Biodiversity Monitoring (BBI1603)

- Books:
  - Primack R. B. 2010. Essentials of Conservation Biology. Macmillan Science
  - Hill D., Fasham M., Tucker G., Shewry M., Shaw P. 2005. Handbook of Biodiversity Methods_ Survey, Evaluation and Monitoring-Cambridge University Press
  - Vorisek P, Klvanova A, Wotton S, Gregory RD (2008) A Best Practice Guide for Wild Bird Monitoring Schemes.

Information in relation to the course:

http://zeus.nye.hu/~szept/kurzusok.htm

What is Biological Diversity?

– Conception

– **Measurable entity**

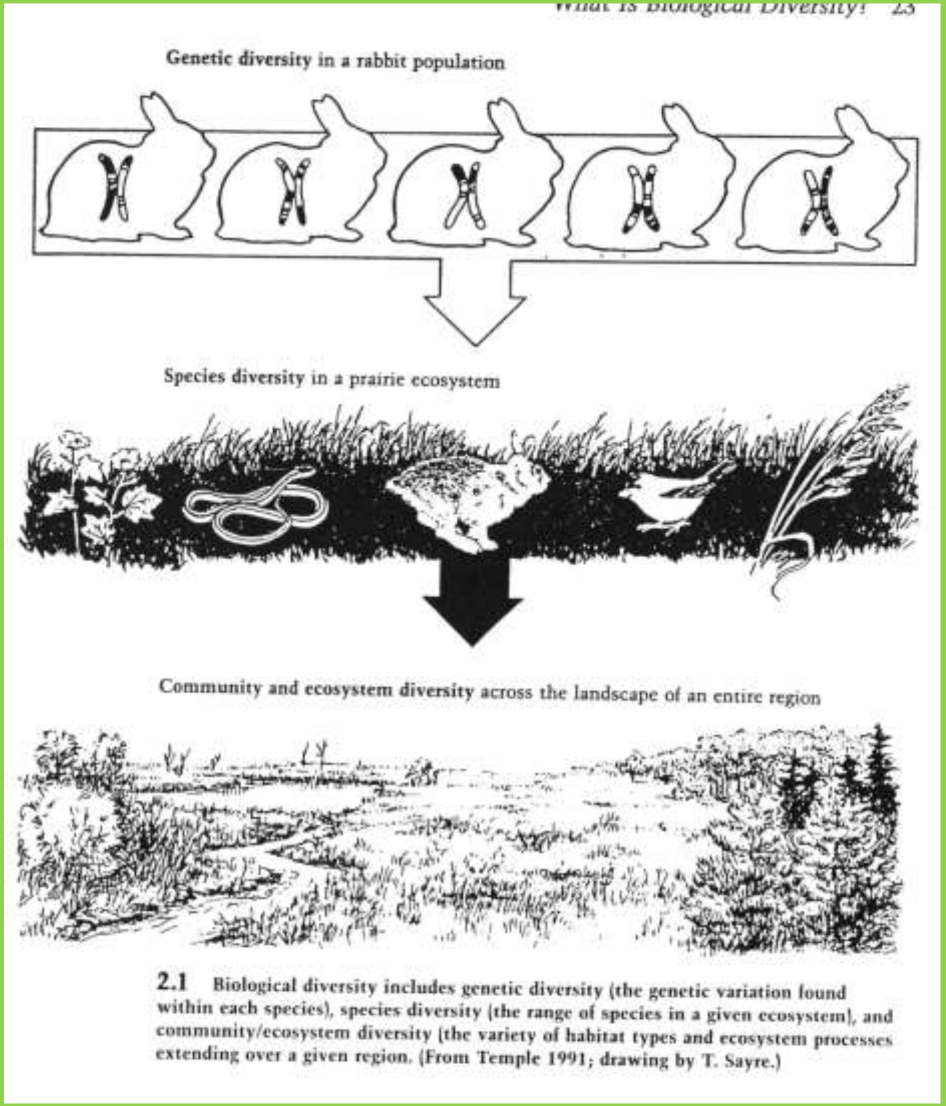
– Scientific field

Level of Biological Diversity

- Genetic diversity

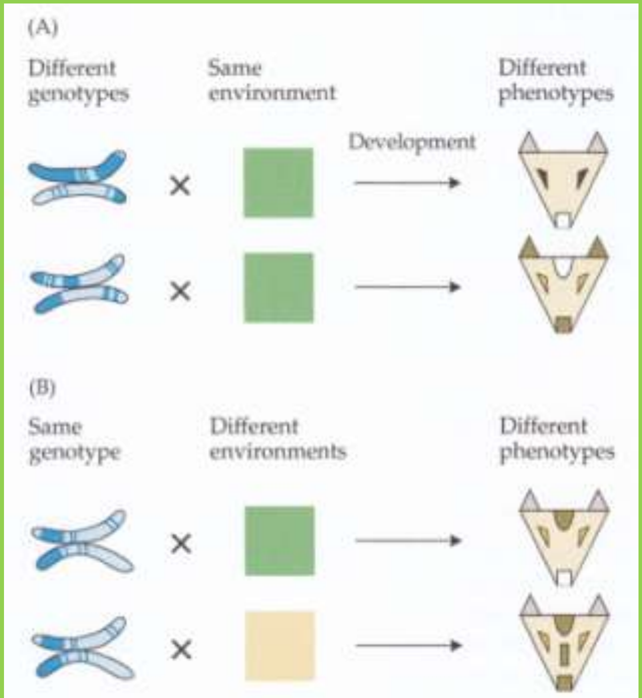
- Taxonomic diversity

- Community diversity

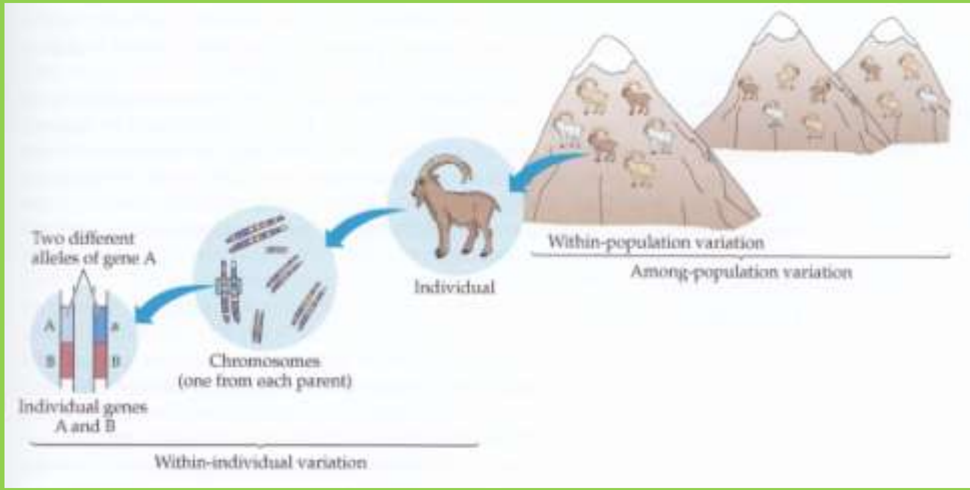


2.1 Biological diversity includes genetic diversity (the genetic variation found within each species), species diversity (the range of species in a given ecosystem), and community/ecosystem diversity (the variety of habitat types and ecosystem processes extending over a given region. (From Temple 1991; drawing by T. Sayre.)

Genetic diversity



- Among species (sibling species – Drosophila)
- Within species, among populations (e.g. dogs,)



Genetic diversity

Measurement

- Phenotypical diversity – isoensims
- Sequence of DNA

