Ecology I.

- http://zeus.nyf.hu/~szept/kurzusok.htm

- Krebs, C. J. (2014) Ecology, The experimental Analysis of Distribution and Abundance.Harper Int. Ed.

https://archive.org/details/KrebsCharlesJ.EcologyTheExperimentalAnalysisOfDistributionAndAbundance201440mb/mode/2up

- M. Begon, J.L. Harper & C.R. Townsend (2021) Ecology, Individuals, Population and Communities. Blackwell Sci. Publ.

Topics

1. Introduction to the Science of Ecology

2. Distribution of living organisms, Factors that limit distributions

3. Populations, Population parameters, Demographic Techniques

4. Population growth

5. Evolution and Ecology

6. Species interactions: Competition, Niche

7. Species interactions: Predation, Herbivory, Mutualism, Parasitism

8. Nature of the Community: structure and change

9. Flux of Energy and Matter trough Ecological systems

10. Natural and artificial ecological systems. Biological diversity

11. Climate change and its ecological consequences

1. Introduction to the Science of Ecology

History of Ecology

Primitive tribes, for example—who depended on hunting, fishing, and food gathering—needed detailed knowledge of where and when their quarry might be found.

Ancient Greeks

Aristotle (IV. B.C): high reproductive rate of field mice could produce more mice than natural predators can reduce. Reduce of mouse plagues can be by heavy rain.

Herodotus and Plato: nature is designed to benefit and preserve each species, number of every species essentially constant, outbreak of some population might occur (punishment of evil-doers). Each species had a special place in nature, and extinction did not occur because it would disrupt this balance and harmony of nature

History of Ecology

- Graunt (1662) Father of demography. Importance of measuring in a quantitative way the birth rate, death rate, sex ratio and age structure of human populations. Concluded, that even without immigration, London could double its population in 64 years.

- Leeuwenhoek (1687) studied the reproductive rate of grain beetles, carrion flies and human lice. One pair of carrion flies could produce 746 496 flies in three months. First attempts to calculate theoretical rates of increase for an animal species

History of Ecology

Buffon (1756) Population of man and other living organism subjected to the same processes.

Great fertility of every species was counterbalanced by innumerable agents of destruction.

Plague populations of field mice checked partly by diseases and scarcity of food (biological factors) – not only the heavy rains

He dealt among the first with population regulation.

- Malthus (1798) „The numbers of organisms can increase geometrically, but their food supply may never increase faster than arithmetically.”

Reproduction is checked by food production.

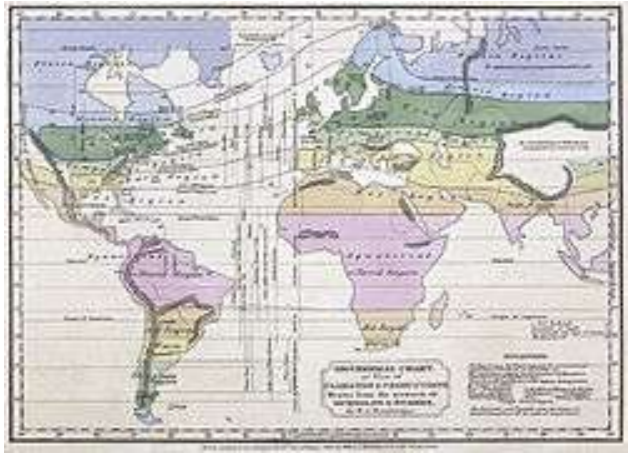
Interest in mathematical aspects of demography increased after Malthus

History of Ecology

- Möbius (1877) Biocoenosis

- Cowles (1899) Plant succession

- Humboldt (XIX century) Relation between climate and vegetation



History of Ecology

- Darwin (1859) Natural selection

Ecology, definition

The roost of ecology lie in natural history.

A word used first by Henry Thoreau (1858) without definition

Haeckel (1869) defined first: as the total relations of the animals to both its organic and inorganic environment -> Too wide definition **!**

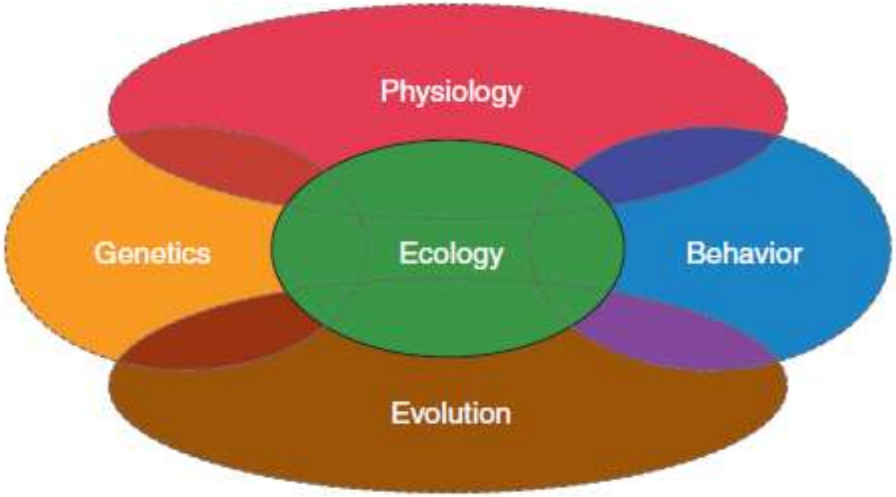
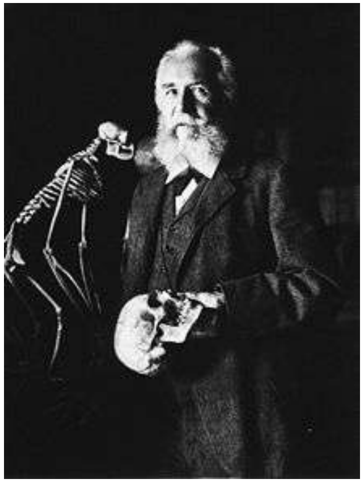


Figure 1 The four biological disciplines closely related to ecology.



Ecology - definition

Elton (1927): Scientific natural history

Odum (1963): Study of the structure and function of nature

Andrewartha (1961): Ecology is the scientific study of the distribution and abundance of organism – problem: this definition is static and leaves out the importance of relationships

Krebs (1985): Ecology is the scientific study of the interactions that determine the distribution and abundance of organism. Where organisms are found, how many occur there, and why

Hungarian approach
Juhász-Nagy Pál (1970):

Ecology:

- focusing on supraindividual levels of biological organisation
- Population is the basic unit of it

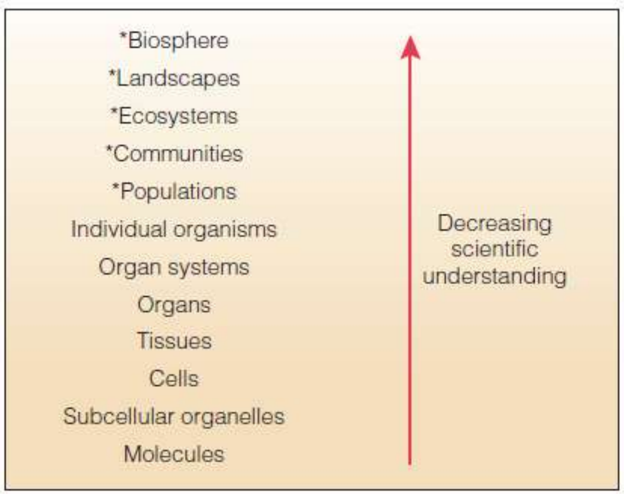
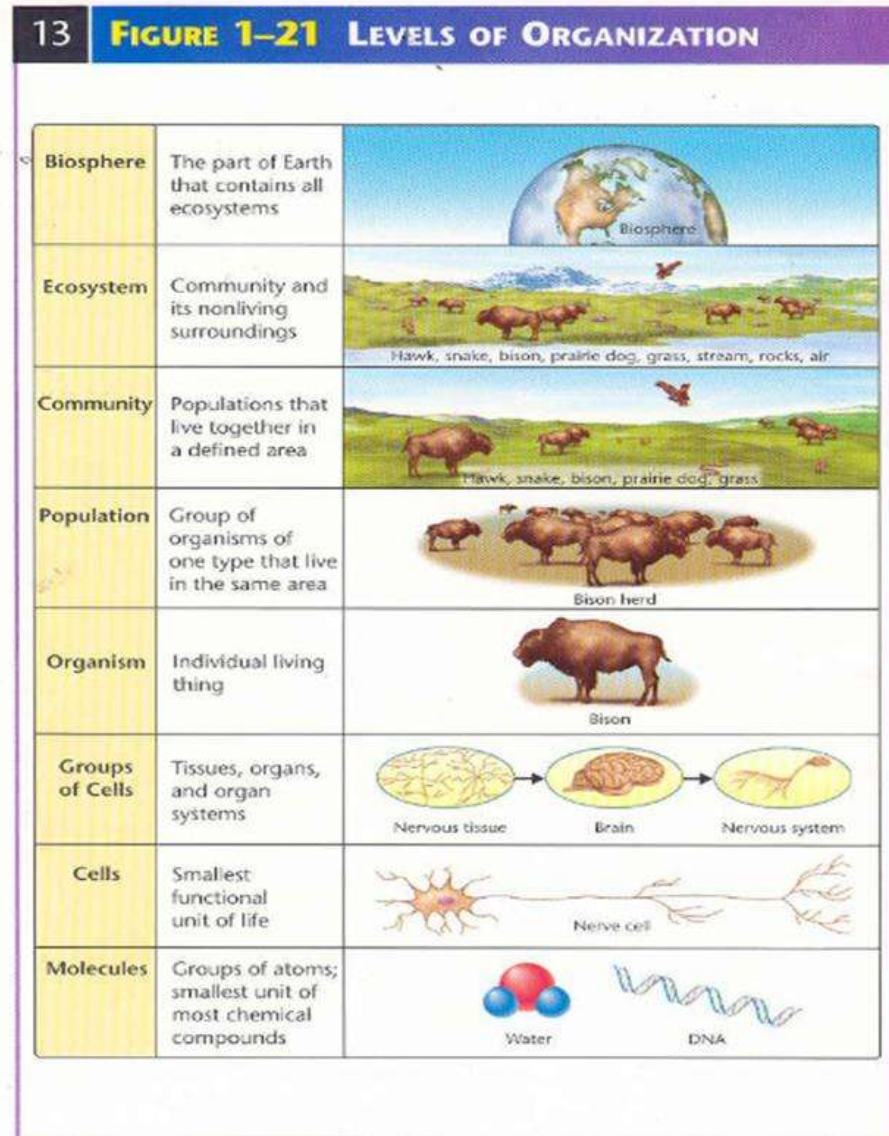


Figure 7 Levels of integration studied in biology.



Hungarian approach

Juhász-Nagy Pál (1970):

Ecology:

- focusing on supraindividual levels of

biological organisation

- Population is the basic unit of it

- Central (null) hypothesis (CH): Any population could find any where, any time, any quantity in the nature – occurrence in space, time and abundance is random

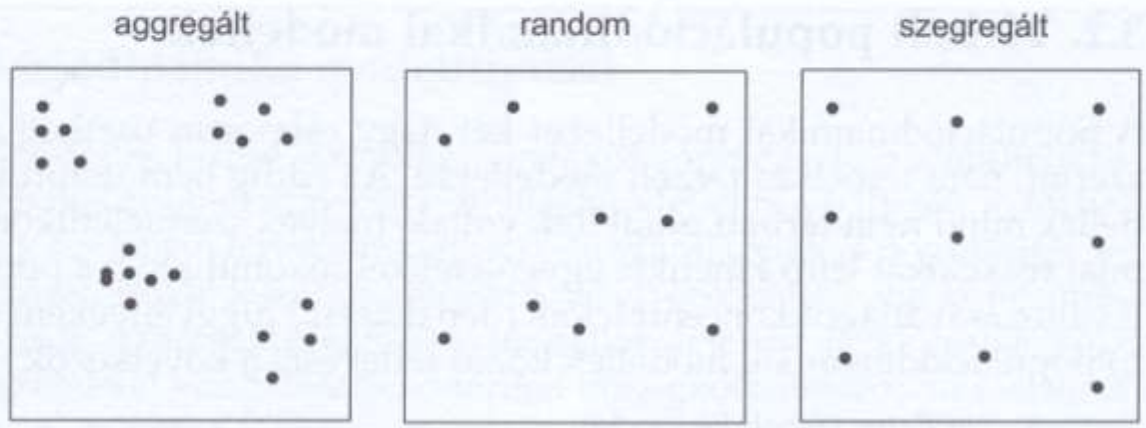
- Central fact: CH could be faulty
- Central problem: How the CH is faulty and Why?

Example: spatial distribution

Three basic distributions:

aggregated random segregated

2. ábra A populációmintázatok típusai.



In the case of non random distribution there is an chance to find factors responsible for the found pattern.

Ecological principles - Opportunities to explain difference from the random distribution

1. Indication principle

-indicators (living organisms)

-indicandum, environmental factor which ones the indicator indicates

2. Complementation principle

- Relation of exterior and interior environments – acting factors and perceptive abilities
- exterior-interior complexes, neighbourhood – living organism

-Exterior complexes, all potentially acting factors in the neighbourhood

- Miliö spectrum, potentially acting factors in the neighbourhood on the base of existing experience

- Miliő, effectively acting factors in the neighbourhood responsible for the found distribution – environment

-Interior complexes, all potentially perceptive abilities

- Tolerance spectrum, potentially perceptive abilities on the base of existing experience

- Tolerance, effectively perceptive abilities responsible for the found distribution

.

Ecological environment: all factors in the neighbourhood which directly and effectively act on the biological object

Neighbourhood –> topological environment

Habitat (biotope): area where the supraindividual biological object occur

3. Multiplural environmental principle

There are several ecological environments in the given topological environment in the given time

4. Limitation principle

- Environmental factors acts together, synergy, any of it which reach range of the tolerance became limiter. Liebig limitation.

  „The strength of the chain depend on the weakest chain link”

Type of ecological studies

- Descriptive

Natural history, describing populations, communities and their relationships

- Functional

Investigations of how the ecological system working. Discovering proximal processes.

- Evolutionary

Explanation of how evolution by natural selection has molded the ecological patterns we observe today. Discovering ultimal processes.

.

Type of ecological studies

.

Plant and animal ecology

Hydro and terrestrial ecology

Population and Community Ecology

Behavioural ecology

Study methods
- Field observation
- Experiment
- Modeling

Synecology – study of group of organisms

Autecology –> individuals organism –> environmental physiology

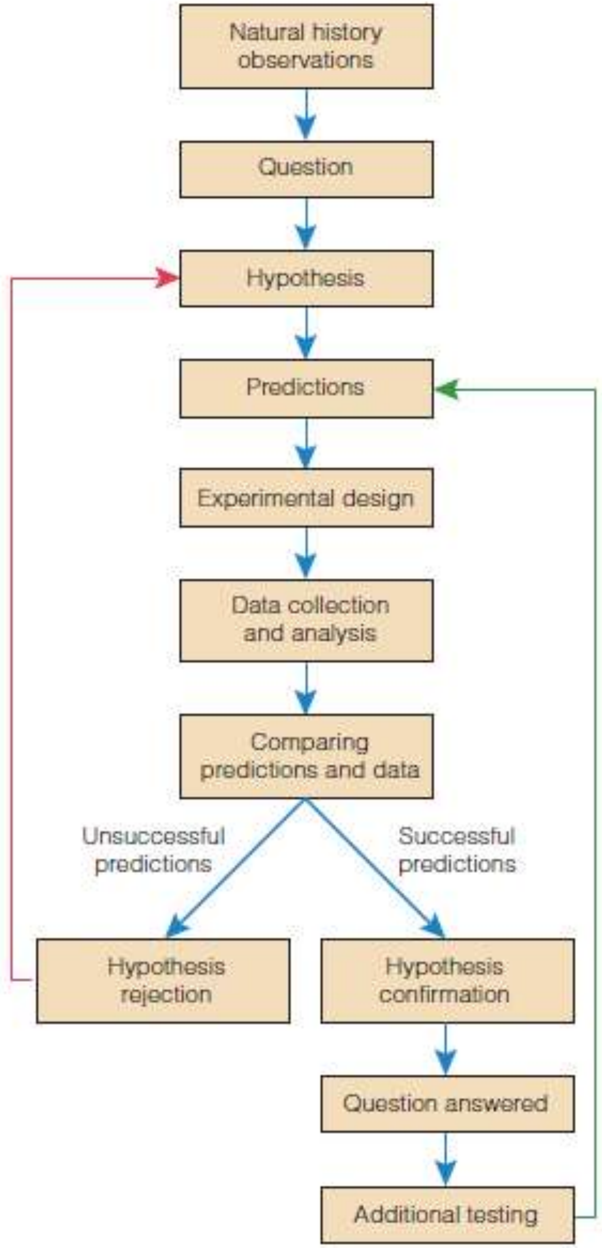
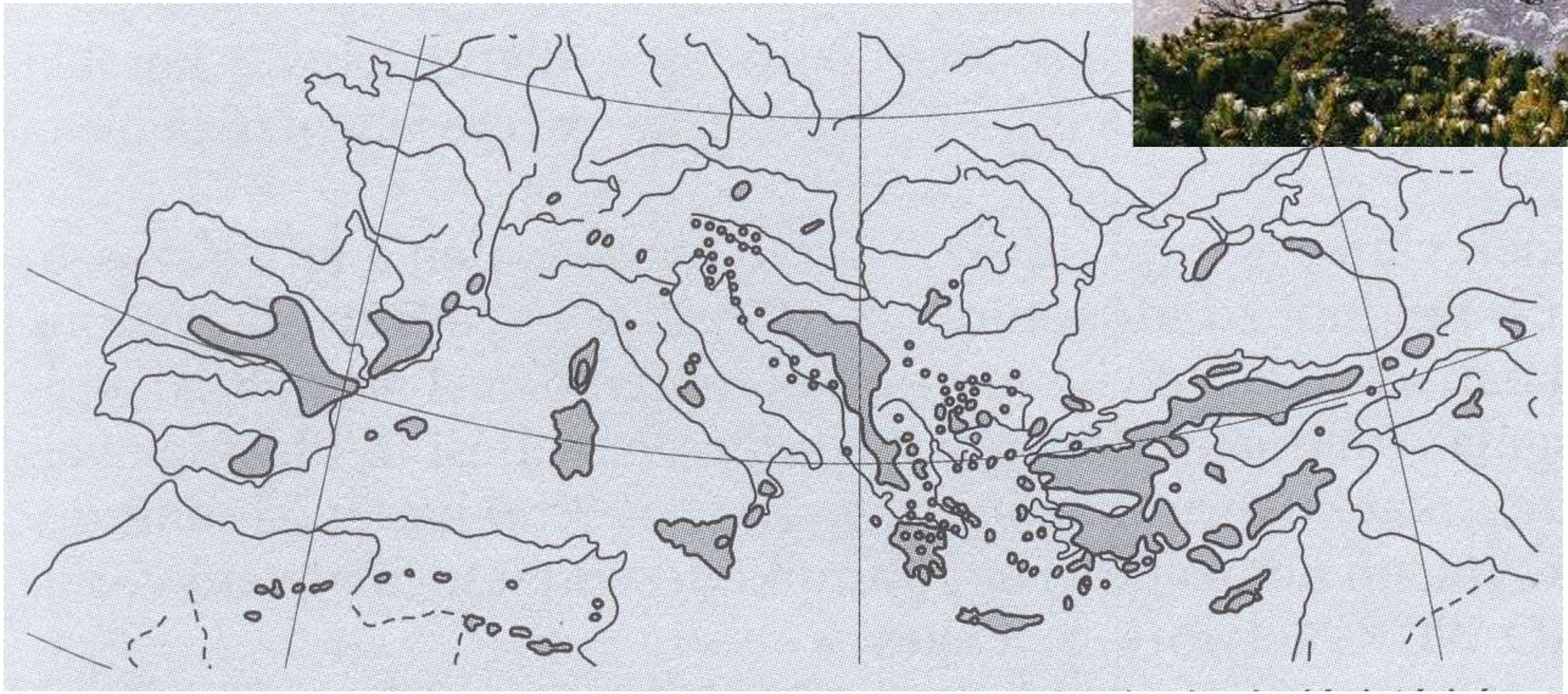


Figure 8 **Schematic illustration of the scientific method as applied to ecological questions.**

09.16

Methods for analysing distribution

What explains the occurence of a species in a given place?



