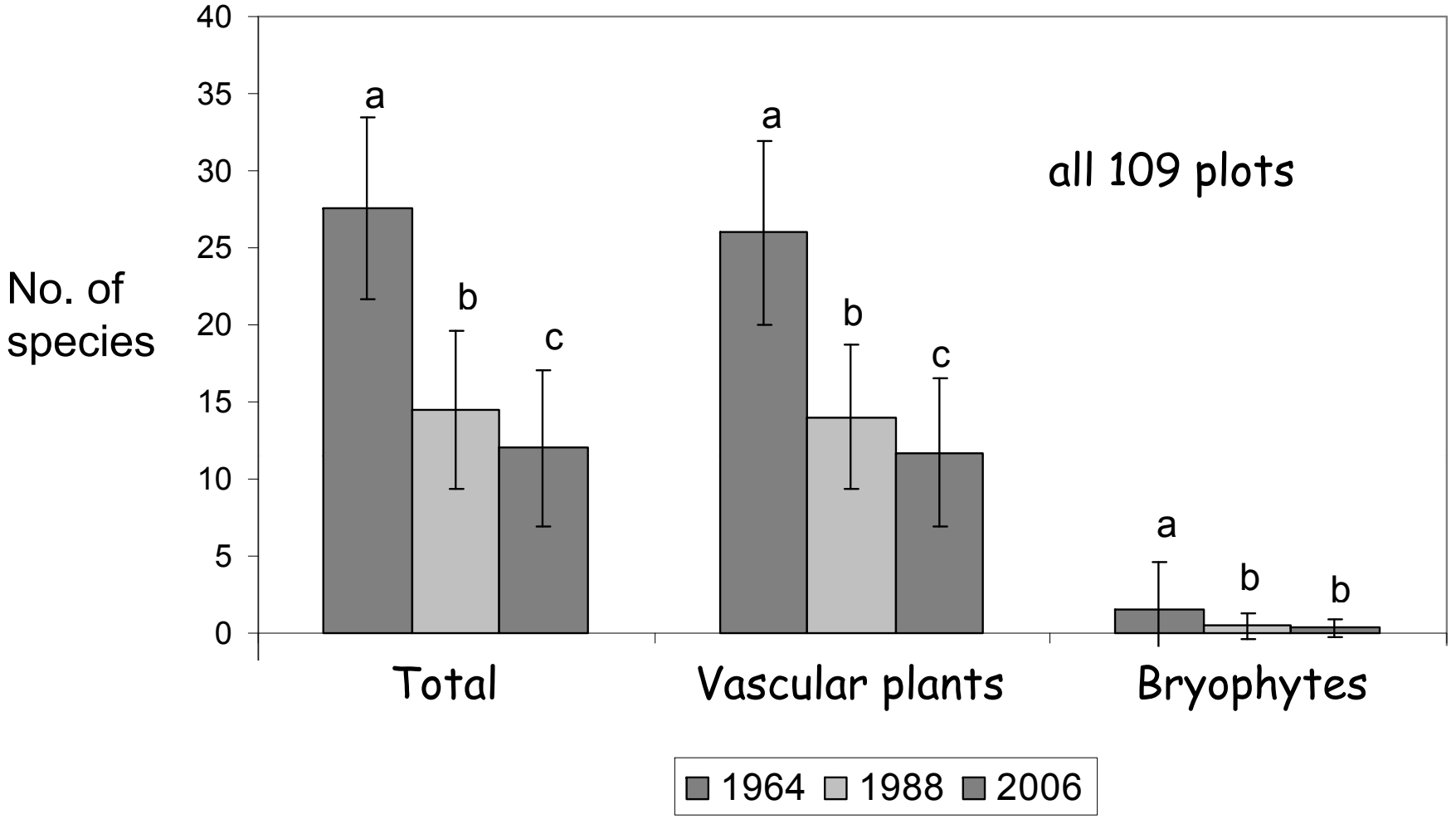
1988: 96

2006: 71

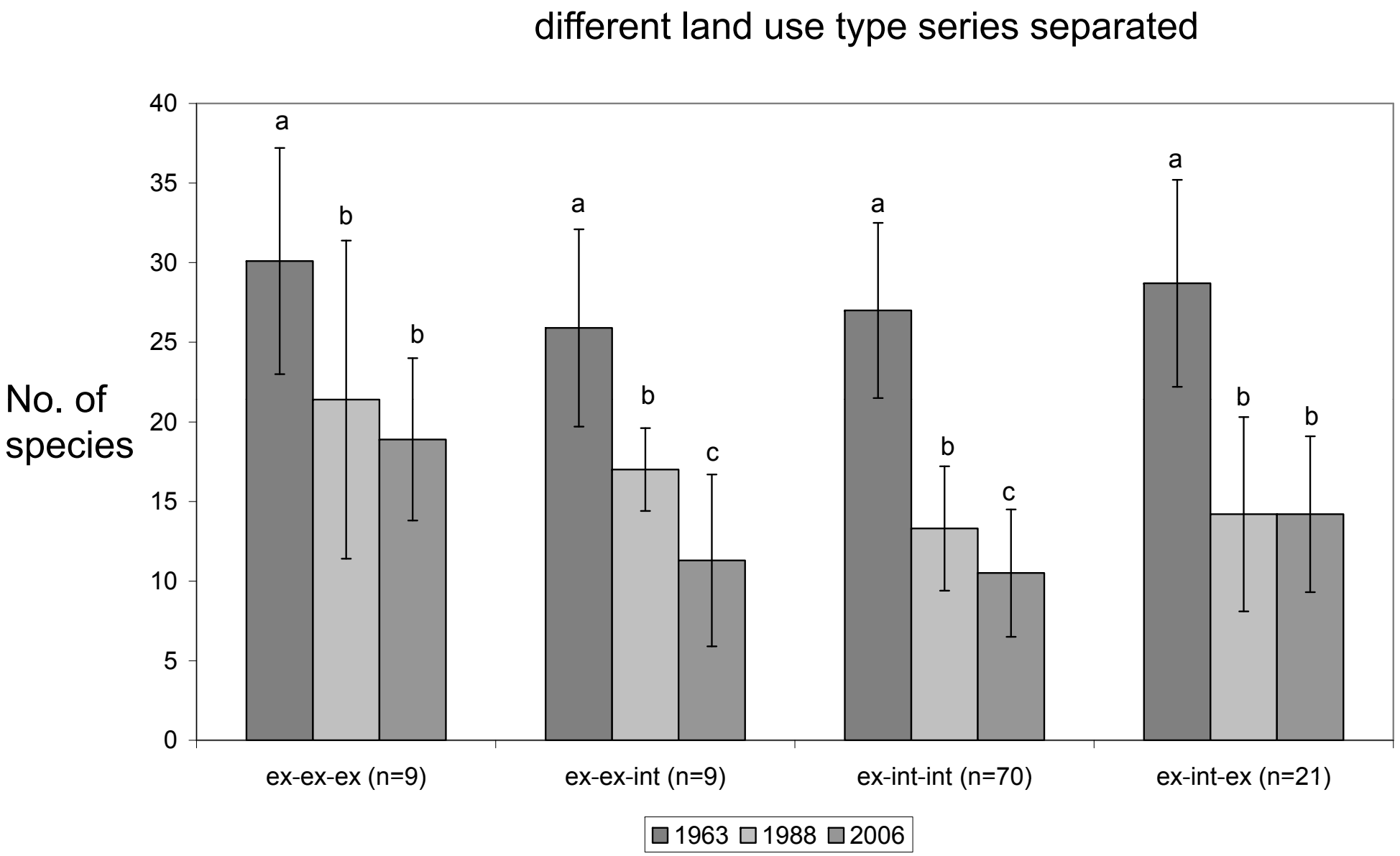
Red-listed species

Extinctions until 1988:
Briza media, Menyanthes trifoliata, Primula elatior, Rhinanthus minor, Stellaria palustris, Triglochin palustre, Valeriana dioica

Extinctions until 2006:
Bromus racemosus, Carex panicea, Dactylorhiza majalis



(Wittig, Waldmann & Diekmann 2007, Hercynia)


different land use type series separated
No. of species
40
35
30
25
20
15
10
5
0
a
b
b
a
b
c
a
b
c
a
b
b
ex-ex-ex (n=9)
ex-ex-int (n=9)
ex-int-int (n=70)
ex-int-ex (n=21)
1963
1988
2006

Resumé

- Habitat fragmentation leads to decreasing habitat patch size and thereby generally to decreasing plant population sizes;

- A decline in population size is most often associated with a decreasing sexual reproduction (due to reduced pollination and a loss in genetic variability);

- However, bad sexual reproduction is also or even more the result of unfavourable environmental conditions;

- If environmental conditions are kept favourable and stable, low sexual reproduction may not matter at all if the plant is capable of reproducing clonally;

- A great problem in fragmented habitats: if species are already lost, plant species may not be able to re-establish - even if the environment has been restored - because surviving populations are too far away!


Thank you very much for your attention!