Polymorphism (P)

- Ratio of genes in the population with polymorphic allele

Heterozygousness (H)

The ratio of genes per individual that are polymorphic

Genetic diversity

Species genetic diversity(H_t)

$H_t = H_s + D_{st}$

H_s: Diversity within population

D_{st}: Diversity between populations

Polymorphism and heterozygousness has positive correlation

Diversity of taxonomic groups

Diversity of species, genus, family, order, class, phylum,,….

Number of species

Diversity index

Shannon-Wiener $$H = -\sum_{i-1}^{S} pi * \ln pi$$

ahol S: number of species, pi: frequency of the i-th species

Evenness

E= H/Hmax, H/lnS

There are several types of diversity index – Diversity ordering used nowadays

A

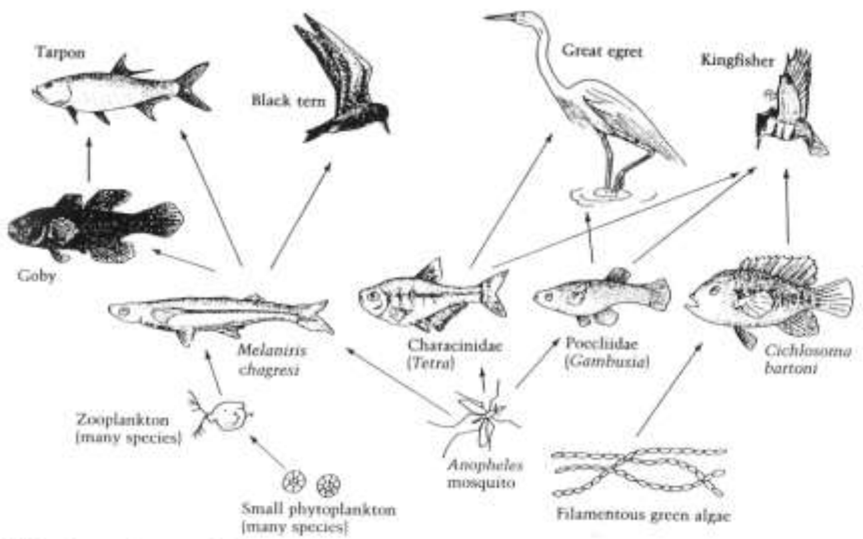
Species	Ni	pi (frequency)	ln pi	pi * ln pi	1/S	ln (1/S)	(1/S) * ln (1/S)
Great tit	13	0.406	-0.901	-0.366	0.143	-1.946	-0.278
Blue tit	8	0.250	-1.386	-0.347	0.143	-1.946	-0.278
Blackbird	4	0.125	-2.079	-0.260	0.143	-1.946	-0.278
Nuthatch	3	0.094	-2.367	-0.222	0.143	-1.946	-0.278
Great spotted woodpecker	2	0.063	-2.773	-0.173	0.143	-1.946	-0.278
Jay	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
Buzzard	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
S	**7**						
N	32						
H				**1.584**			
Hmax							1.946
E							**0.814**