Distribution of black pine (Pinus nigra) in Europe

What explains the occurence of a species in a given place?

Area accessible yes← **Dispersal** → no

↓

Dispersal

- Spread of the African honey bee in South America

Dispersal: undirected movement

Migration: directed movement (e.g. bird migration)

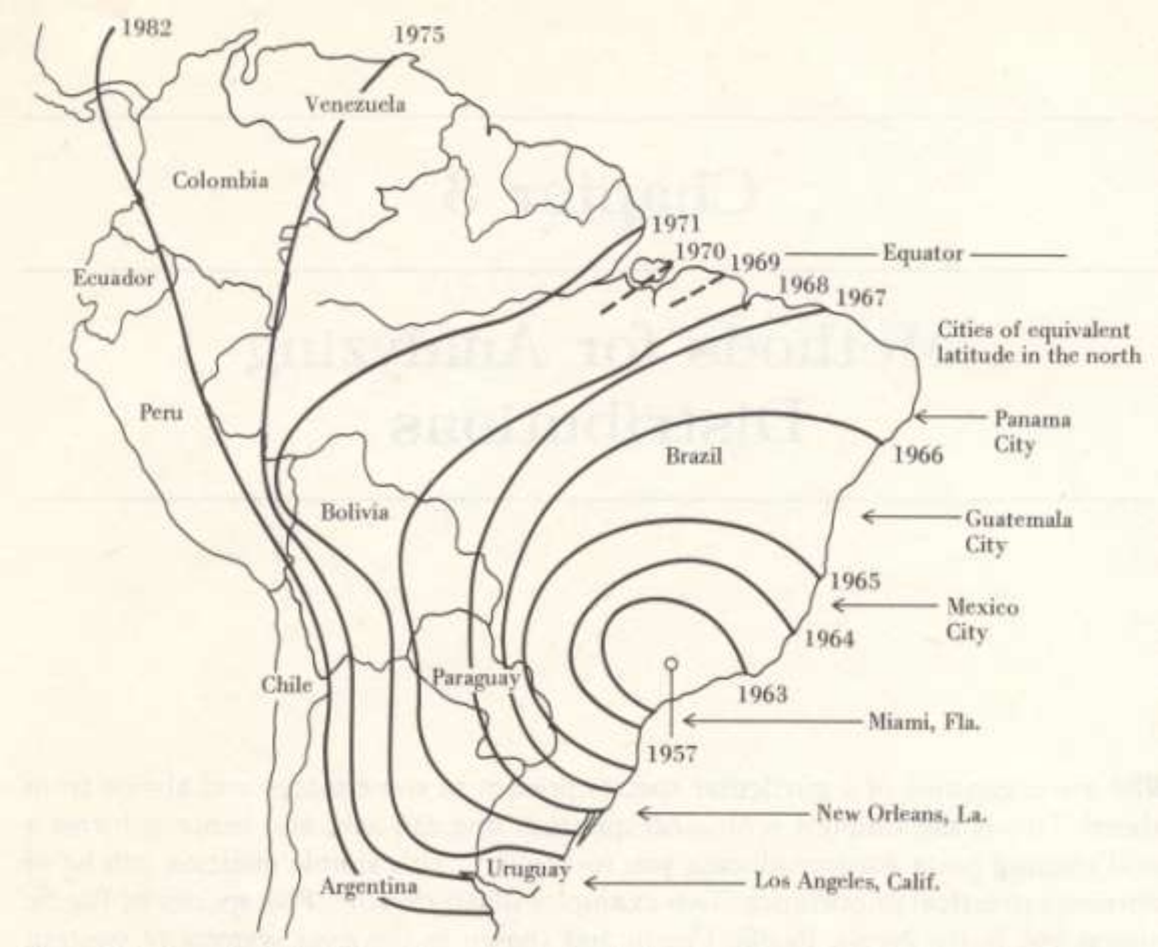


Figure 3.1 Spread of the African honey bee in South America since 1956. Southward and westward expansion has been slight since 1971. Further northward spread is occurring. (After Michener 1975 and personal communication.)

Dispersal

Part of Biogeography

European starling (Sturnus vulgaris) introduce to USA

Between 1850-1889 at many sites – no success
Introduce in 1918 at New York 80 males and 80 females, slow dispersal
Young individuals has the most important role

Types:
- Diffusion
- Jump dispersal
- Secular migration (in evolutionary Scale) (e.g. opossum)

The role of barriers
(Oceans, deserts, high mountains,..e.g.)

Colonisation and extinction -> part of dispersal

What is the function of the dispersal ?
- Option to invade new habitats

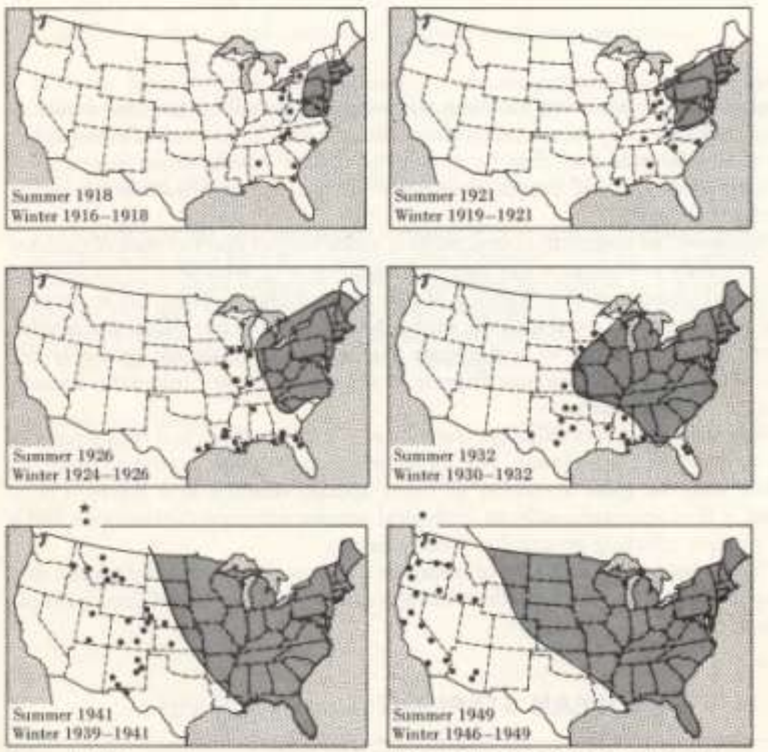
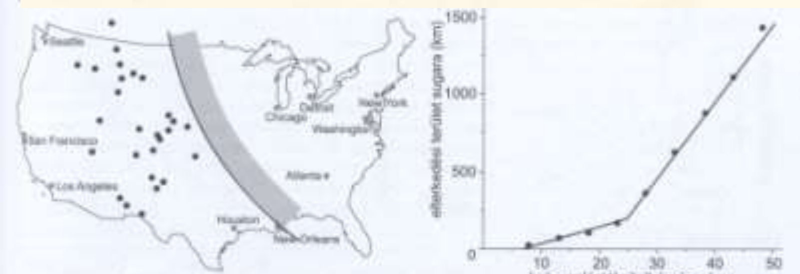
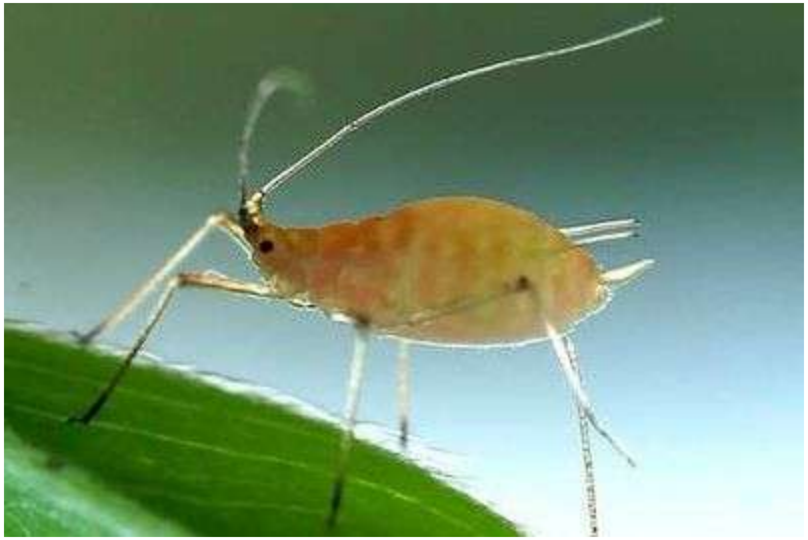


Figure 4.1 Westward expansion of the range of the starling. The shaded area shows the approximate breeding range for a given summer; the dots indicate winter occurrences outside the breeding range for the same year and two or three previous years. The star indicates an unusually advanced breeding record, in 1934, at Camrose, Alberta. (After Kessel 1953.)



21. ábra Európai seregélyek elterjedése (a) terjedési front és szórványos előfordulások (•), (b) elterjedési terület változása az idővel.

Aphids



Aphids

Different forms:

– winged, sexual reproduction, high dispersal

- wingless, partenogenetic reproduction

Speed of dispersal

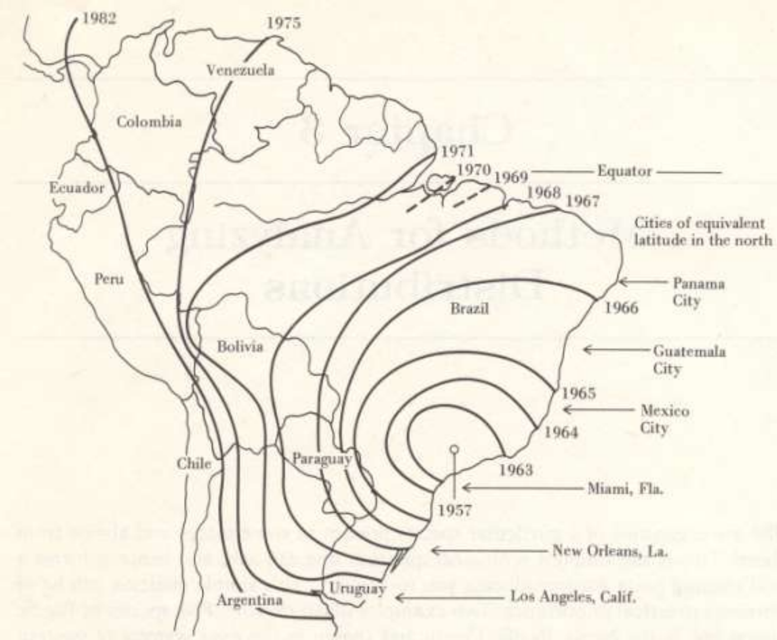
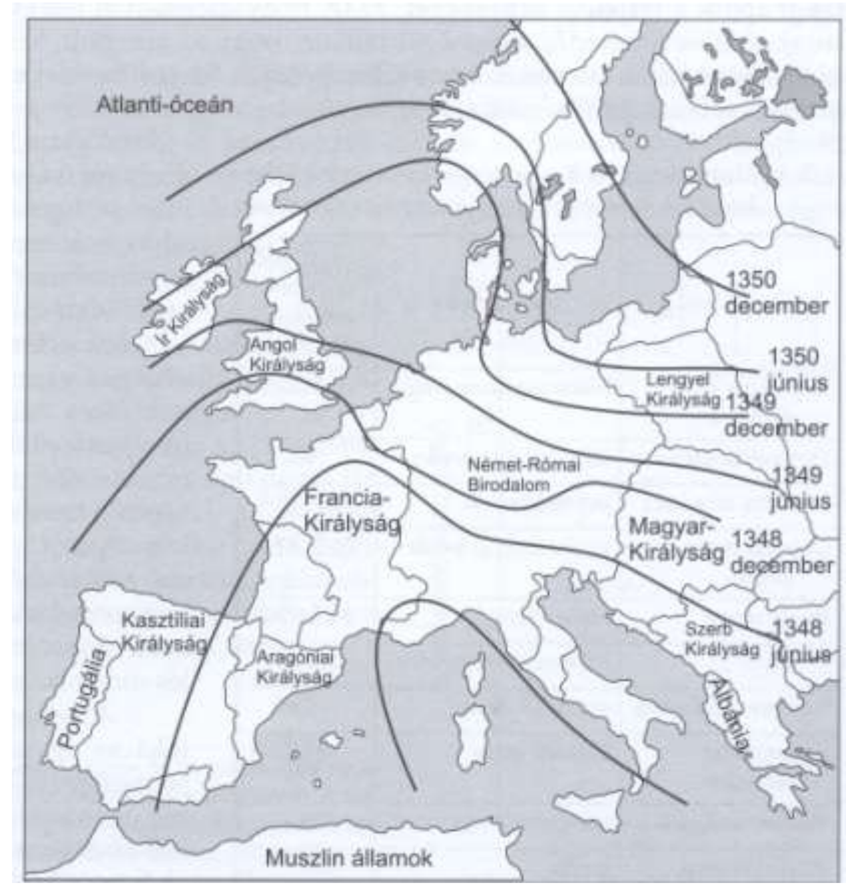


Figure 3.1 Spread of the African honey bee in South America since 1956. Southward and westward expansion has been slight since 1971. Further northward spread is occurring. (After Michener 1975 and personal communication.)

Latin name	Hungarian	speed km/year
Impatiens glandulifera	bíbor nebáncsvirág	9,4–32,9
Lymantria dispar	erdei gyapjaslepke	9,6
Ondatra zibethica	pézsmapocok	0,9–25,4
Oulema melanopus	vetésfehérítő bogár	26,5–89,5
Pieris rapae	répapillangó	14,7–170
	róka veszettség vírus	30–60
Sciurus caroliensis	szürke mókus	7,66
Streptopelia decaocto	balkáni gerle	43,7
Sturnus vulgaris	seregély	200
Yersinia pestis	pestis	400



Spread of pestis (Yersinia pestis) plague in Europe

Dispersal

Invasive species -> economic, health and conservation problems

„10% role”

An average 10% of an introduced alien species survive in the new area

↑ An average 10% of these species could live longer in the new area

↑ An average 10% of these species could reproduce extremly-> invasive species

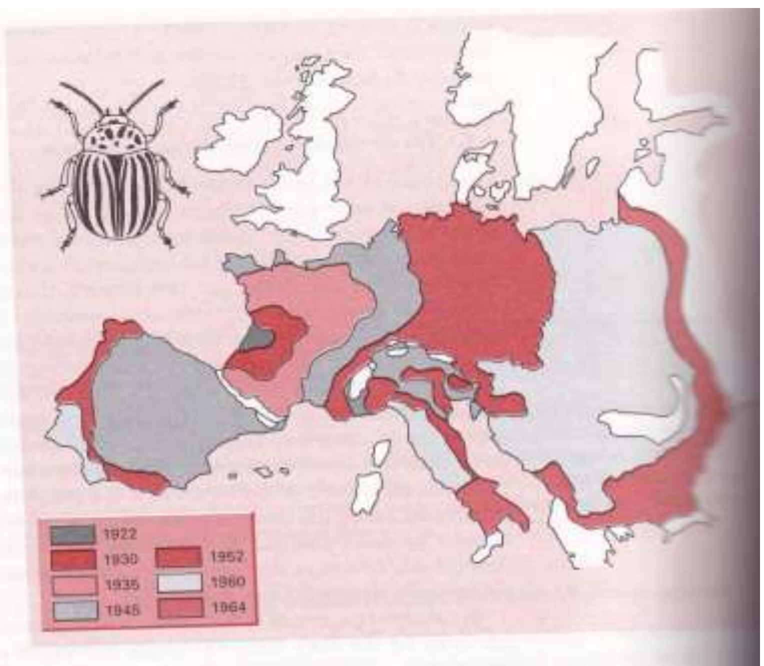
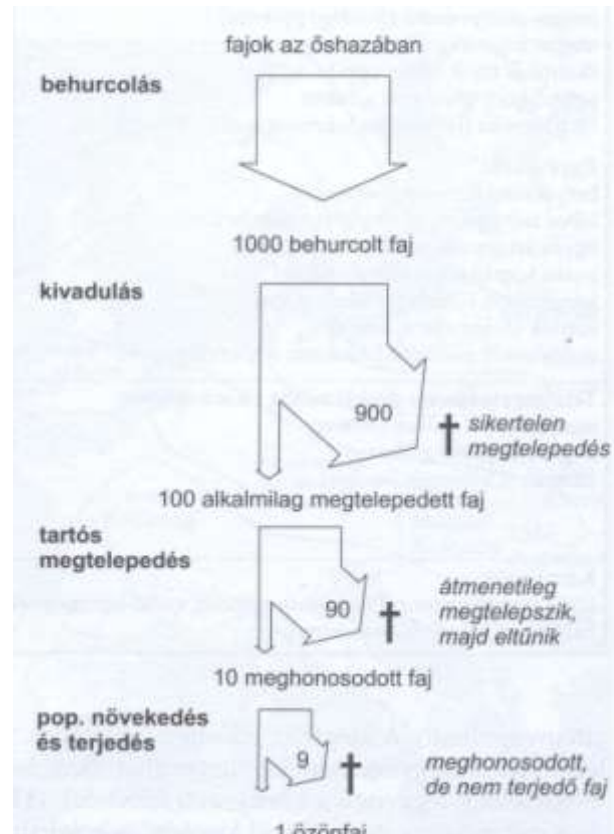


Figure 5.4 Spread of the Colorado beetle (*Leptinotarsa decemlineata*) in Europe. (After Johnson, 1967.)



13. ábra Az özönfajjá válás 10-es szabálya (Williamson és Fitter 1996 nyomán).

What explains the occurence of a species in a given place?