B

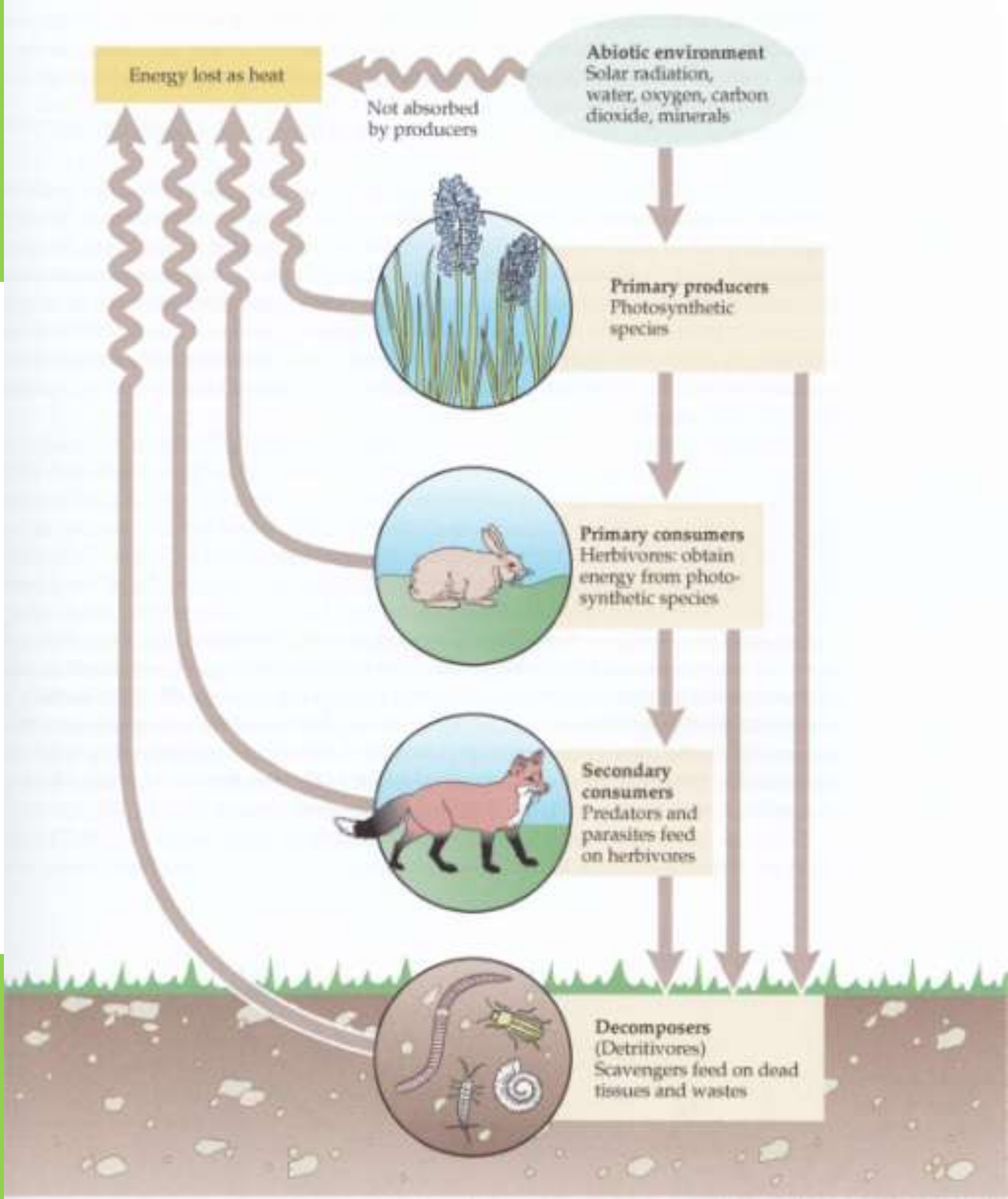
Species	Ni	pi (frequency)	ln pi	pi * ln pi	1/S	ln (1/S)	(1/S) * ln (1/S)
Great tit	20	0.625	-0.470	-0.294	0.143	-1.946	-0.278
Blue tit	5	0.156	-1.856	-0.290	0.143	-1.946	-0.278
Blackbird	3	0.094	-2.367	-0.222	0.143	-1.946	-0.278
Nuthatch	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
Great spotted woodpecker	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
Jay	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
Buzzard	1	0.031	-3.466	-0.108	0.143	-1.946	-0.278
S	**7**						
N	32						
H				**1.239**			
Hmax							1.946
E							**0.637**

Community ecosystem diversity

- Diversity of functional groups



2.9 Diagram of an actual food web studied in Gatun Lake, Panama. Phytoplankton ("floating plants") such as green algae are the primary producers at the base of the web. Zooplankton are tiny, often microscopic, floating animals; they are primary consumers, not photosynthesizers, but they, along with insects and algae, are crucial food sources for fish in aquatic ecosystems. (Courtesy of G. H. Orians.)



Community ecosystem diversity

- Diversity of habitats
- Diversity of habitat patches

Biodiversity

The importance of species varies in the nature

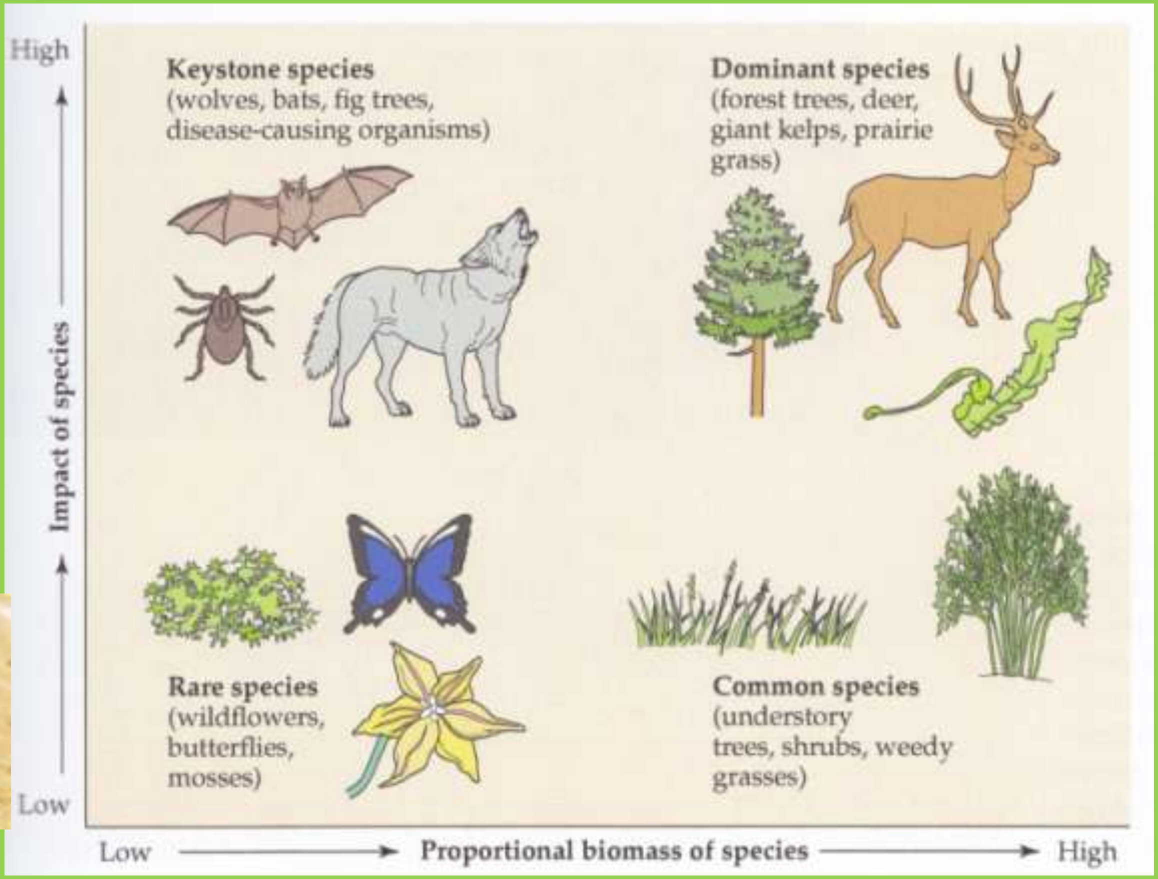
Naturalness – rarity - threateness

Keystone species

- Top predators– e.g. wolf

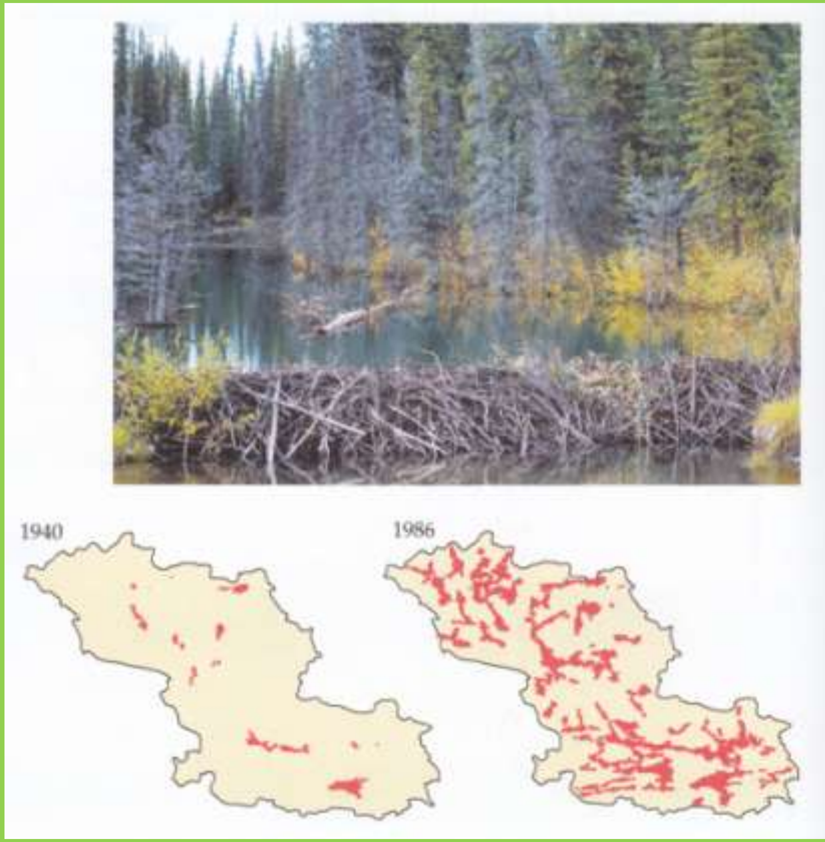
- Flying foxes

- Ecosystem engineers – beaver, elephant, dung beetles



Ecosystem engineers

- Beavers



Ecosystem engineers

- Elephant





Keystone Resources

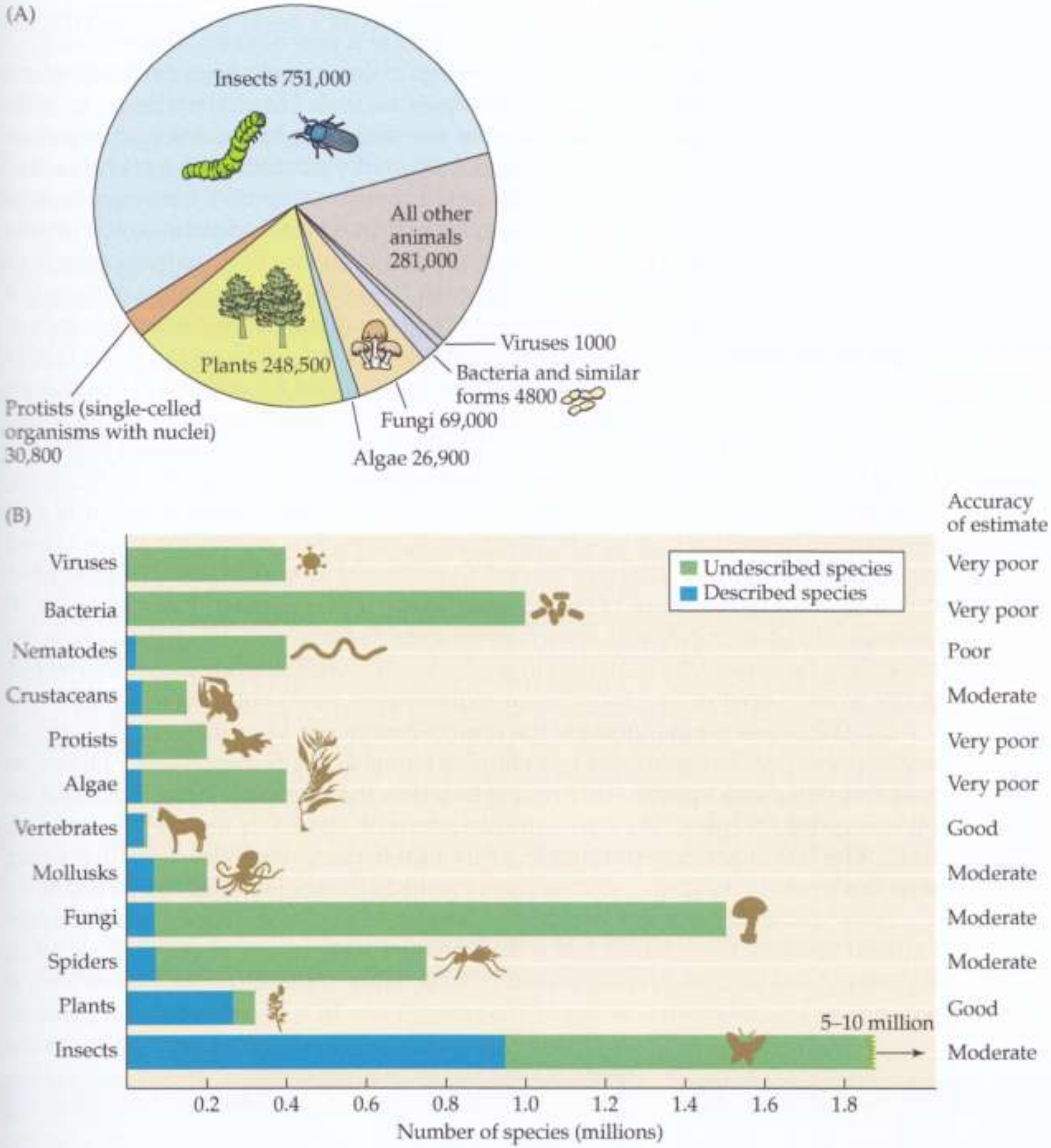
- Salt-licks and mineral pools
- Deep pools
- Elevational gradients
- Mangroves