Area accessible　　　yes← **Dispersal** → no

↓

Habitat yes← **Behaviour** → no

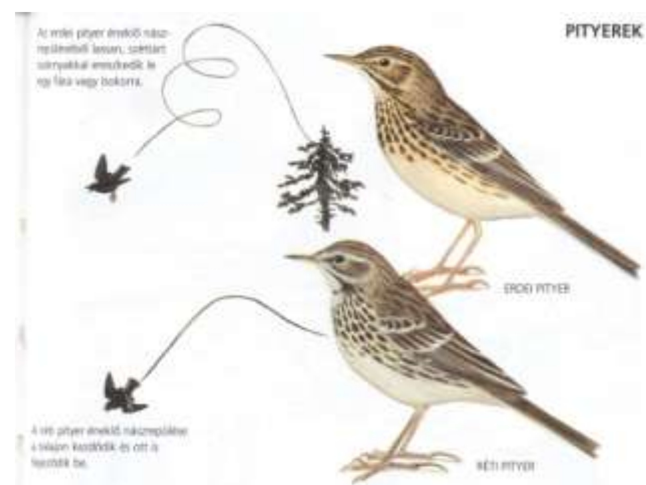
selection　　　↓

Habitat selection

Several animals do not occupay all their potential range even though they are able to disperse into the unoccupied area

Anopheline mosquitoes – malaria infection – the mosquitoes lay eggs in much smaller areas as they able to do – height of vegetation above the surface of water influence the egglaying habit of the female mosquitoes – they prefer the open surface to during ovipositing dance

Lapwing (Vanellus vanellus) prefer the brown colored grassland in spring against the green one for nesting -> proper height of the vegetation during incubation



Two pipit bird species (Anthus trivialis, Anthus pratensis)

A. trivialis need trees in the habitat – important during pair-formation

Habitat selection

Fretwell (1972) Ideal free distribution model

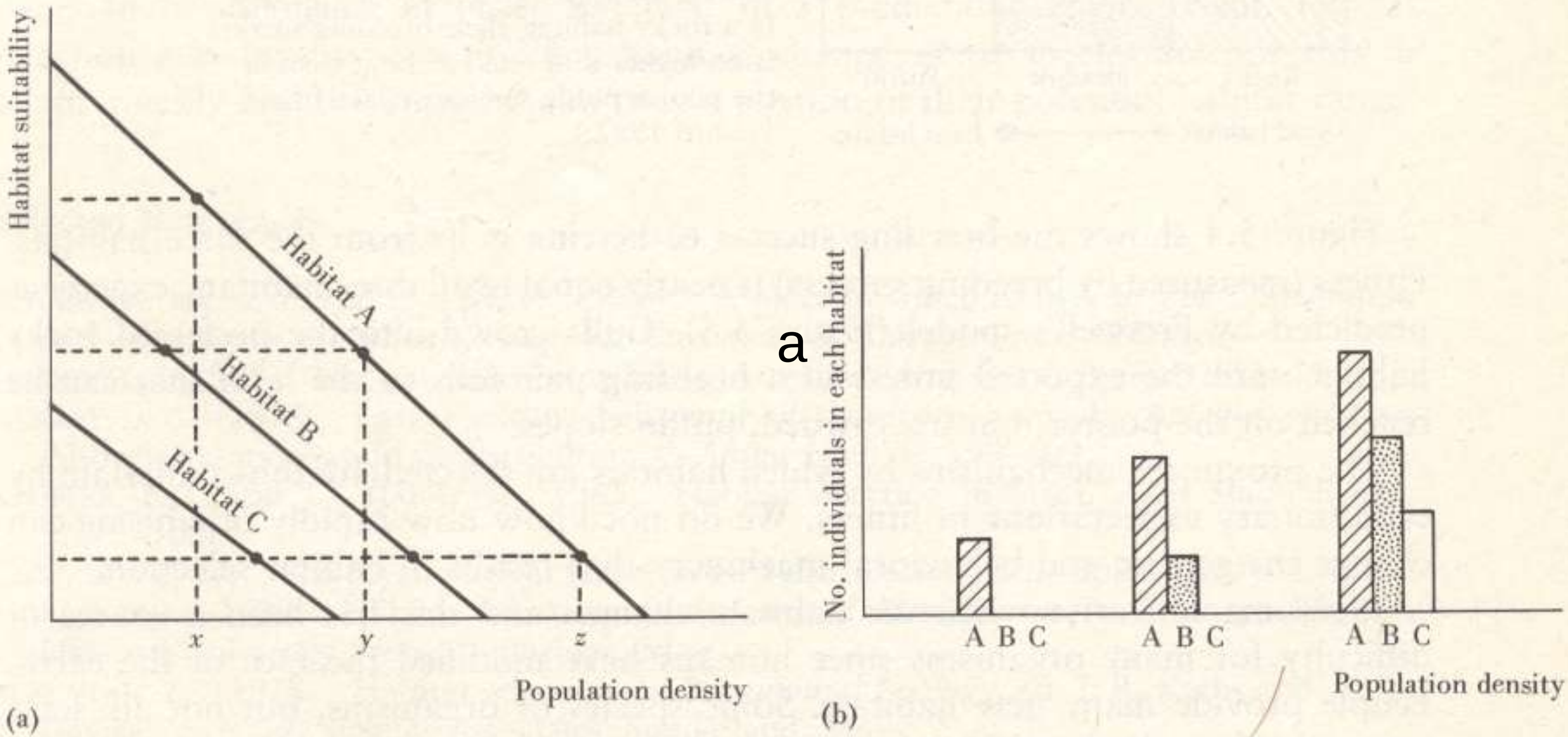


Figure 5.3 A simple model of habitat selection. Three habitats are used for illustration (A = good habitat, C = poor habitat). Habitat suitability is measured by the fitness of individuals living in that habitat. For illustrative purposes, three levels of population density are indicated (*x*, *y*, *z*). At low density *x*, all individuals live in favored habitat A. At high density *z*, all three habitats are occupied. (Modified from Fretwell 1972.)

What explains the occurence of a species in a given place?

Area accessible yes← **Dispersal** → no

↓

Habitat selection yes← **Behaviour** → no

↓

yes← **Other species** → no

Predation

Competition

Parasitism

Mutualism

Interrelations with other organisms

Burrowing rats distribution before discovering by European (grey area) and recently (black dots) – cause: fox (predation) és rabbit (competition)

Figure 6.4 Geographic distribution of the burrowing rat kangaroo (*Bettongia lesueur*) in Australia. This small kangaroo is now extinct on the mainland and survives on only three islands. (From Ovington 1978.)

Interrelations with other organisms

Competition

Redwing territories (upper map) before the Tricolored blackbird arrival in spring and territories of these two species after arrival of Tricolored blackbird (lower map).

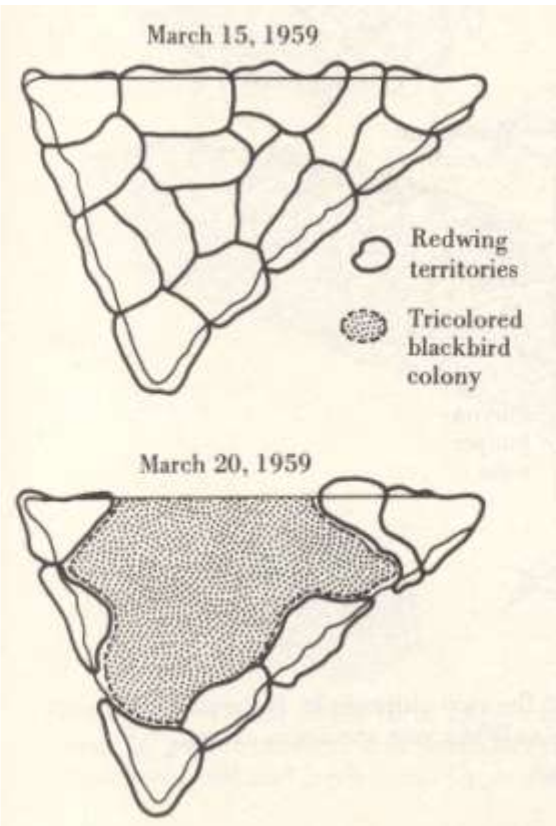


Figure 6.9 Interactions between redwing and tricolored blackbirds at Hidden Valley Marsh, Ventura County, California, in 1959. (After Orians and Collier 1963.)

Interrelations with other organisms

Allelopathy

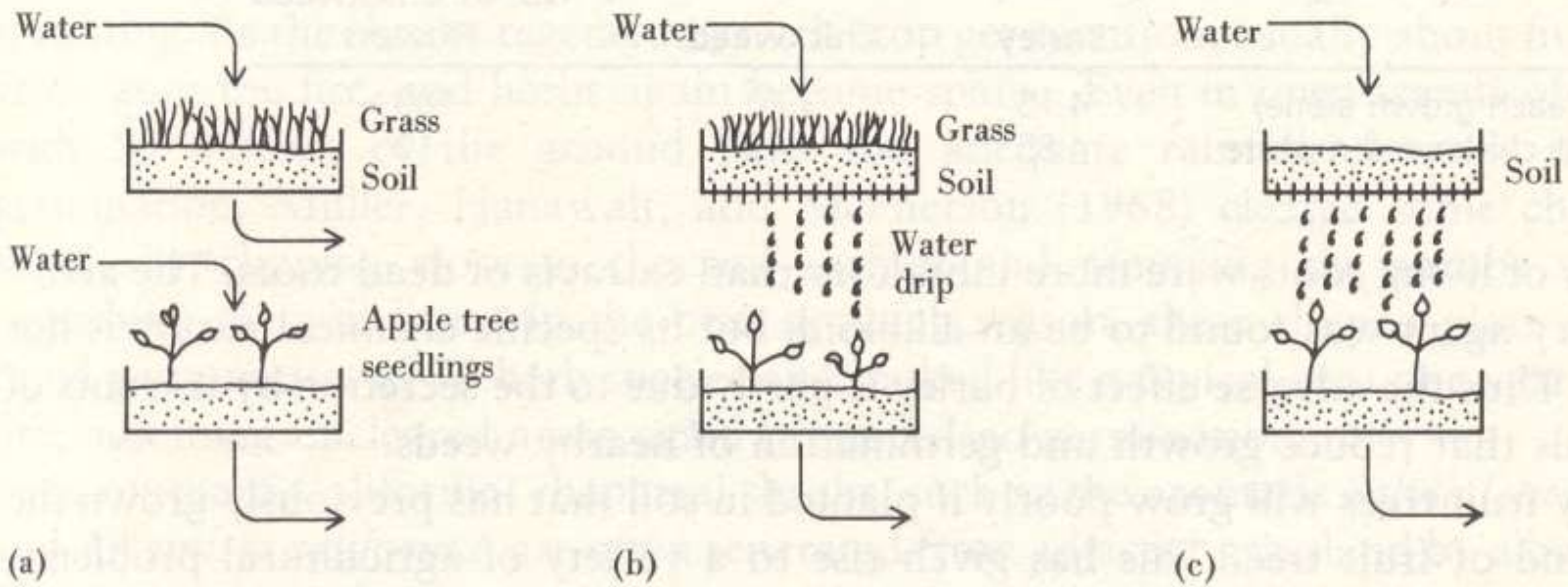


Figure 6.5 Experiments that demonstrated the detrimental effects of grass on apple tree seedlings. Grass and tree seedlings are grown in separate flats in a greenhouse. Water is provided either (a) independently to both grass and trees, (b) as a single source to the grass and soil, or (c) to the soil alone. Water drip provides moisture for the apple seedlings in (b) and (c). Apple tree seedlings do not grow properly when the water has passed through grass first (b).

Interrelations with other organisms

Parasitism

e.g. Mosquitoes and reindeer in the tundra

Mutualism

e.g. Fungies and Pine trees

e.g.

Ant species (Pseudomyrmex triplarinus) and a tree (Triplaris americana) in South America

What explains the occurence of a species in a given place?

Area accessible yes← **Dispersal** → no

↓

Habitat selection yes← **Behaviour** → no

↓

yes← **Other species** → no

Predation

Competition

Parasitism

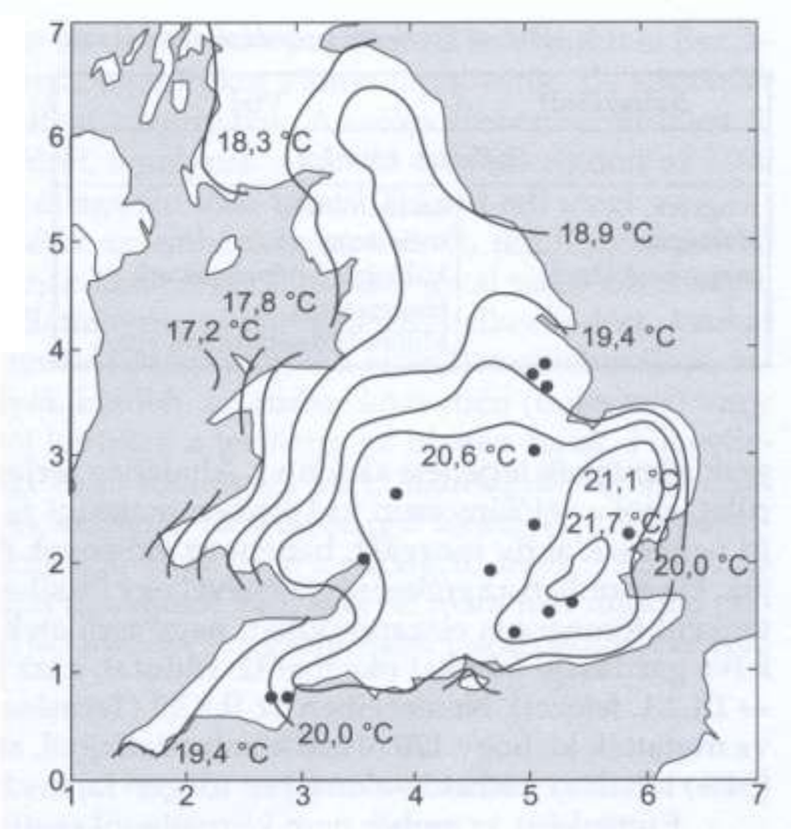
Mutualism

Physical and Chemical factors

Temperature	Water
Light	Oxygen
Soil structure	Salinity
Fire	pH
Currents	Soil nutrients
etc.	Etc.

Physical and Chemical factors

Tree species (Tilia cordata) distribution in UK
Lines- daily maximum temperature in August
Points – occurence of the tree species



Effects:
-Survival
-Reproduction
-Development of young organisms
-Competition

Temperature

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e.g. Mynah (Sturnus cristattellus) – not able to breed in (Vancouver, USA) because of the very low hatching rate of eggs

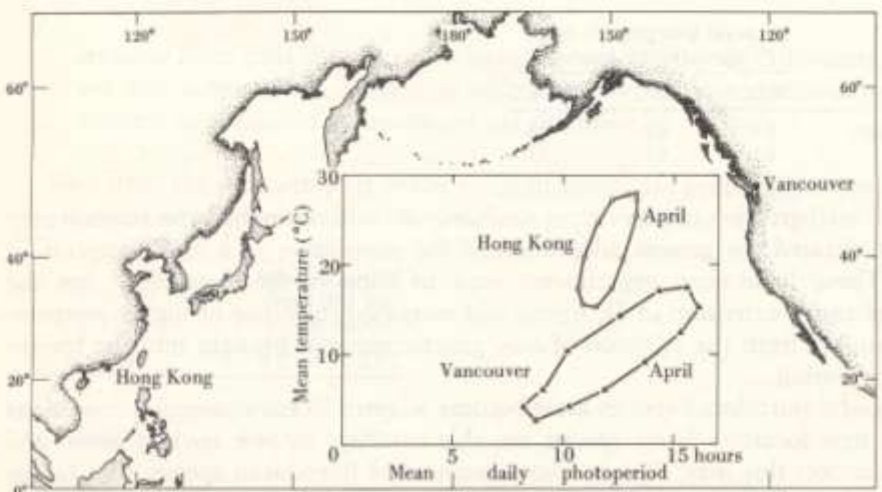

Figure 7.15 Comparison of native (Hong Kong) and introduced (Vancouver) home of the crested mynah (*Sturnus cristatellus*). The climatograms are constructed by connecting means (air temperature and photoperiod) for succeeding calendar months. Egg laying starts in April at both localities. (After Johnson 1971.)

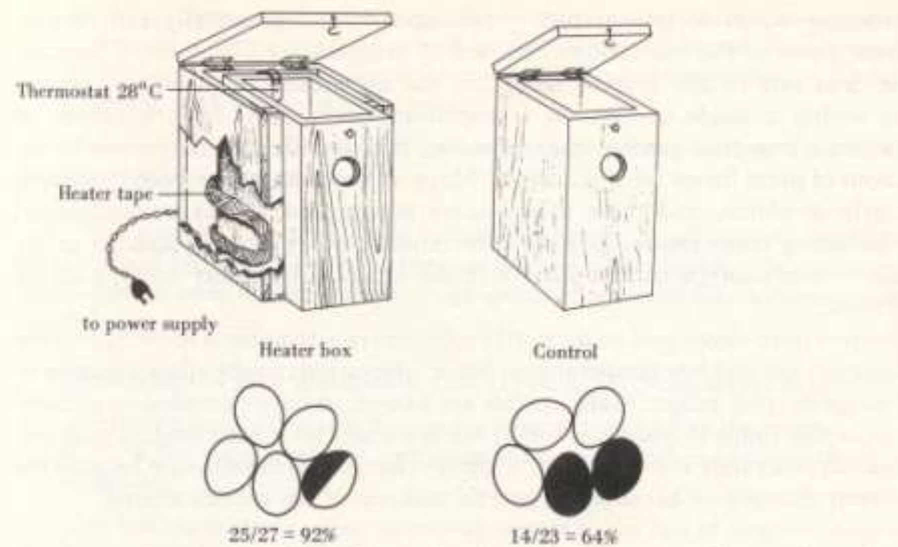

Figure 7.16 Experiment with altered nest microclimate in Vancouver; at five crested mynah nests, a heater was installed and nest temperature was maintained at Hong Kong levels (28°C). Hatching success at these nests is contrasted with the controls exposed to natural temperature fluctuations. (After Johnson 1971.)