Indicators

- Flagship species (Panda, Californian Condor)

http://wwf.panda.org/what_we_do/endangered_species/

- Umbrella species (e.g. Grizzly Bears)

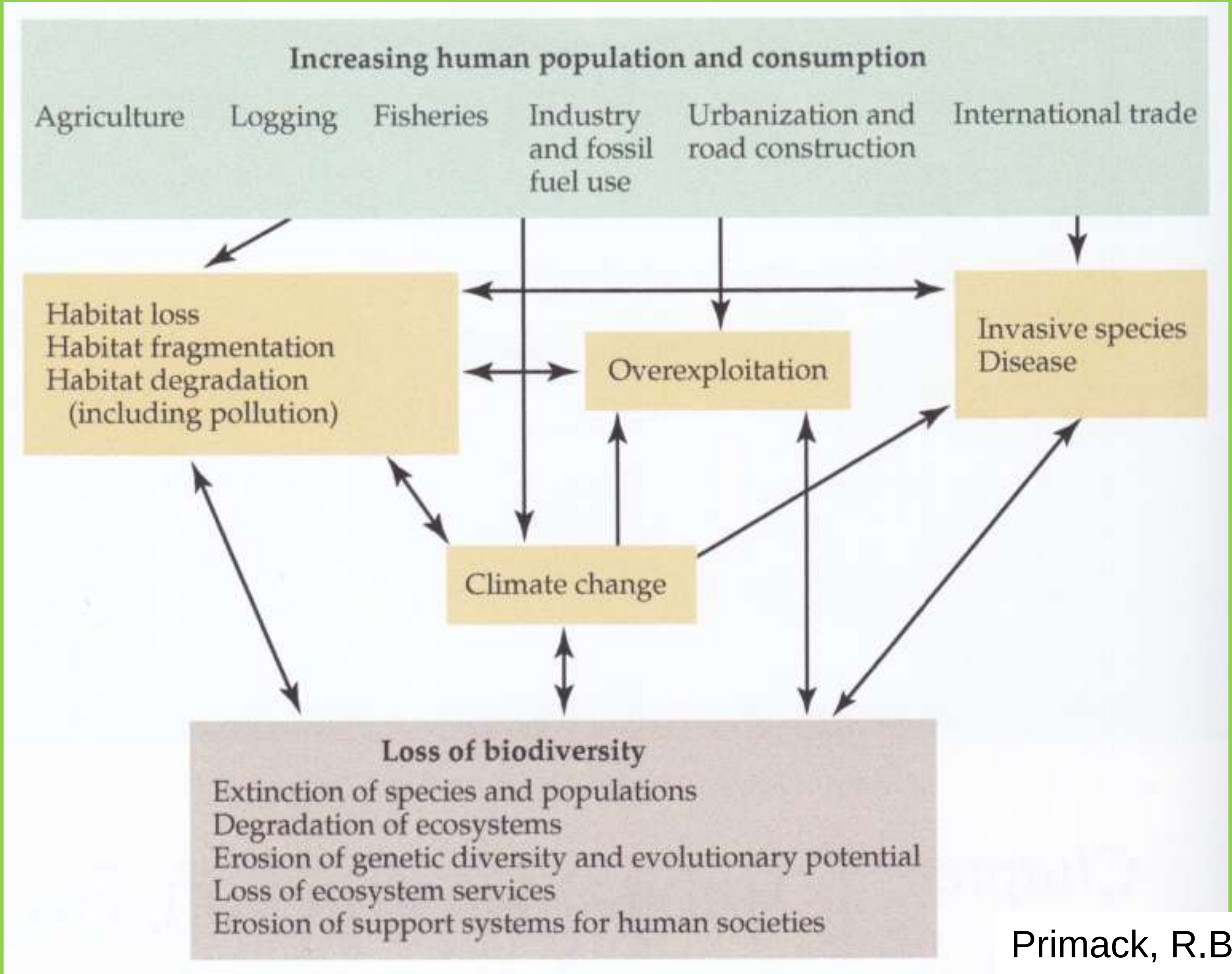


Biological Diversity

The science described ~2.000.000 species,

however the estimated number of species on the Earth are over 10 millions

The planet has lost 58% of its biodiversity since 1970 according to a 2016 study by the World Wildlife Fund



Primack, R.B. 2014

Biodiversity Monitoring

is essential:

- To collection information about status of the biodiversity for researchers, decision makers and public
- To detect adverse trends of populations, species, communities, habitats, ecosystems
- To measure efficiency of actions against adverse trends

Importance of indicators in the biodiversity monitoring

Not feasible to monitor regularly and in details all species !

Biodiversity indicators (species, groups of species) tools to indirectly get information about status of several other species, communities, habitats

Requirements of biodiversity indicators:

- Easy to survey even by not specialist –> for large spatial coverage
- Low cost of survey –> cost effective way of getting proper data
- Ecological meaningful and properly explanatory data –> investigation
- Known by the public and/or has economic values -> interpretation
- …

Birds – exclusive role in the biodiversity monitoring

- Proper indicators in regional and country level

- Intensively studied animals – large amount of research to interpret the data

- National (e.g. In Hungary: MME/BirdLife Hungary) and International professional organisations (e.g. In Europe: EBCC, EURING, BirdLife Europe) with standard of methods, data handlings and cooperations

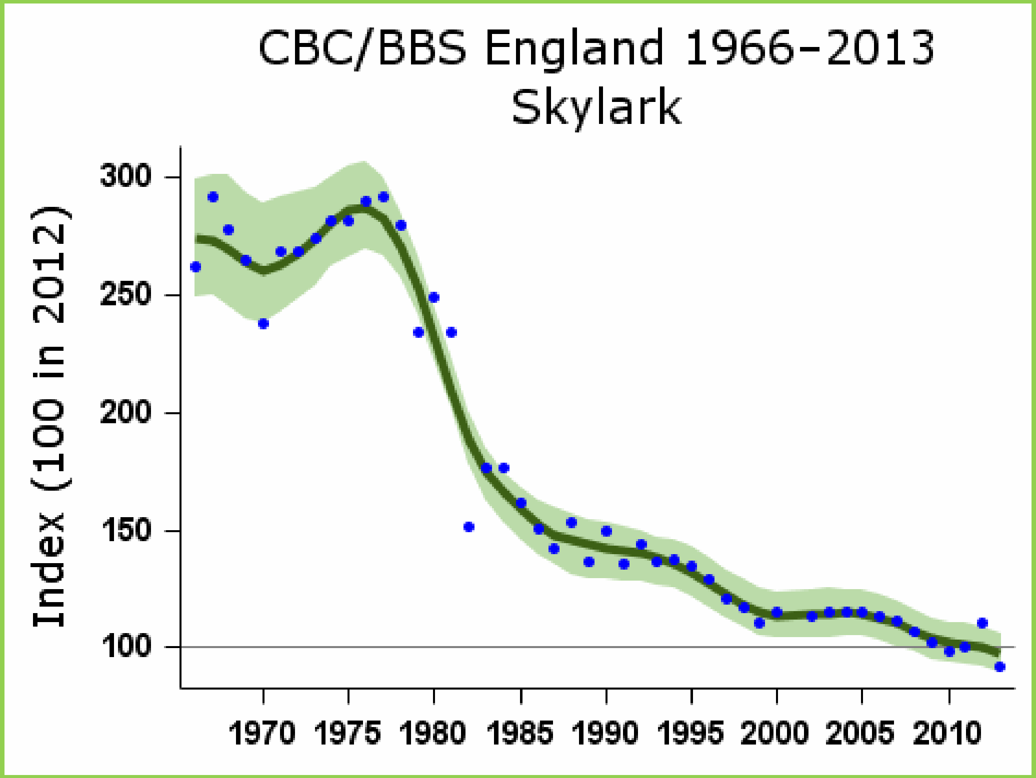
- Large database in space and time

- Opportunity to collect data with much lower cost comparing to other animals– **largest network of voluntary people for surveying**

- One of the best now animal group for the general public – large interest by the public

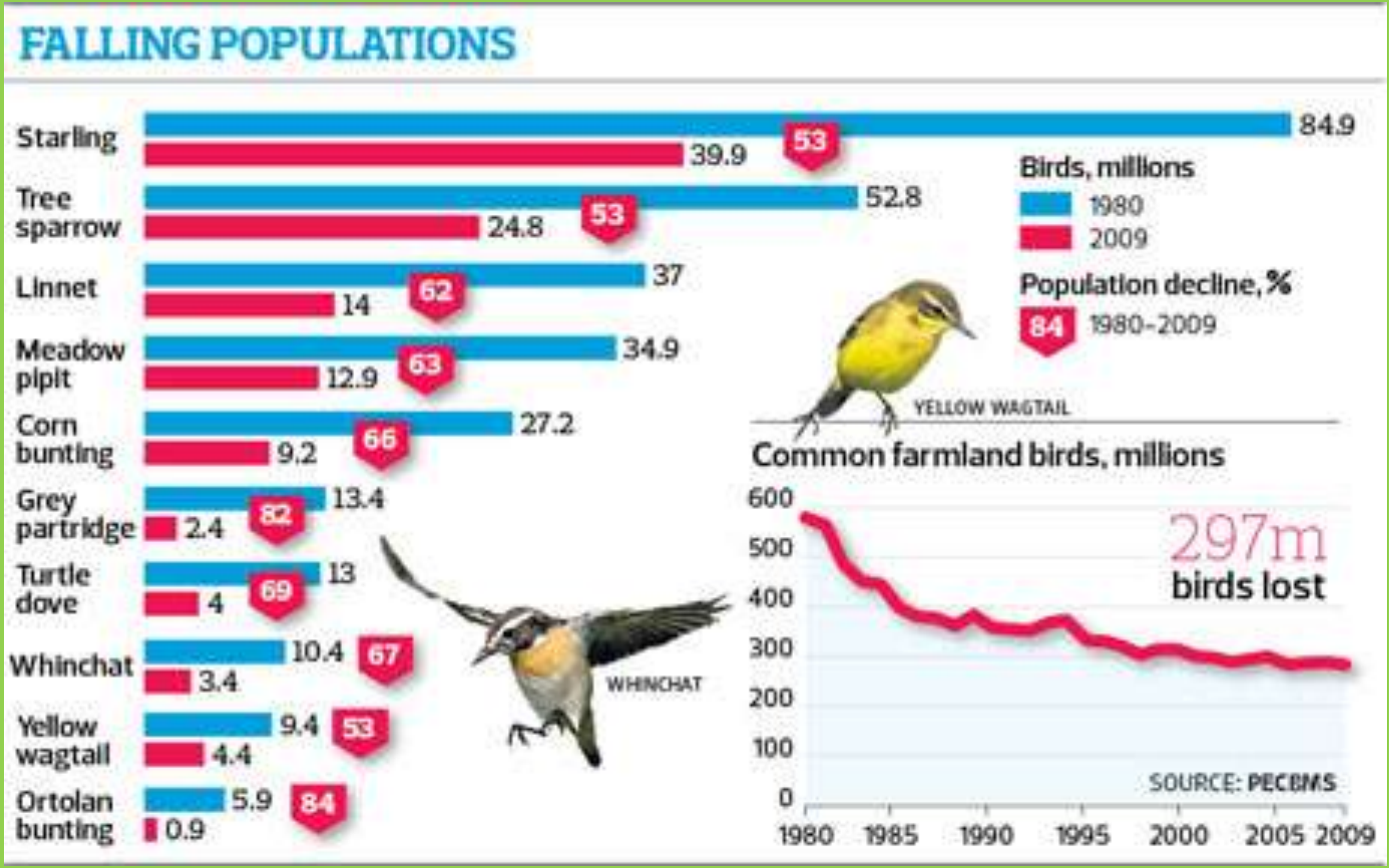
Biodiversity monitoring with birds in Europe