Physical and Chemical factors

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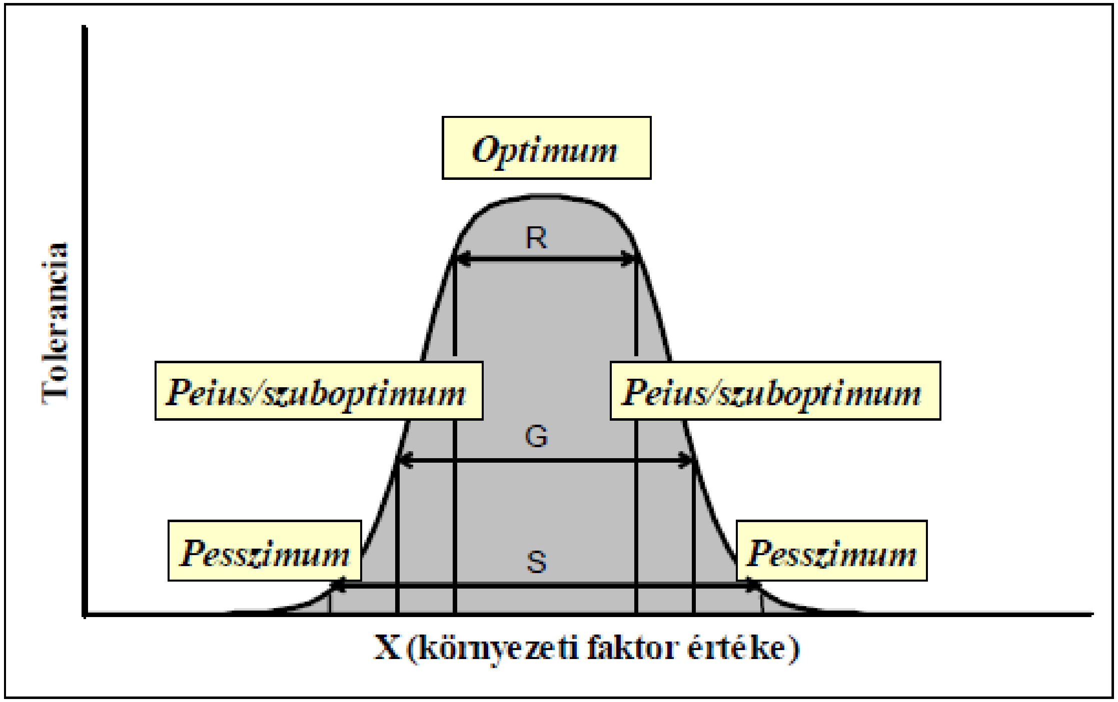


Tolerance curve and intervalls in relation to an X environmental factors

optimum (reproduction)

peiusz – suboptimum (only growing without reproduction)

pesszium (only surviving)

Physical and Chemical factors

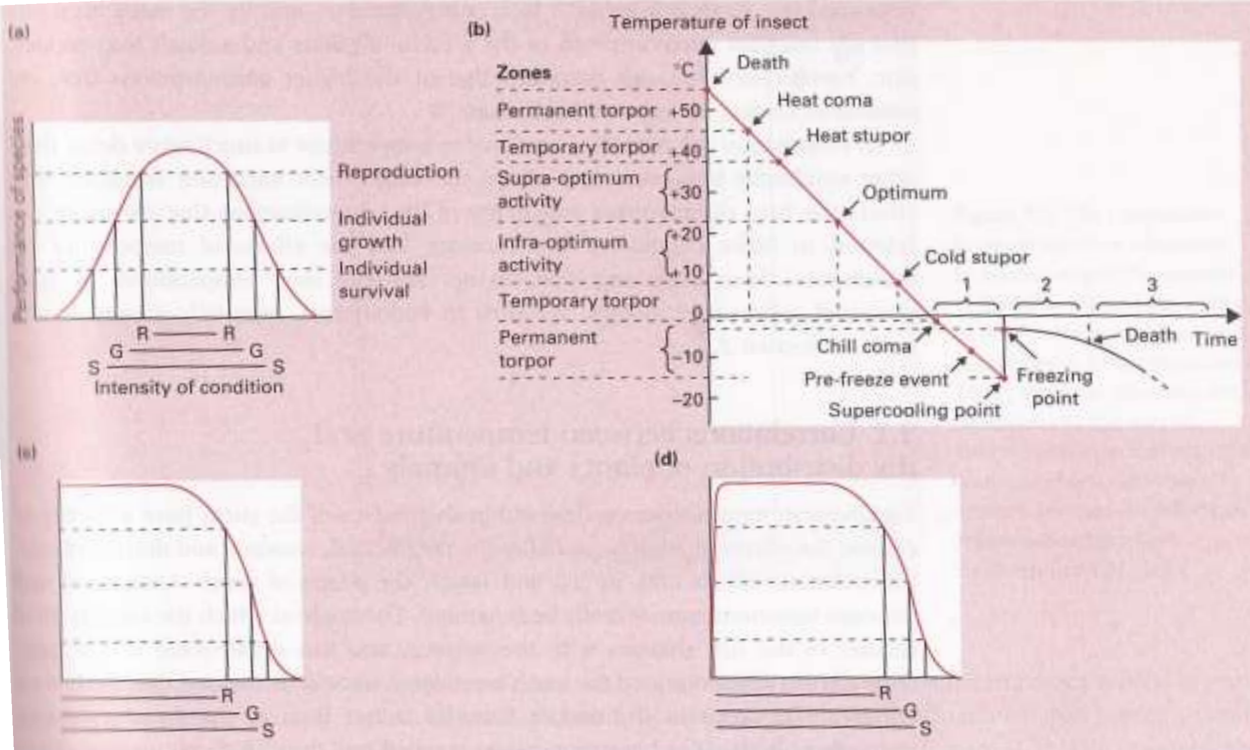
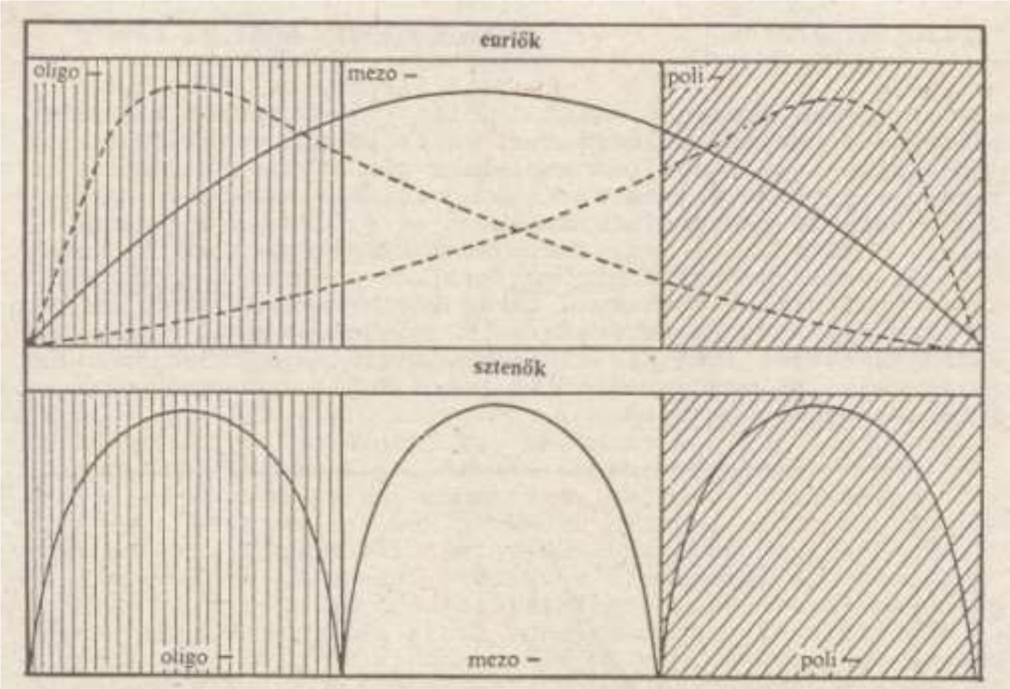


Figure 2.1 (a) A generalized graphical representation of the manner in which the activities of an organism may relate to the intensity of an environmental condition, such as temperature or pH. The narrow range over which reproduction can occur (R–R) usually dictates where continued existence of the species is possible (although the patterns of distribution of some species may be maintained by the repeated dispersal and recruitment of individuals into areas where they could not otherwise maintain themselves). (b) The thermobiology of an arthropod which does not tolerate freezing. Note that a symmetrical sequence of physiological states is recognized passing through stupor into temporary torpor and coma to permanent torpor and death as conditions become much hotter or cooler than the optimum. (After Vannier, 1987; Block, 1990.) (c) A generalized response curve of the form that relates the activities of an organism to the level, concentration or intensity of a condition (e.g. toxin, radioactive emission or pollutant which is harmful only at high levels). (d) As (c) but as the level, concentration or intensity of a condition is increased it changes from being an essential resource for growth at low levels to becoming damaging or lethal at higher concentrations (e.g. micronutrients such as copper and zinc).

Physical and Chemical factors

.growing

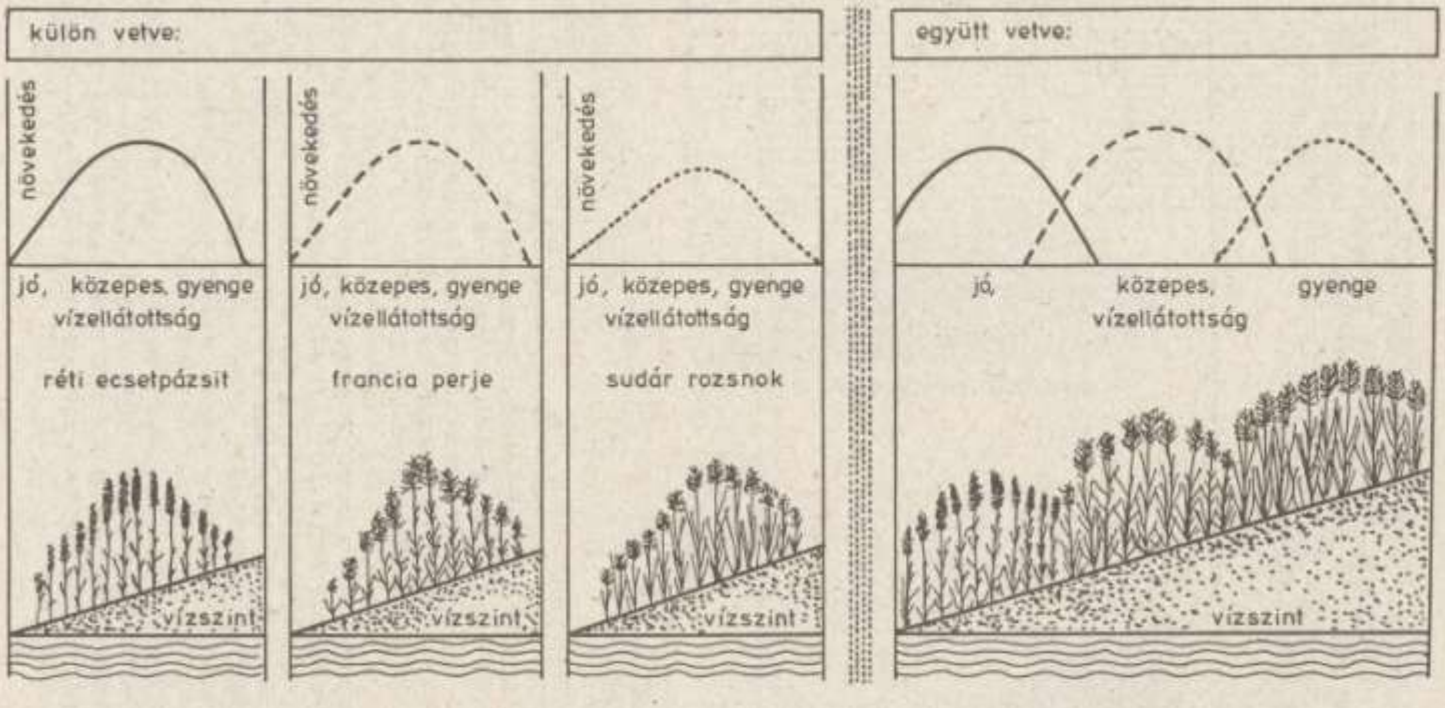


quantity of an environmental factor

Euriök - generalist

sztenők - specialist

Physical and Chemical factors



109. ábra: A vízellátottság hatása füvek növekedésére konkurencia mentes és együttes termesztés esetén (Láng E. nyomán)

physiological – ecological optimum

Growth of three grass species

réti ecsetpázsit: Meadow Foxtail (Alopecurus pratensis),

francia perje: Perennial Ryegrass (Lolium perenne)

sudár rozsnok: Upright Brome (Bromus erectus)

in relation to water availability when it was seeding separatelly (left part) and mixed way (right part).

Climatic, edafic (soil), and hydrological factors

.

Light

Photoperiodism

-long-day plants, wheat

-short-day plants, rice

- spektrum

Light intensity

-heliophile, Maize

-sciophilous, leaf frogs

-scotophil, earthworm

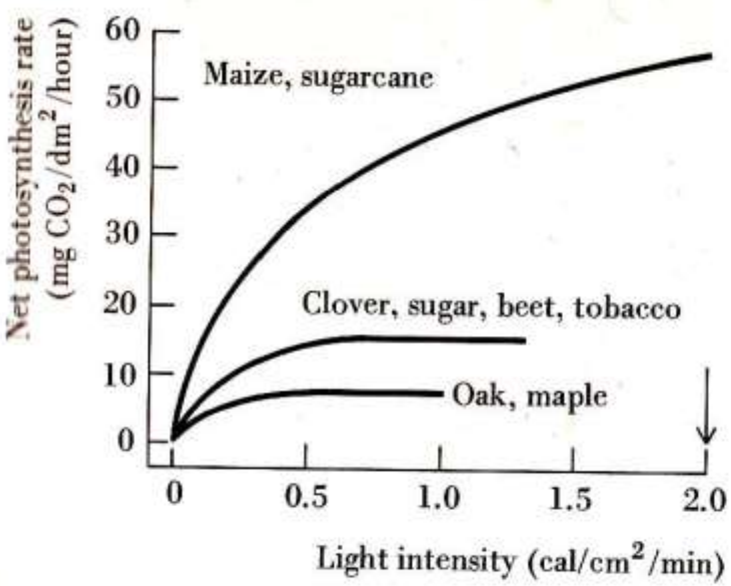


Figure 9.1 The effect of light intensity on the rate of photosynthesis in several species of plants. Photosynthesis was measured by CO_2 uptake at 30°C and 300 ppm CO_2 in air. The arrow on the light axis marks the approximate equivalent of full summer sunlight. (After Zelitch 1971.)

Water

- hydrophytes, lemna
- heliophytes, reed
- mezophytes, violet
- xerophytes, succulent
- halophytes, sea lavender

Soil

- Structure
- Nutrients

Salinity

pH

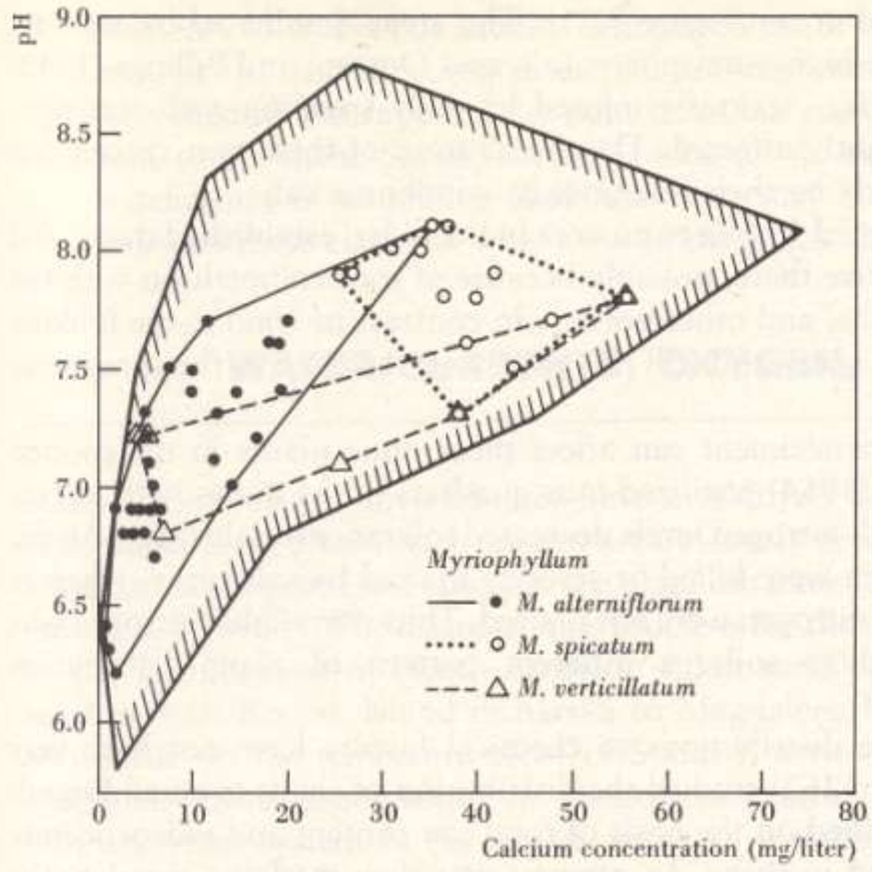


Figure 9.10 Occurrences of the three species of *Myriophyllum* in the lakes of central Sweden in relation to calcium concentration and pH. The shaded envelope encloses the points for all the lakes studied in the region. (After Hutchinson 1970.)

Water currents

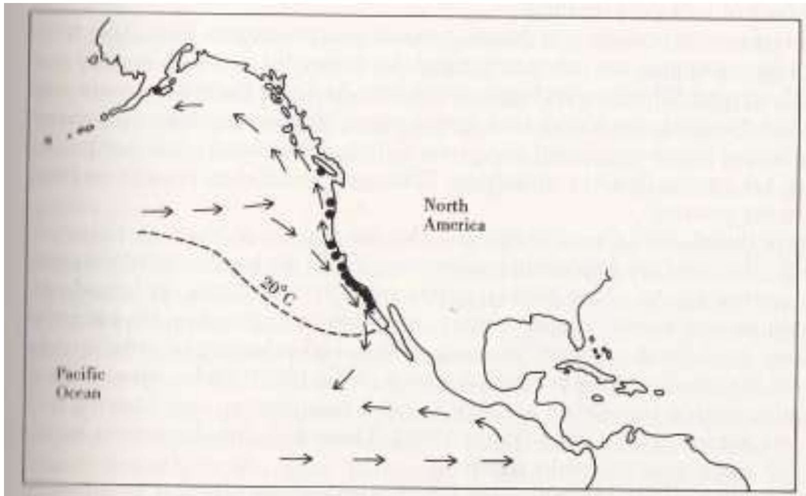


Figure 9.12 Distribution of the sand crab *Emerita analoga* in North America and the surface currents of the North Pacific. Dashed line marks approximate position of average annual sea-surface temperature of 20°C. (After Efford 1969.)

Oxygen

- Its level vary hardly in freshwaters

Fire

- Occurence is important for several Species/communities

What explains the occurence of a species in a given place?

Area accessible yes← **Dispersal** → no

↓

Habitat selection yes← **Behaviour** → no

↓

yes← **Other species** → no

Predation

Competition

Parasitism

Mutualism

Physical and Chemical factors

Temperature	Water
Light	Oxygen
Soil structure	Salinity
Fire	pH
Currents	Soil nutrients
etc.	Etc.