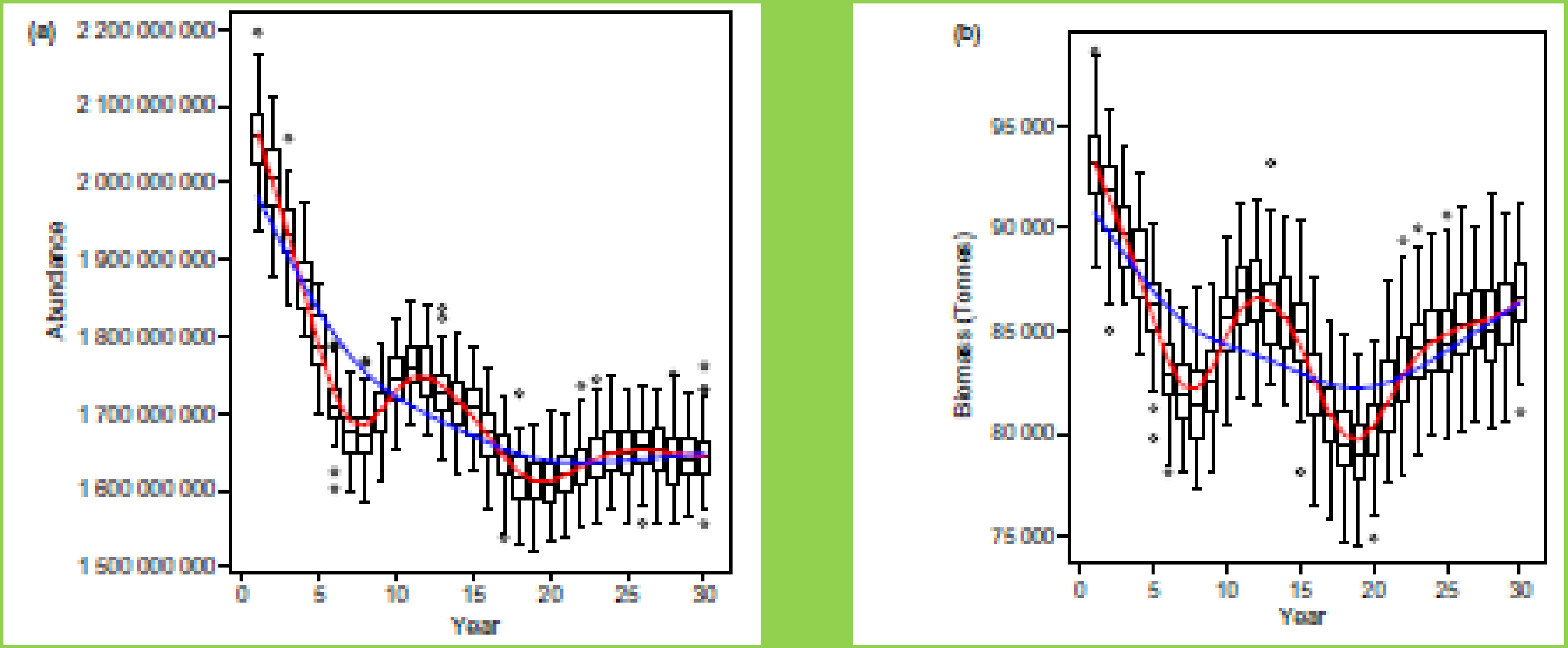
-In Europe, ~2/3 of the areas transformed to agricultural land during centuries
-Large loss of the biodiversity in this dominant habitats from 1980 indicated by breeding bird species in Western Europe



Trend of population size of skylark (Alauda arvensis) in England

Large decline of the population size of breeding bird farmland species in Western Europe from 1980
-
Common Agricultural Policy (CAP) started in the European Union in 1980

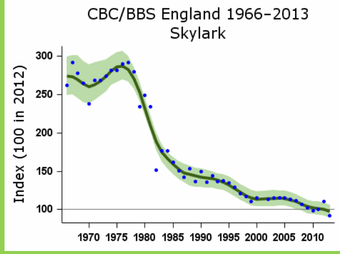




(a) Number of individuals and (b) estimated biomass

In Europe, 421 million bird individuals missing, (7 000 tons of bird biomass) between 1980-1994 *(Inger et al. Ecology Letters, 2014)*.

Main causes



Common Agricultural Policy (CAP) of EU

- Large increase of the agricultural intensification -> large negative influence on farmland species *(Butler et al. 2007. Science)*

  -Spring to autumn sowing

  -Loss on non-cropped habitat

  -Increased agrochemical inputs

  -Land drainage

  -Switch from hay to silage and earlier harvesting

  -Intensified grassland management

  Direct effects on Birds:

  – ***Decline of foraging site during the breeding and wintering seasons***

  – ***Decline of food during the breeding and wintering seasons***

  – ***Decline of breeding sites***

Pan-European Common Bird Monitoring Scheme (PECBMS) by the EBCC

Main goal is to use common birds as indicators of the general state of nature using large-scale and long-term monitoring data on changes in breeding populations across Europe

Common birds are good indicators as they are widespread, relatively easy to identify and count, sensitive to land use and climate change, and are popular with the public.

PECBMS

EBCC European Bird Census Council every bird counts

https://pecbms.info/

Pan-European Common Bird Monitoring Scheme (PECBMS) by the EBCC

Common bird indicators (multi-species composite indices)