Populations, Population parameters, Demographic Techniques

Population ecology

- Biological and statistical definitions

  Biological: A population is the number of organisms of the same species that live in a particular geographic area at the same time, with the capability of interbreeding

  Statistical: A group of organisms of the same species occupying a particular space at a particular time

- Abundance (N)

individuals, pairs, biomass (genet-clonal plants), colonies (eusocial insects)

- Density (D)
  - Abundance/Area, Abundance/Volume

Estimation Abundance/Density

Absolute methods

- total counts (census)

  Count all individuals of the population

  (human, rare or very low density species)

Sampling methods

- estimation of density in sampling area

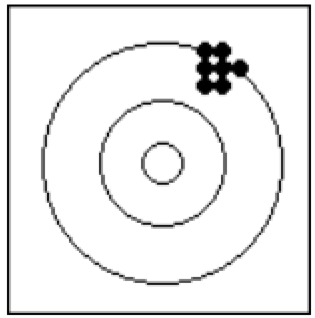
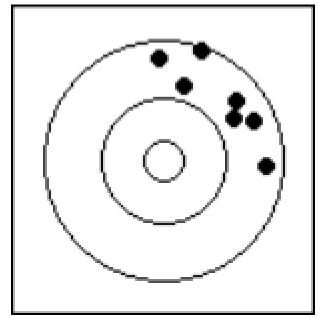
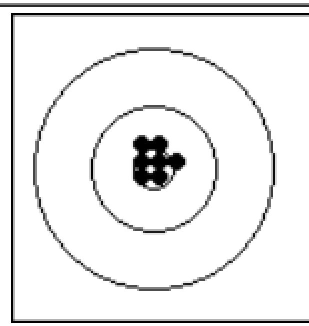
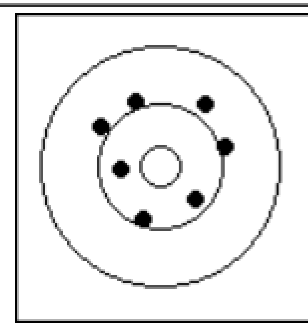
  Count all individuas in the sampled areas (quadrats), estimate the density and estimate the abundance for the entire area of the population

  Condition:

  - Total counts in the samples area
  - Known the size of the sampled area
  - Sampled areas must be representative to the entire area of the population -> proper sampling strategy to minimase the bias and precision

Accuracy of an Estimation

Accuracy, Precision, and Bias

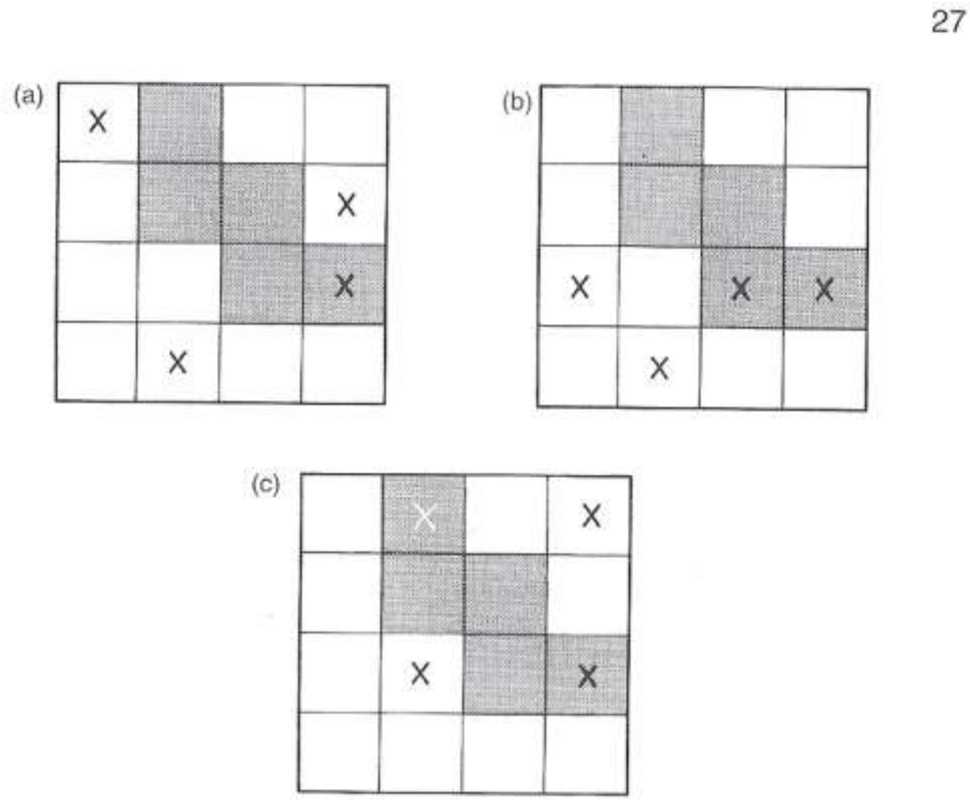
	Precise	Imprecise
Biased		
Unbiased		

Sampling strategy

Random (a)

Stratified random (b)

Regular (c)



Estimation Abundance/Density

Sampling methods

- Capture-recapture method

e.g. Lincoln index:

$$\frac{m_2}{n_2} = \frac{n_1}{N}$$

N: abundance of the population

n_1: # of caught and marked individuals during the first capture, released back to the population

n_2: # of caught and marked individuals during the second capture, released back to the population

m_2: # of marked individuals among individuals caught in the second capture

N': estimated abundance of the population

$$N' = \frac{n_1 * n_2}{m_2}$$

Estimation Abundance/Density

Relative methods – Population indeces

- # of trapped individuals
- # of fecal pellets
- Vocalisation frequency
- Pelt records
- # of artifacts
- Questionnaires
- Cover
- Feeding capacity
- Roadside counts

Hungarian Common Bird Monitoring scheme since 1999

Mindennapi Madaraink Monitoringja (MMM)

Started with the help of RSPB and EBCC

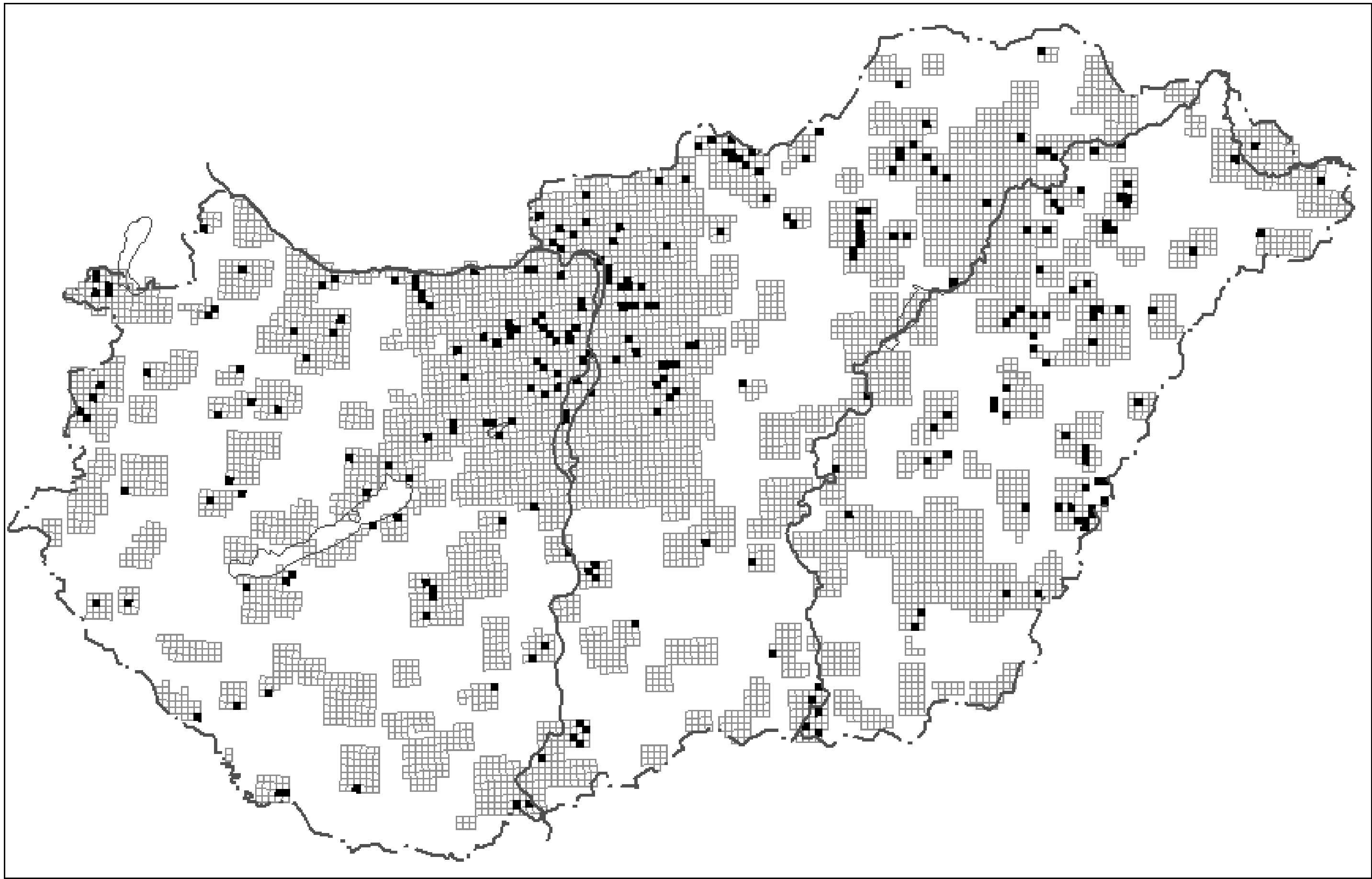
- Szép, T. and Gibbons, D. 2000. Monitoring of common breeding birds in Hungary using a randomised sampling design. The Ring 22: 45-55.

- **http://mmm.mme.hu**

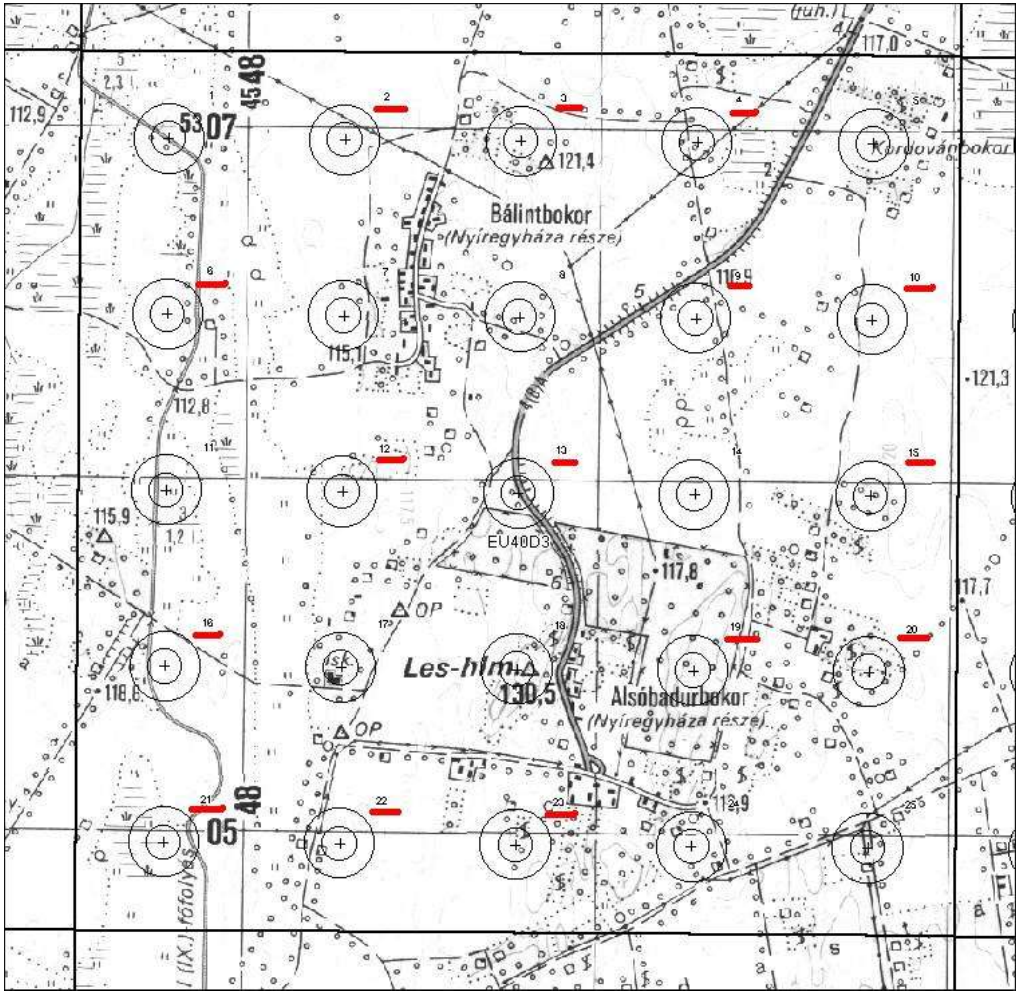
Sampling design

Semi-random selection of the surveyed 2.5*2.5km UTM squares

- Unit: 2.5*2.5 km UTM square
- randomly selected within the minimum 100 km^2 large area indicated by the observers



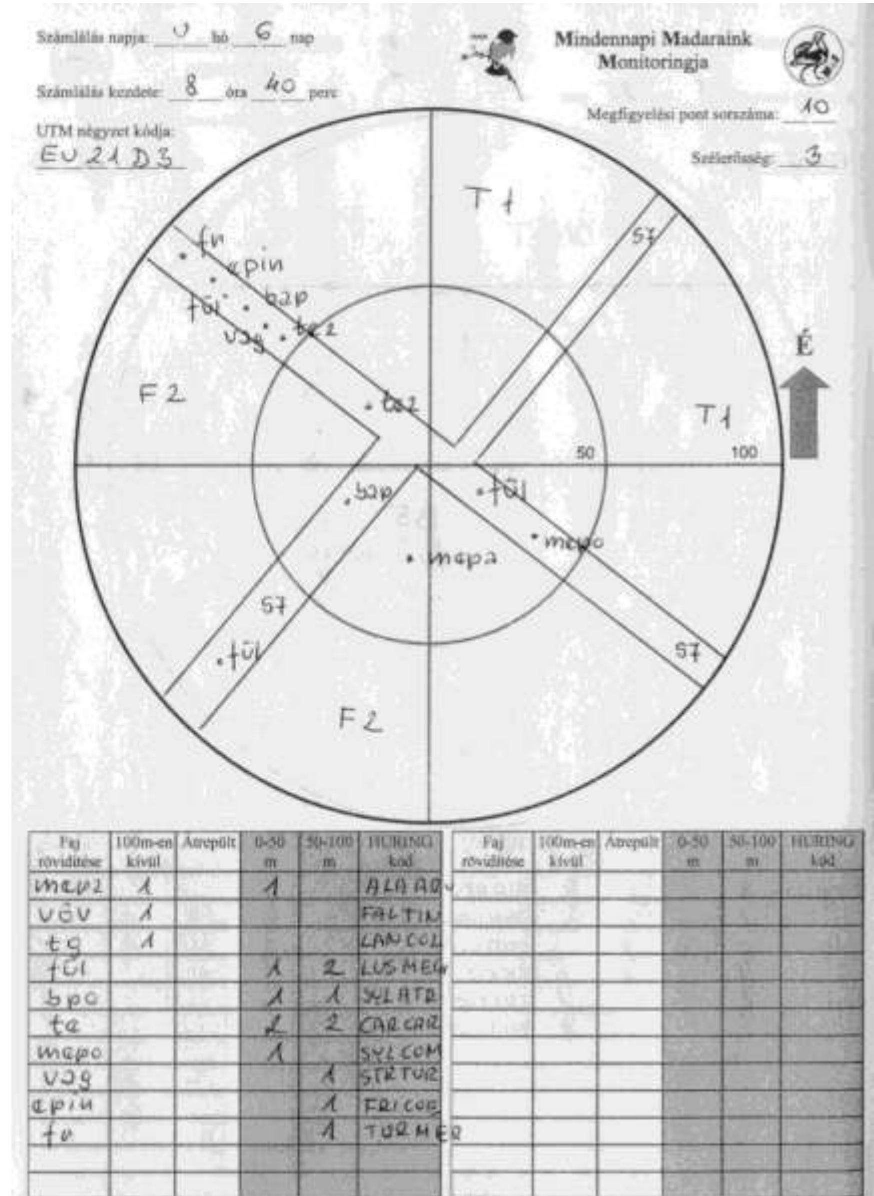
Sampling design



- Randomly selected 15 observation points within the selected 2.5*2.5 km UTM squares
- Map (coordinates) with exact position of the observation points provided

Standard Method

- 5 minutes point counts two times per breeding season (early, late) between 5-10 am
- Distance (0-50m, 51-100m,101-200m, fly over), habitat and wind recorded



Identification skill of the observers

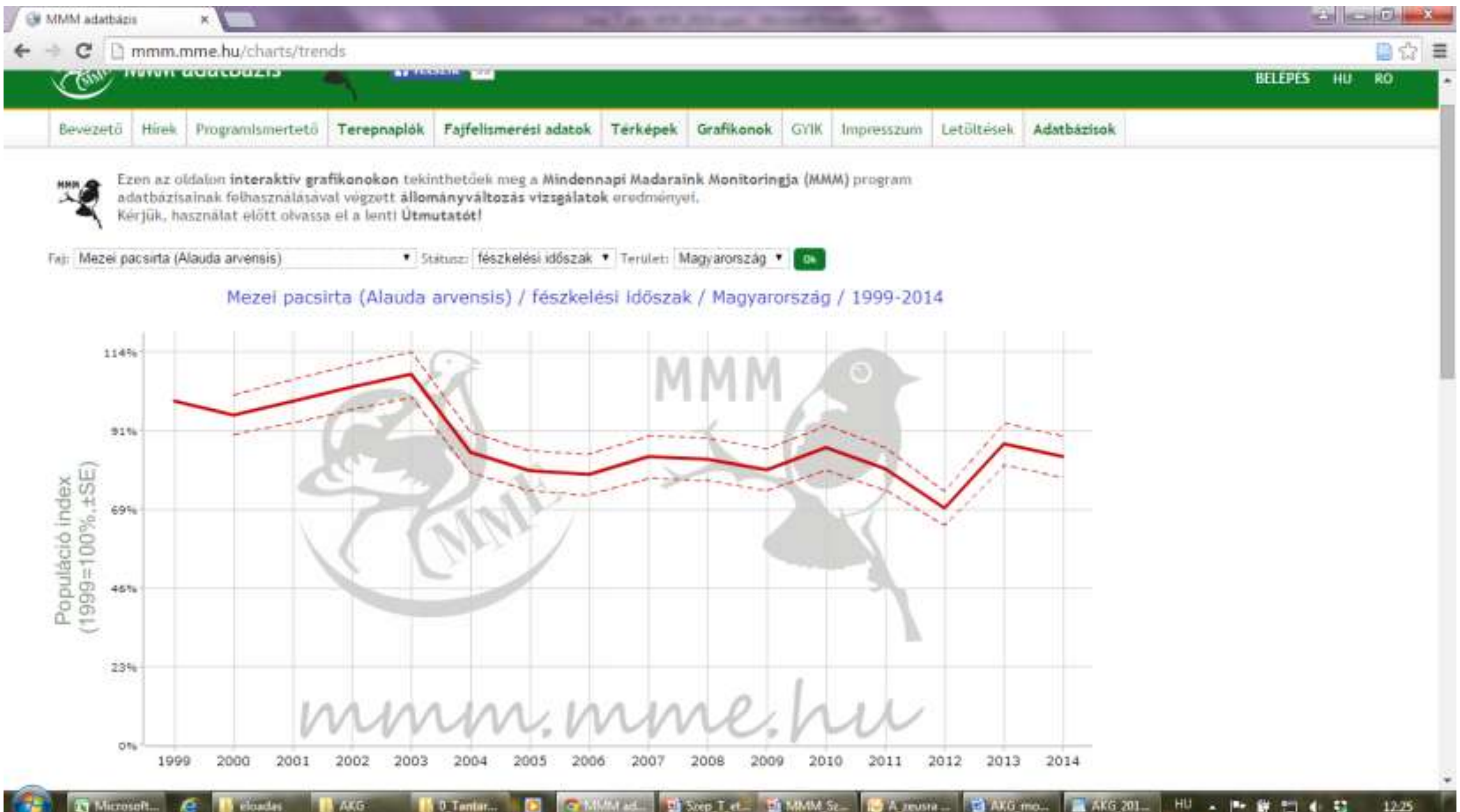
- Annual survey of the species identification skill of the observers for each species occurring in Hungary
  - „How can you identify the given species?”
      - only by view
      - only by sound
      - by view and sound
      - I’m uncertain to identify

  - Control the cause of the absence of the given species in the given squares – real absence or identification problems of the observers

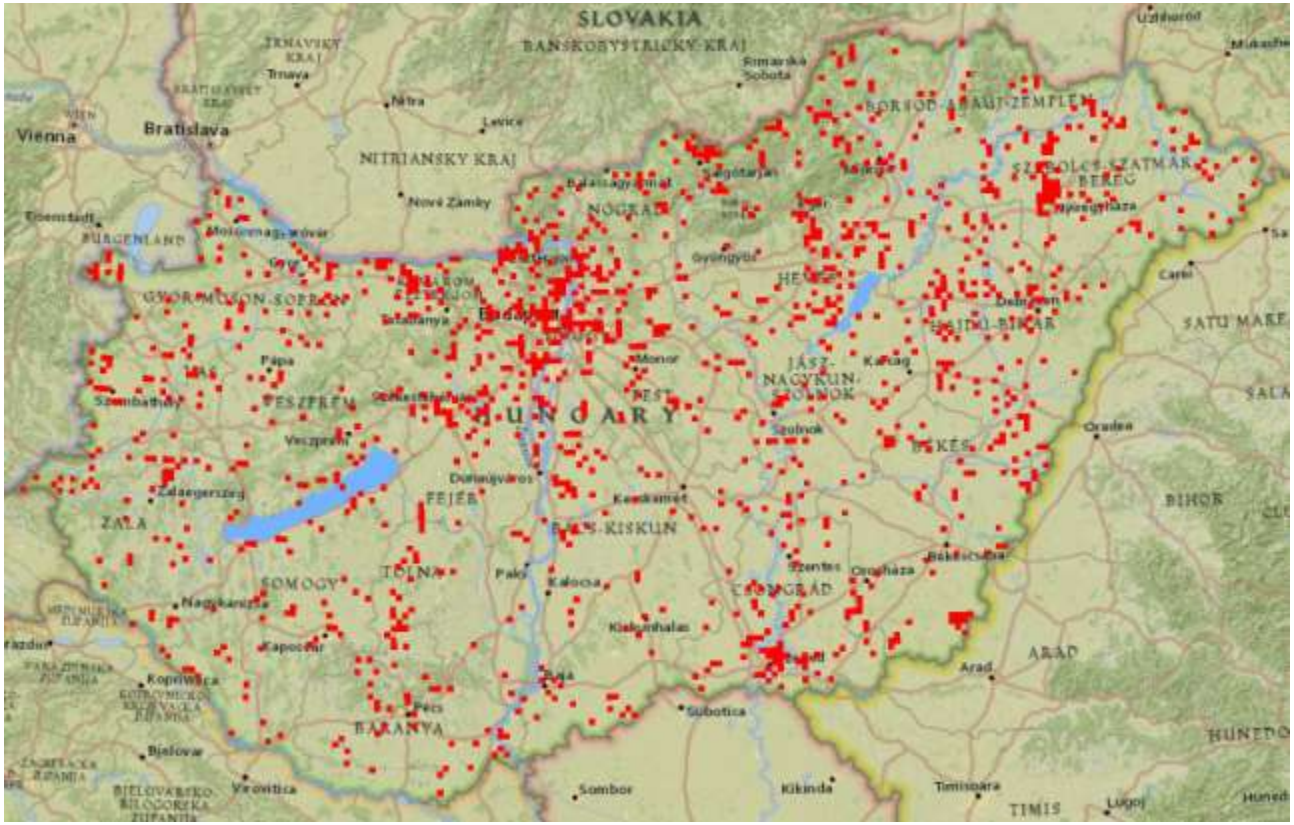
On-line database

http://mmm.mme.hu

- Input and verification of field data
- Maps, Results, Additional information for observers



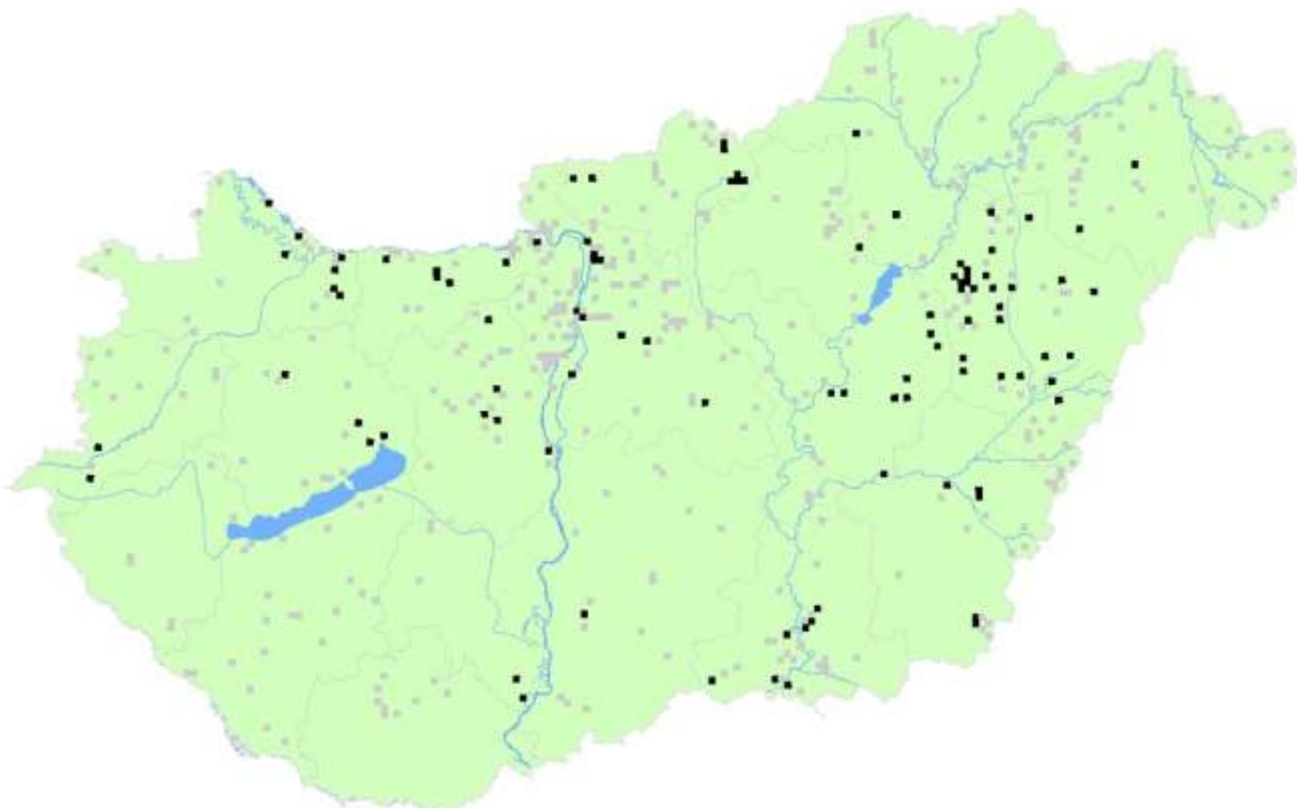
Surveyed UTM squares between 1999-2021 during the breeding season



Surveyed UTM squares

- More than 1000 squares surveyed minimum in two years
- More than 1000 participating observers
- One of the largest database on common birds in Central-Eastern Europe, based on random sampling desing, 44,5 million records (UTM, point, species, date, number)
- 200-300 UTM surveyed annually (~2% of the country territory)

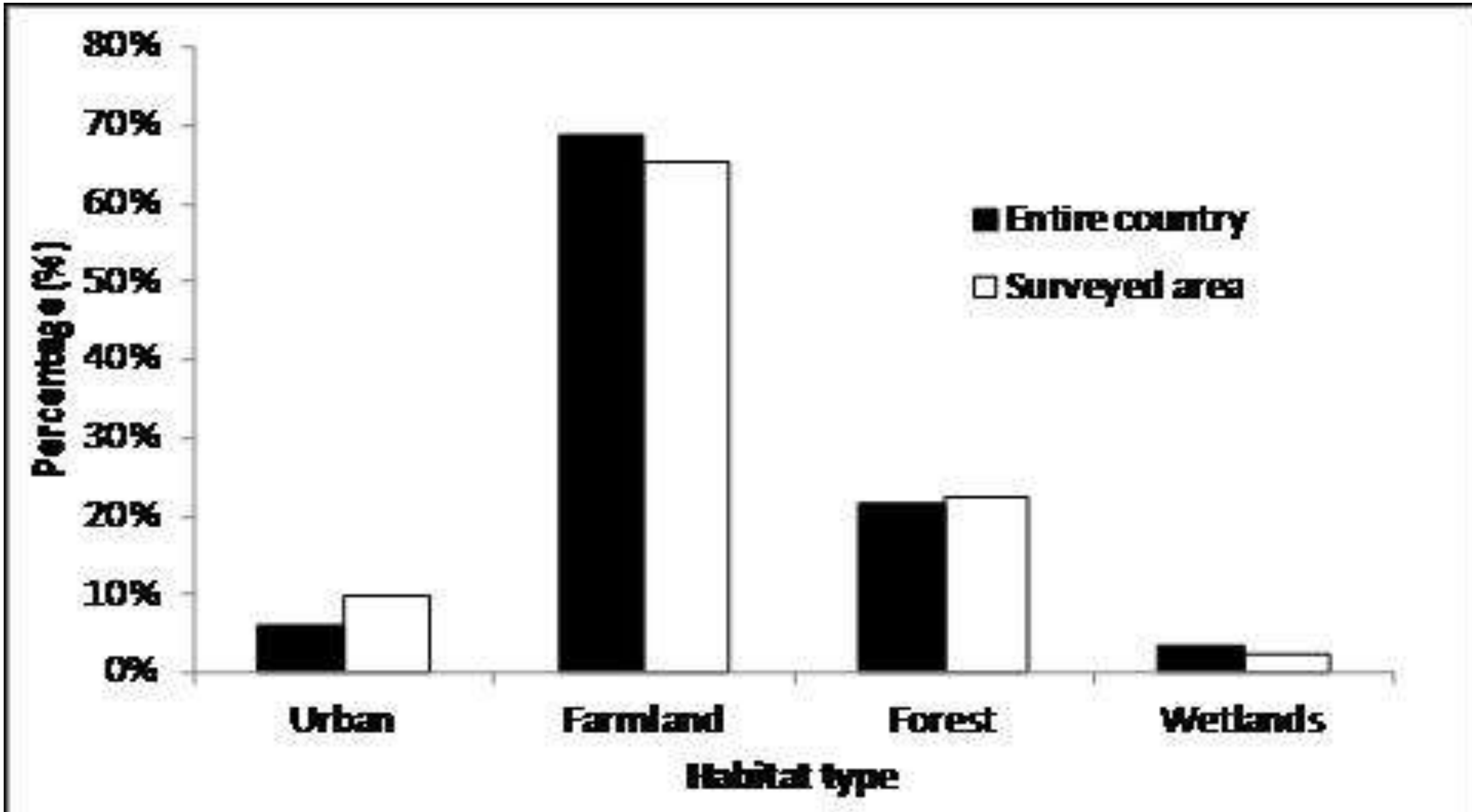
Surveyed UTM squares between 2000-2021 during the wintering season (January)



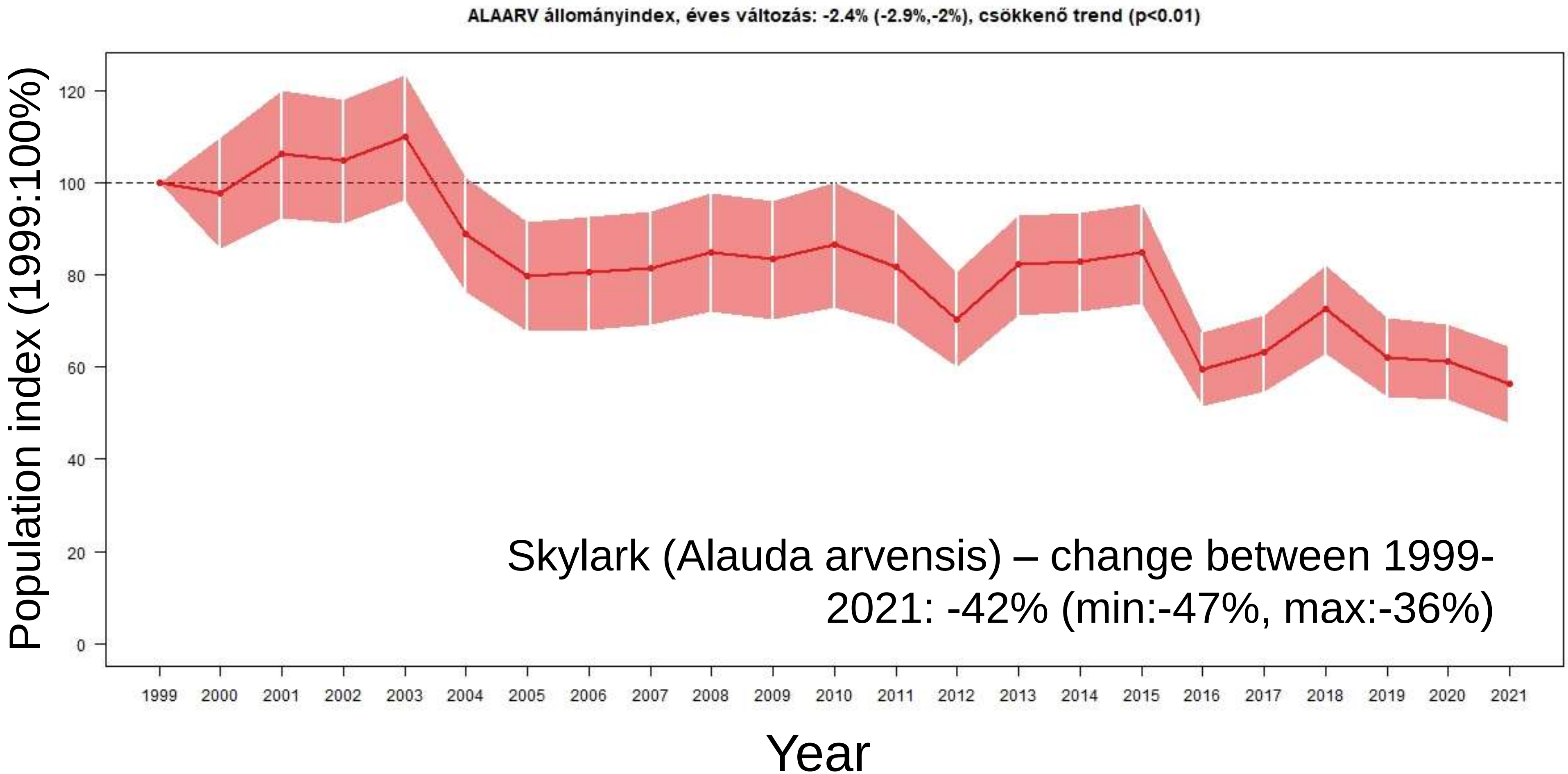
Colors of the UTM squares indicate the number of surveyed years

- Standard survey during the wintering season for monitoring occurence and abundance of species
- Use of similar field protocol as during the breeding season (but: only one visit in January, during daylight period)

Distribution of habitats in Hungary and in the area surveyed (Corine)

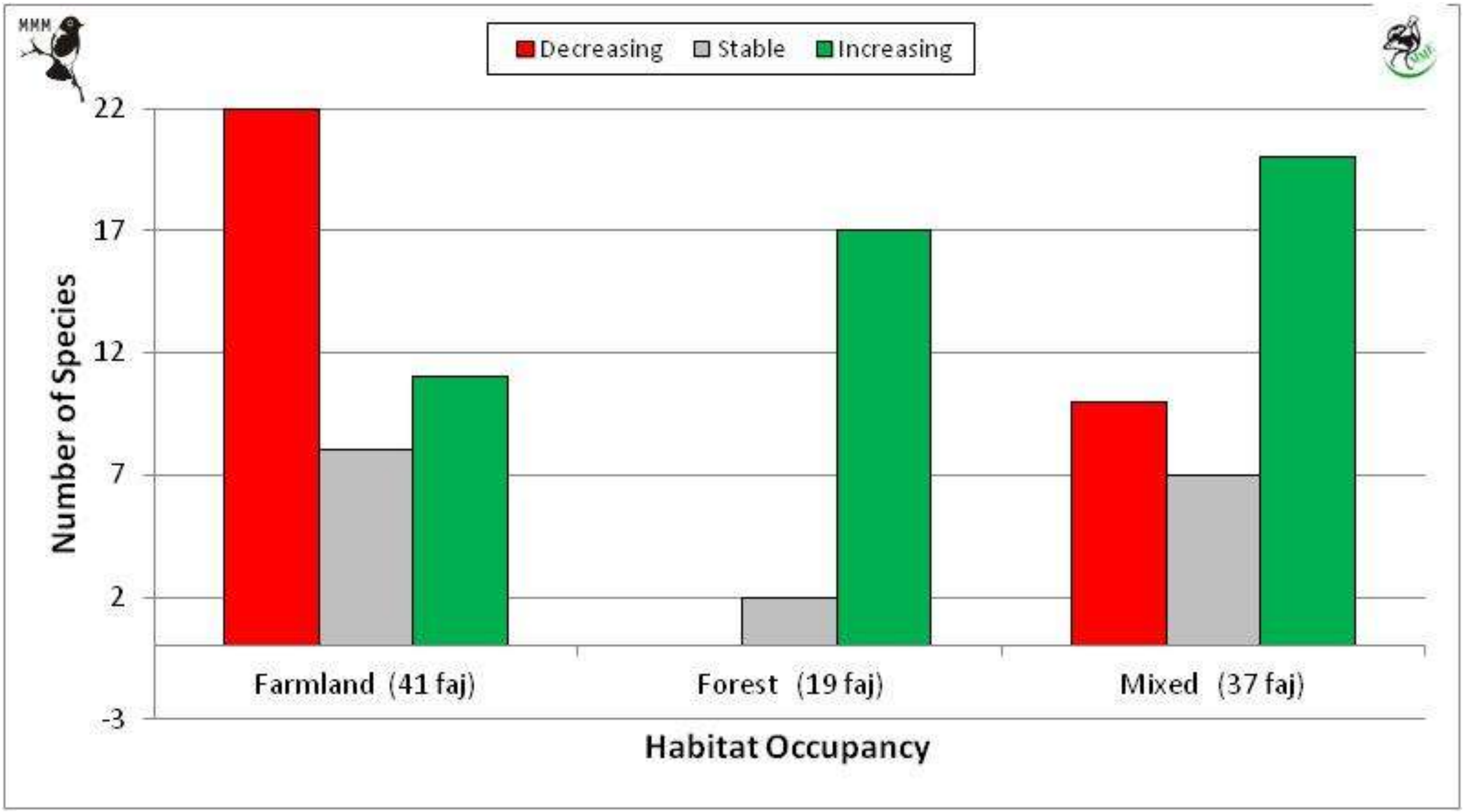


Size of the country: 93 000 km^2



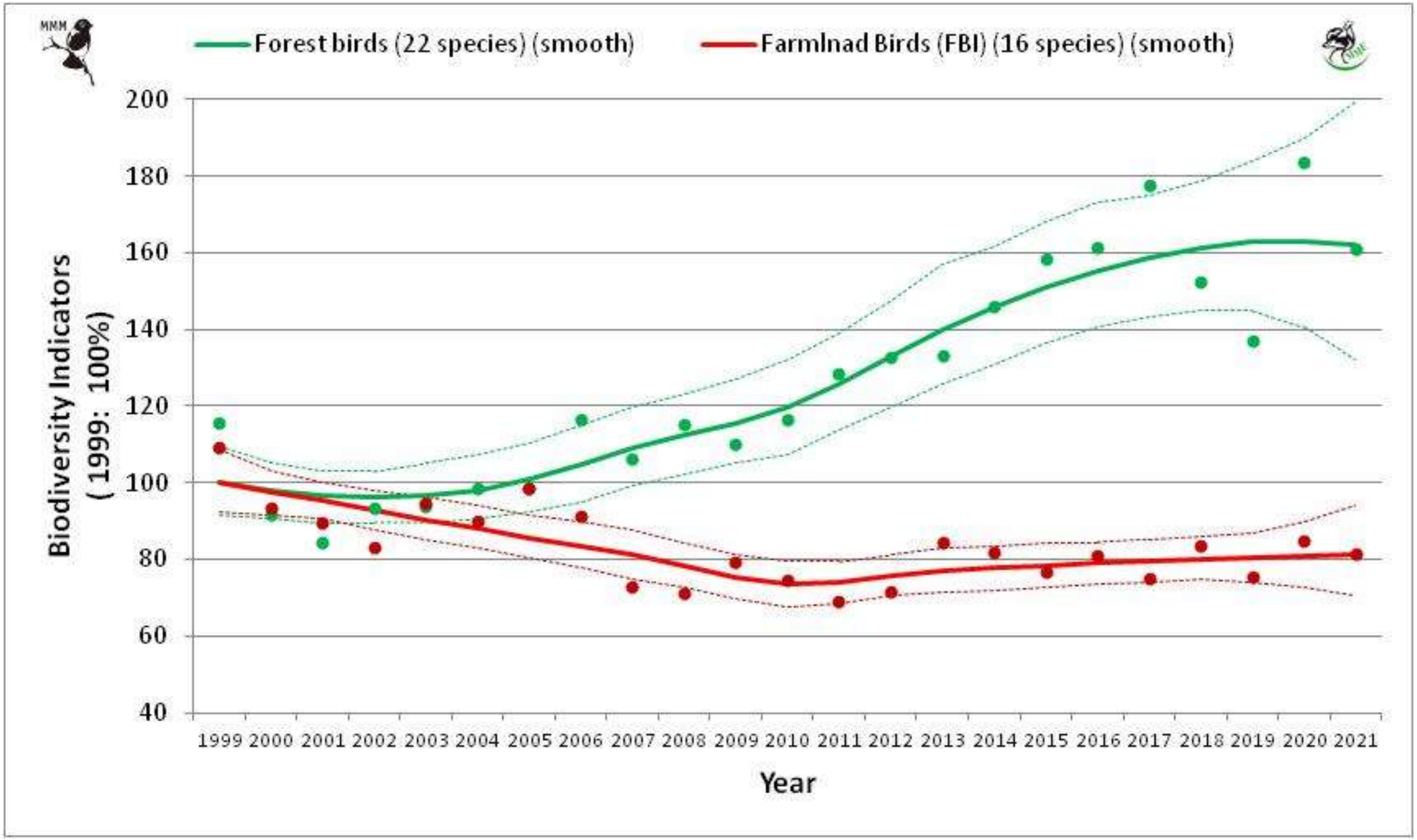
Skylark (Alauda arvensis) – change between 1999-2021: -42% (min:-47%, max:-36%)

Trends of 100 breeding species were identified by TRIM between 1999-2021, habitats



54% of farmland bird species has significant declining trend during 1999-2021

Recent trends of Bird Indicators in Hungary, habitat



Farmland biodiversity (FBI) show a marked decline between 1999-2021 (slope: -0.9% (SE=0.3%, P<0.01)

There is an opposite trend for the forest (slope=3.1%, SE=0.4, P<0.01)

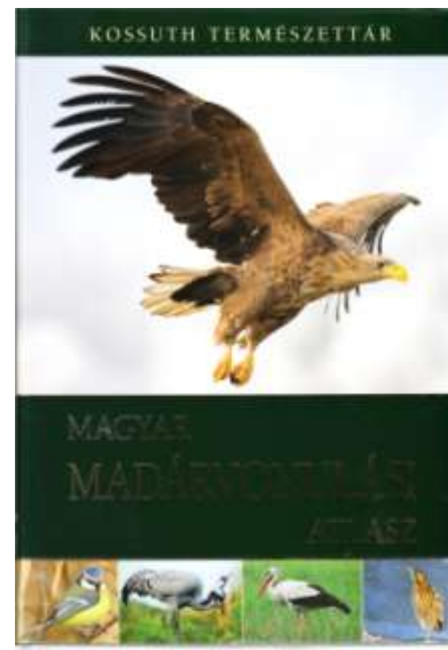
Classification species on migration strategy

Breeding species in Hungary was classified on the base of recent Hungarian Bird Migration Atlas (Csörgő et al. 2009)

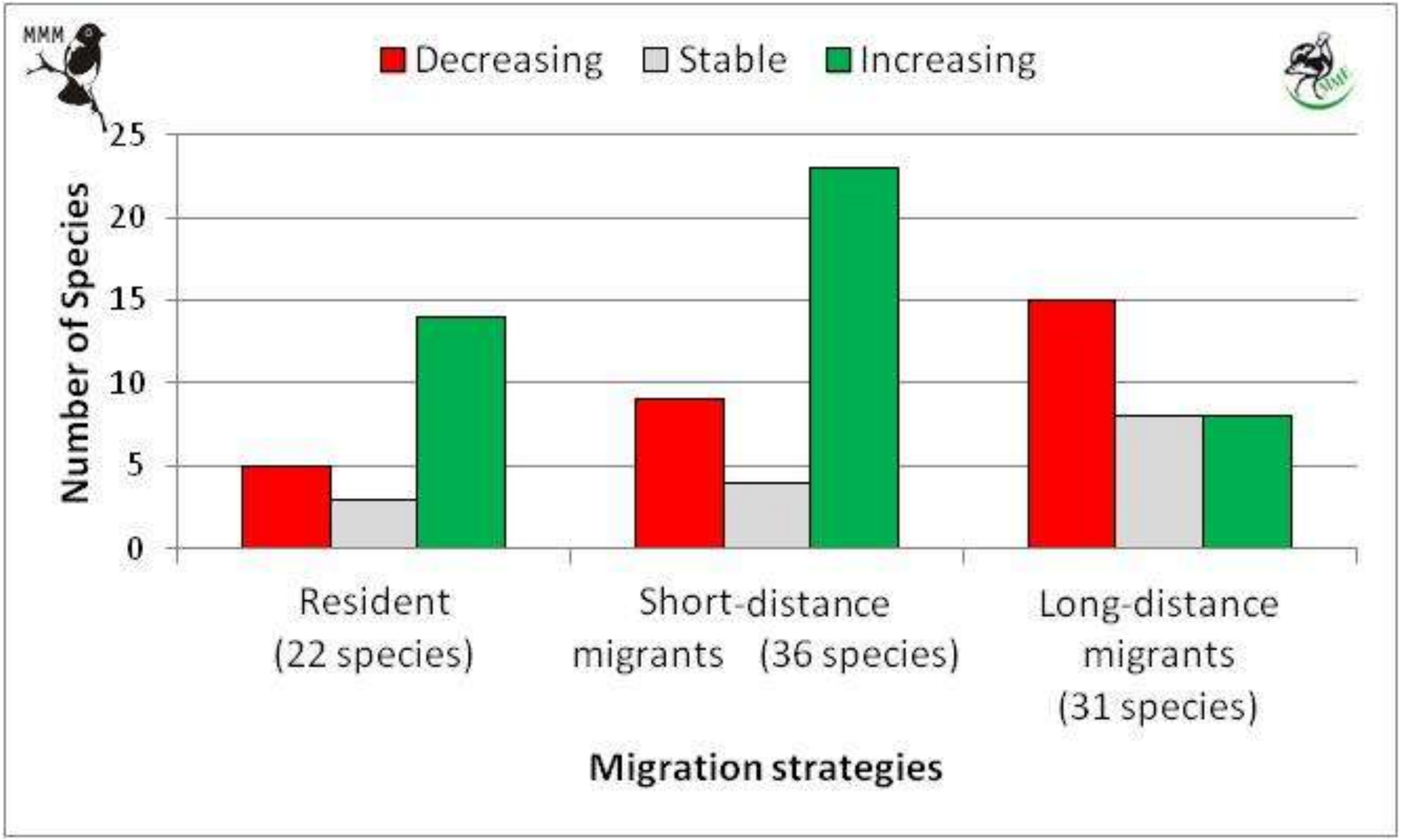
– Resident – spend entire year in the breeding area

– Partial and/or short-distance migrants – migrate only until the Mediterranean region

– Long-distance migrants – migrate over the Sahara

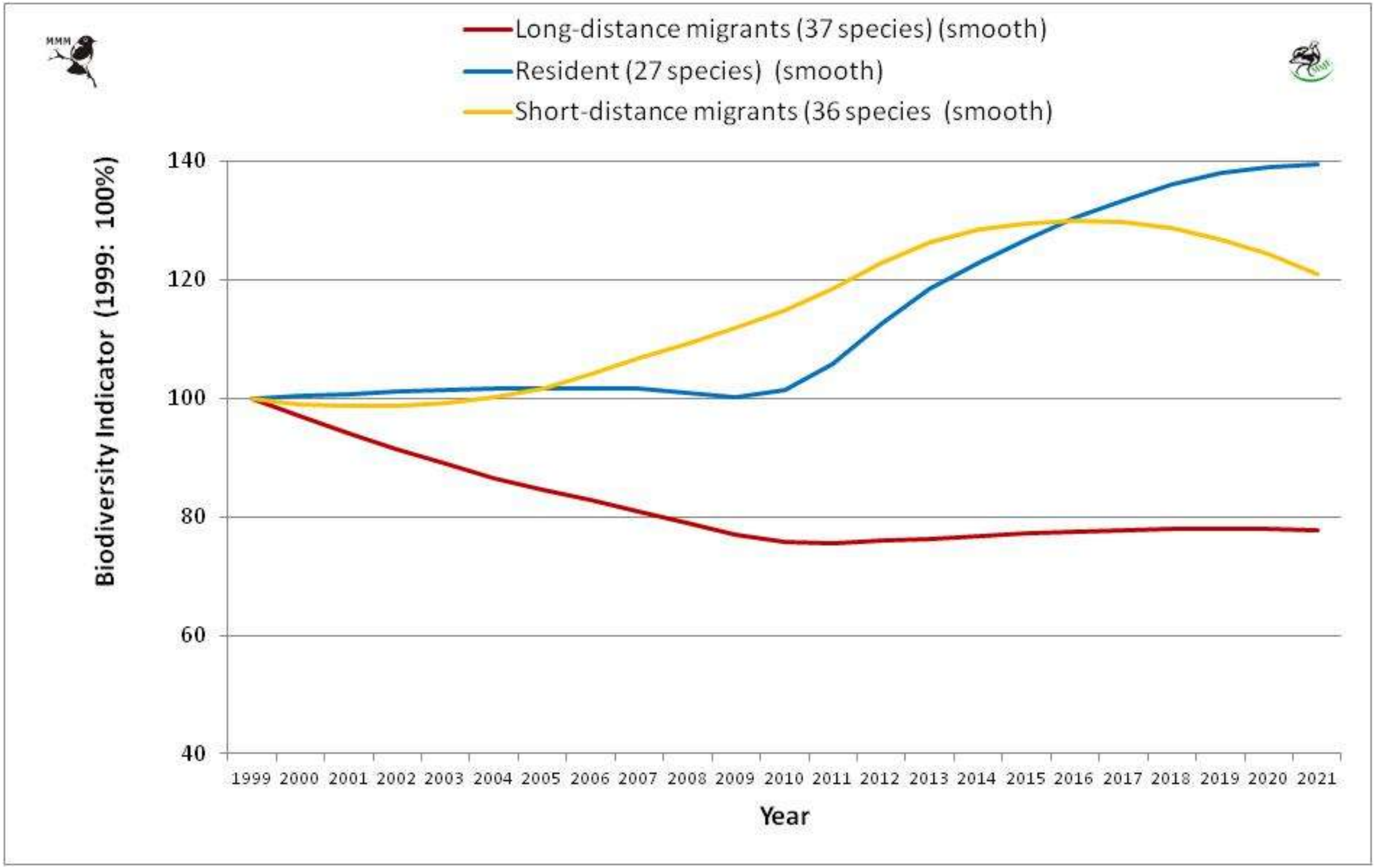


Trends of 100 breeding species were identified by TRIM between 1999-2021



48% of long-distance migrants bird species has significant declining trends, while other two groups has increasing trends during 1999-2021

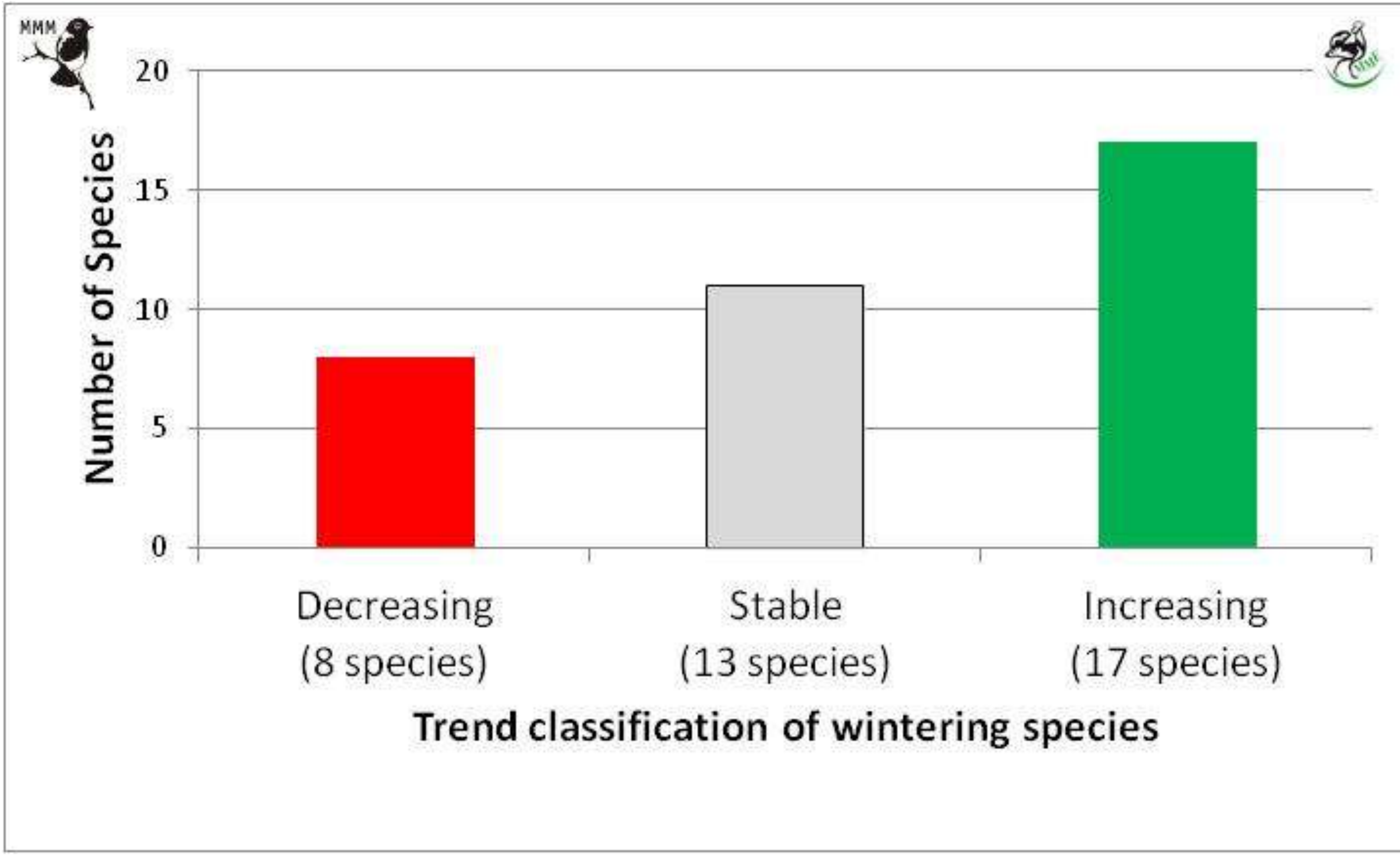
Recent trends of Bird Indicators in Hungary, migration strategy



Long-distance migrant species show decline between 1999-2021 (slope= -1.0%, (SE=0.3%, P<0.01)

In constrast, short-distance migrants (slope=1.5%, SE=0.3%, P<0.05) and resident (slope=1.8%, SE=0.4%, P<0.01) has increasing trends,

Recent trends of wintering common species in Hungary



44% of common wintering species in Hungary has significant increasing wintering population size

Recent tendencies in the biodiversity, based on common birds in Hungary

- Farmland biodiversity show marked decline since EU CAP has implemented in Hungary!

- Contrasting population trends of long distance migrants versus resident and partially/short migrants since start of the monitoring indicate climate related processes (Stephens et al. 2016, Science)

- Increasing trends of wintering populations indicate climate related processes as well (warmer winter, lower mortality)

- Behind the increasing trends of forest birds, climate change could have important influence because dominant part of this species resident and/or partially or short distance migrants

Primary population parameters

Immigration

+

natality + N - mortality

-

Emigration

- **natality**
  - potential fecundity, human (9-11 months)
  - realized - " –, human (8 per years)

natality rate – offspring/unit time

- **mortality**
  - potential longevity
  - realized - " -
  - human girls (Rome 21 years, 1780 UK 39 years, 1976 USA 77 years
- **immigration-emigration**

Secondary population parameters

- Sex ratio

- Age composition

- Distribution

- Genetical composition

Population demography

– Examines and measures the dimensions and dynamics of populations

Life table

Table 3 Cohort life table for the song sparrow on Mandarte Island, British Columbia.[a]

Age in years (x)	Observed no. of birds alive (n_x)	Proportion surviving at start of age interval x (l_x)	No. dying within age interval x to x + 1 (d_x)	Rate of mortality (q_x)
0	115	1.0	90	0.78
1	25	0.217	6	0.24
2	19	0.165	7	0.37
3	12	0.104	10	0.83
4	2	0.017	1	0.50
5	1	0.009	1	1.0
6	0	0.0	—	—

[a] Males hatched in 1976 were followed from hatching until all had died six years later.

SOURCE: From Smith (1988).

.

Life table (mortality) of women in Canada

Table 4 Static life table for the human female population of Canada, 2006.

Age group (yr)	No. in each age group	Deaths in each age group	Mortality rate per 1000 persons (1000 q_x)
0–4	829,300	911	1.10
5–9	899,500	70	0.08
10–14	1,016,500	136	0.13
15–19	1055500	317	0.30
20–24	1,100,200	370	0.34
25–29	1,101,200	377	0.34
30–34	1,101,100	511	0.46
35–39	1,168,400	853	0.73
40–44	1,341,700	1481	1.10
45–49	1,336,900	2364	1.77
50–54	1,193,800	3338	2.80
55–59	1,054,000	4775	4.53
60–64	805,500	5729	7.11
65–69	636,800	7253	11.39
70–74	554,300	10,210	18.42
75–79	490,800	15,221	31.01
80–84	389,200	21,236	54.56
85–90	227,900	22,256	97.66
90 and above	125,300	38,742	309.19

SOURCE: Statistics Canada (2007).

Survivorship curve

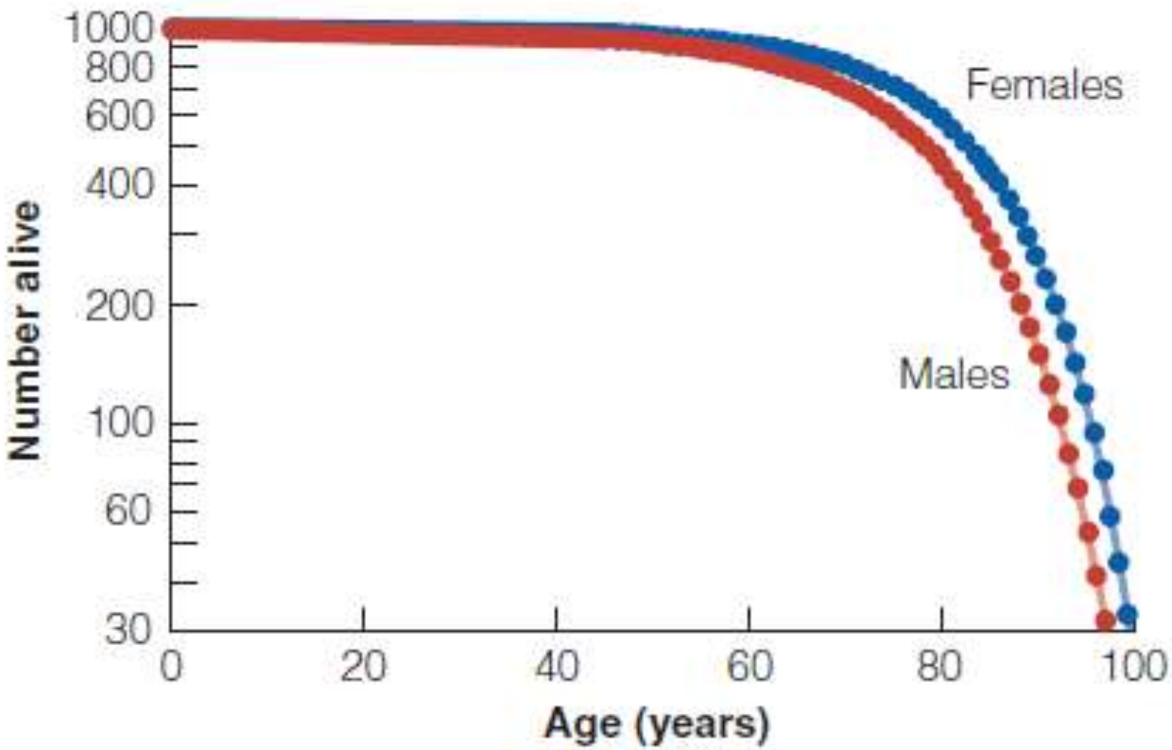


Figure 5 Survivorship curve for all males (red) and females (blue) in the United States in 2003 for a starting cohort of 1000 individuals. Life expectancy at birth was 75 years for males and 80 years for females. (Data from the U.S. National Center for Health Statistics, 2006.)

Survivorship curve

Type I- large mortality in the old age (e.g. humans)

Type II- similar mortality among different age groups (e.g. birds)

Type III- large mortality in the young age (e.g. insects)

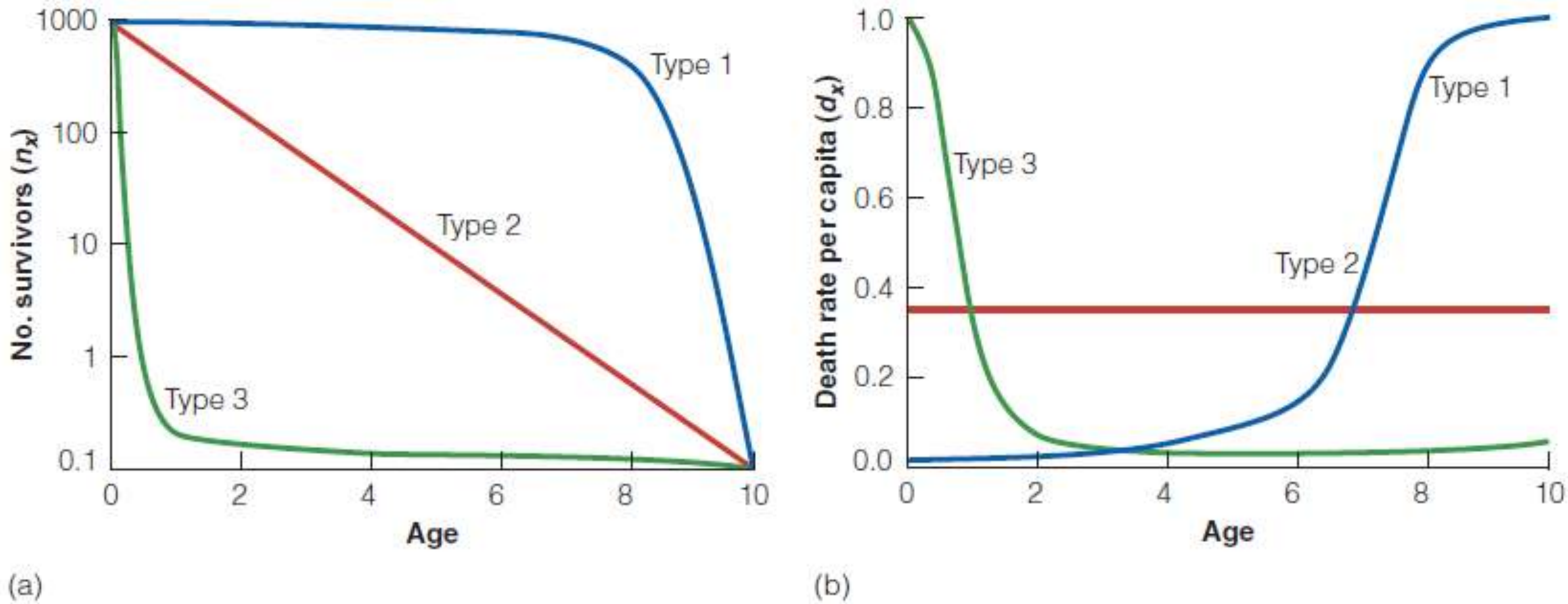


Figure 6 Types of survivorship curves. (a) Hypothetical survivorship curves (n_x). (b) Mortality rate (d_x) curves corresponding to these hypothetical survivorship curves. Type 2 (red) curves show constant survival rate with respect to age. Type 1 (blue) curves show increasing mortality late in life, and Type 3 (green) curves show the highest mortality early in life. (After Pearl 1928.)

Fertility

l_x: proportion of the population surviving to age x.

a_x/a_0 (a_0: # of young individuals, a_x: # of individuals surviving x. age)

b_x: number of offspring by females in their x age

Net reproductive rate (R_0): $\sum_{x=1}^{\text{max. age}} (l_x * b_x)$

If R_0=1, population size did not change

Table 5 Survivorship schedule (l_x) and fertility schedule (b_x) for women in the United States, 2007.

Age group	Midpoint or pivotal age x	Proportion surviving to pivotal age l_x	No. female offspring per female aged x per 5-year period (b_x)	Product of l_x and b_x
0–9	5.0	0.9945	0	0.0000
10–14	12.5	0.9939	0.0020	0.0020
15–19	17.5	0.9929	0.1432	0.1422
20–24	22.5	0.9913	0.2855	0.2830
25–29	27.5	0.9896	0.2863	0.2833
30–34	32.5	0.9878	0.2160	0.2134
35–39	37.5	0.9851	0.0918	0.0904
40–44	42.5	0.9809	0.0175	0.0172
45–49	47.5	0.9743	0.0075	0.0073
50 +	—	—	0.0	0.00
				$R_0 = \sum_0^\infty l_x b_x = 1.0388$

SOURCE: *Statistical Abstract of the United States 2007*.

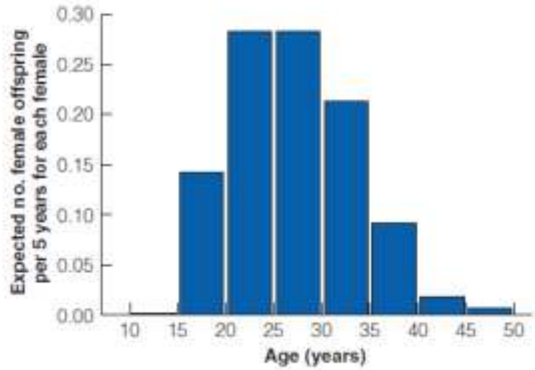


Figure 9 **Expected number of female offspring per five-year period for each female in the United States in 2007.** Data are from the final column in Table 5. The area under the histogram is the net reproductive rate R_0. (Data from the *Statistical Abstract of the United States 2007*.)

Reproductive value

Reproductive value at age x = (V_x): $$\sum_{t=x}^{\text{max. age}} (l_t/l_x)*b_t$$

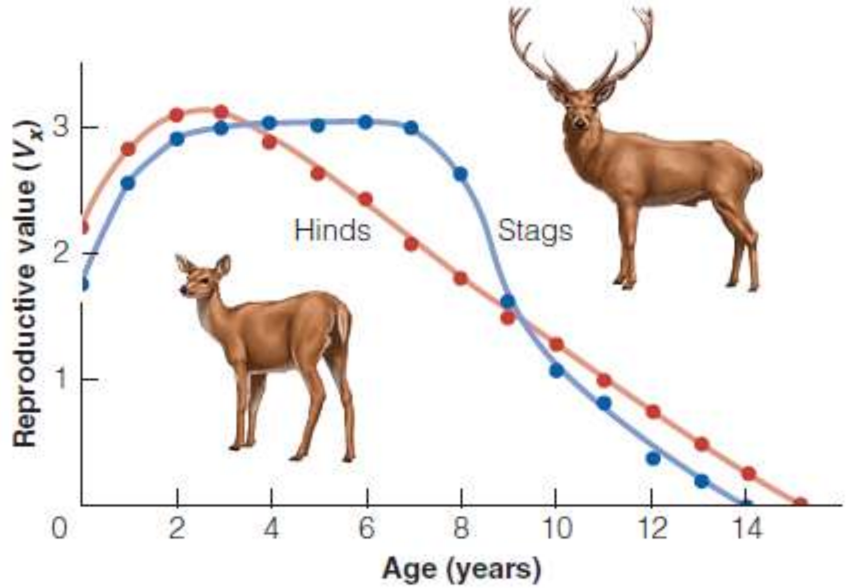
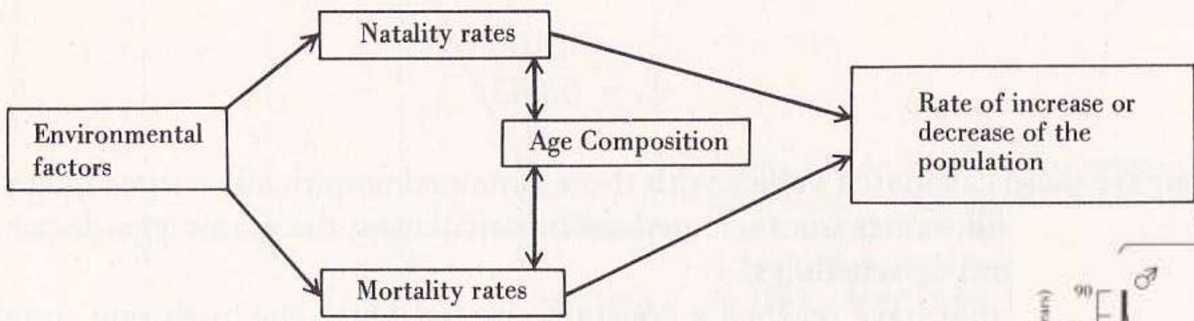


Figure 15 Reproductive value for red deer stags (males) of different ages, compared with that of hinds (females) on the island of Rhum, Scotland. Reproductive value is calculated in terms of the number of female offspring surviving to one year of age that parents of different ages can expect to produce in the future. (From Clutton-Brock et al. 1982.)

Age distribution



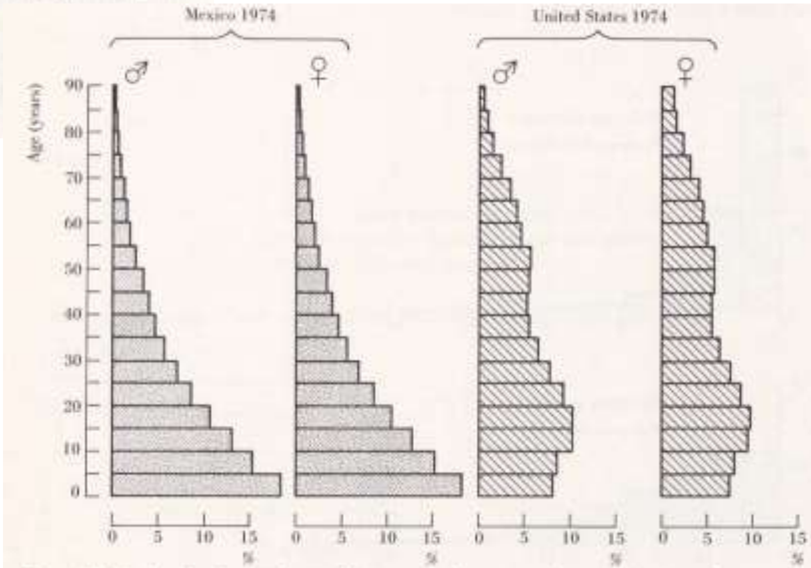
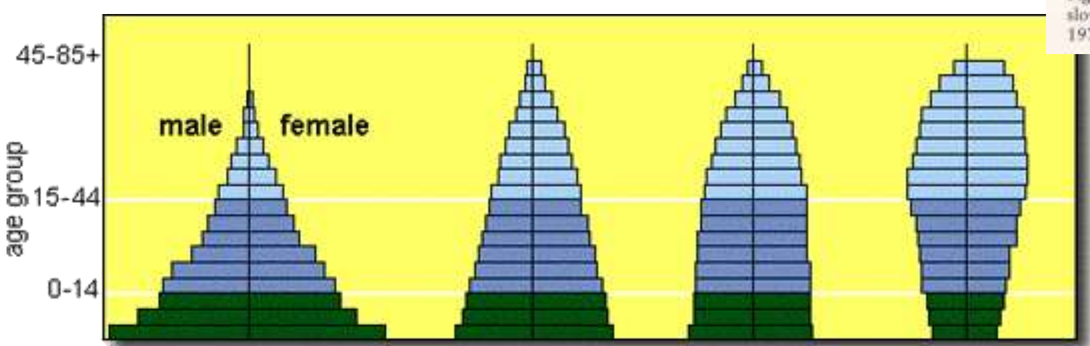


Figure 11.18 Age distributions for rapidly increasing human population in Mexico and slowly increasing population in the United States. (Data from Demographic Yearbook 1974.)



Rapid Growth
Kenya
Nigeria
Saudi Arabia

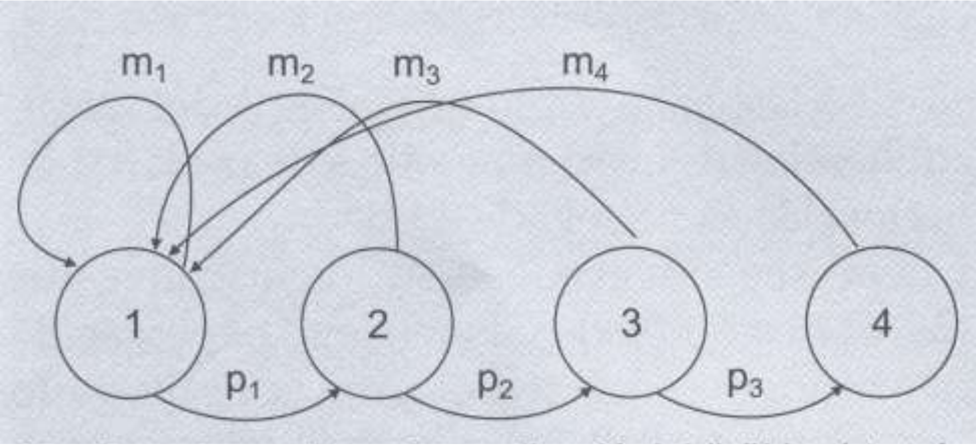
Slow Growth
United States
Australia
Canada

Zero Growth
Denmark
Austria
Italy

Negative Growth
Germany
Bulgaria
Hungary

Modeling population size on the base of life table data

- Leslie model
  - If we know for each age group (a) the survival rate (p_a) and fertility (m_a)
  - Population size of each age groups (n_a), by which the entire population is estimatable for the next period (t)



Pl.

$n_1(t+1)=n_1(t)*m_1+n_2(t)*m_2+\ldots.$

$n_2(t+1)=n_1(t)*p_1$

$n_3(t+1)=n_2(t)*p_2$

.

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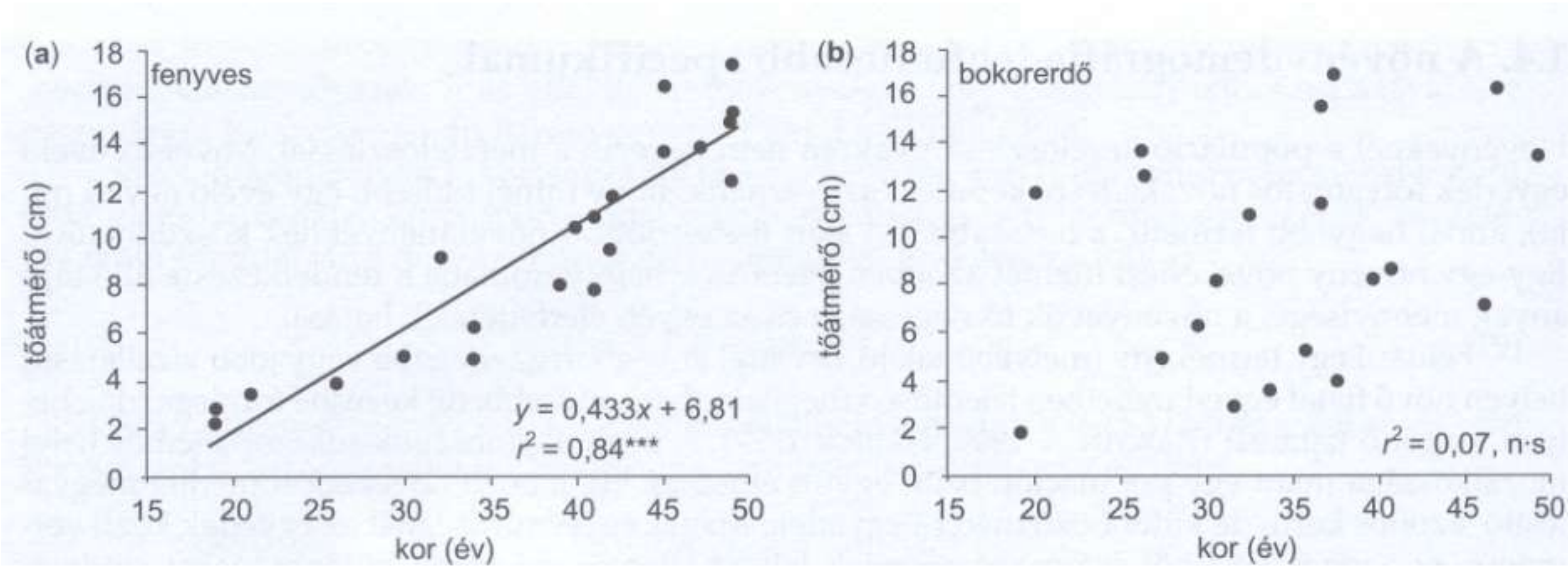
Speciality of plant demography

Age distribution could be different form size distribution – survival and fertility are size dependent for most plants



Manna tree (Fraxinus ornus) age (kor év) and size (diameter of stump, tőátmérő cm) at two different habitats:

- fenyves- soil with similar depth
- bokorerdő- soil with very varying depth