Geometric mean of annual indices of species use similar habitat

Farmland Bird Indicator (**FBI**) in Europe between 1980 and 2019

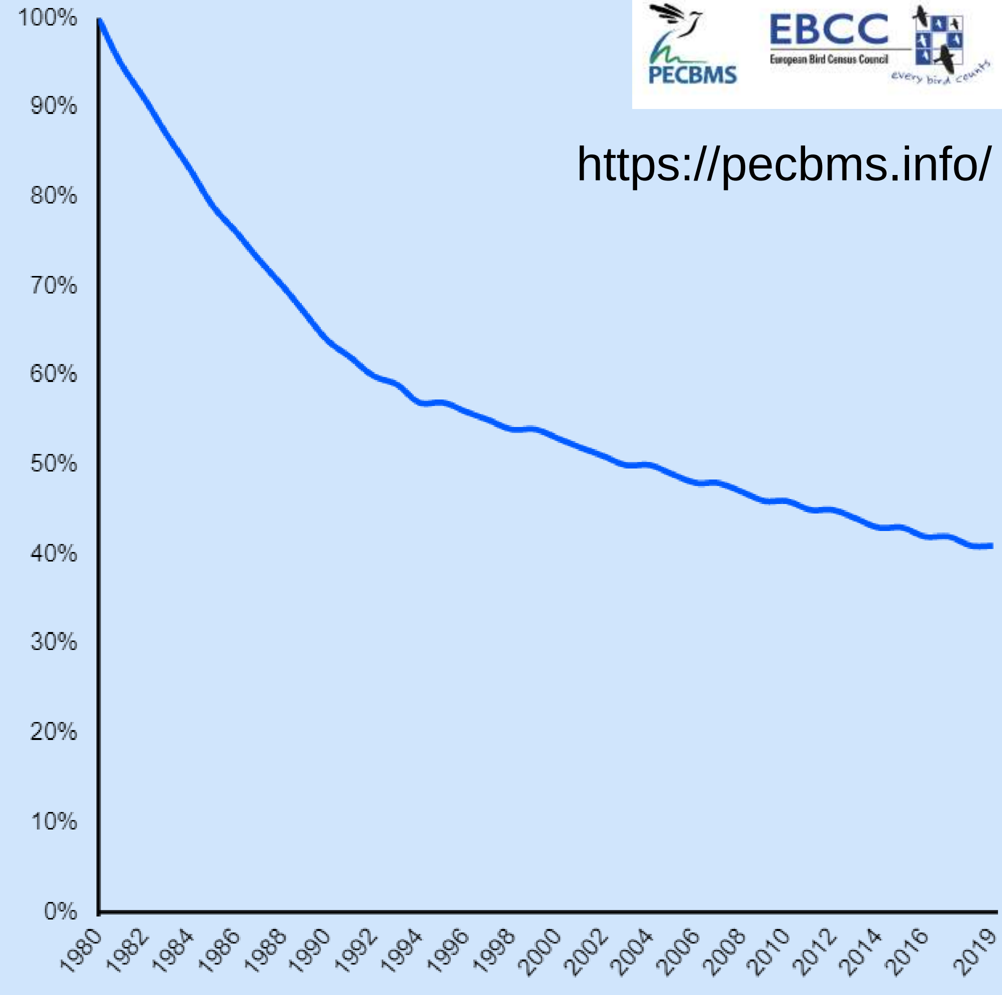
PECBMS

EBCC

European Bird Census Council

every bird counts

https://pecbms.info/

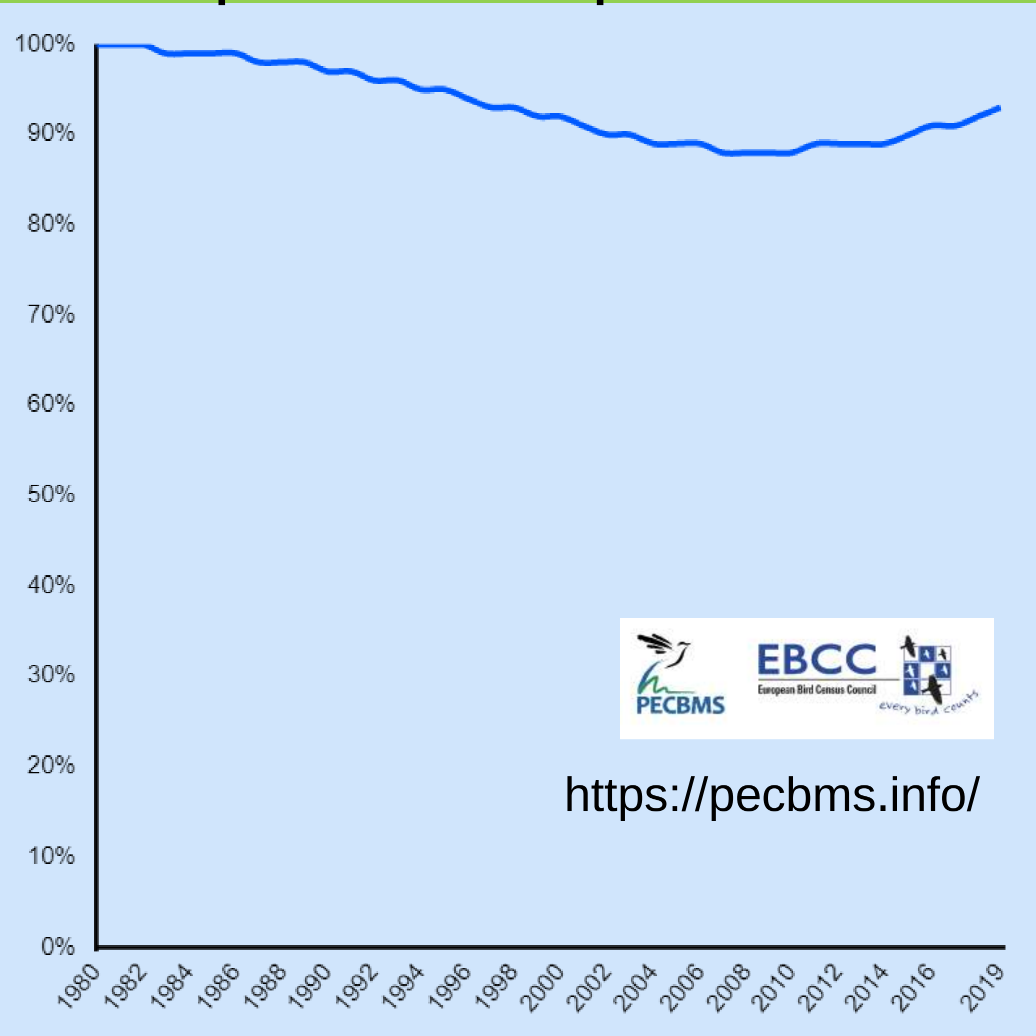


Pan-European Common Bird Monitoring Scheme (PECBMS) by the EBCC

Common bird indicators (multi-species composite indices)

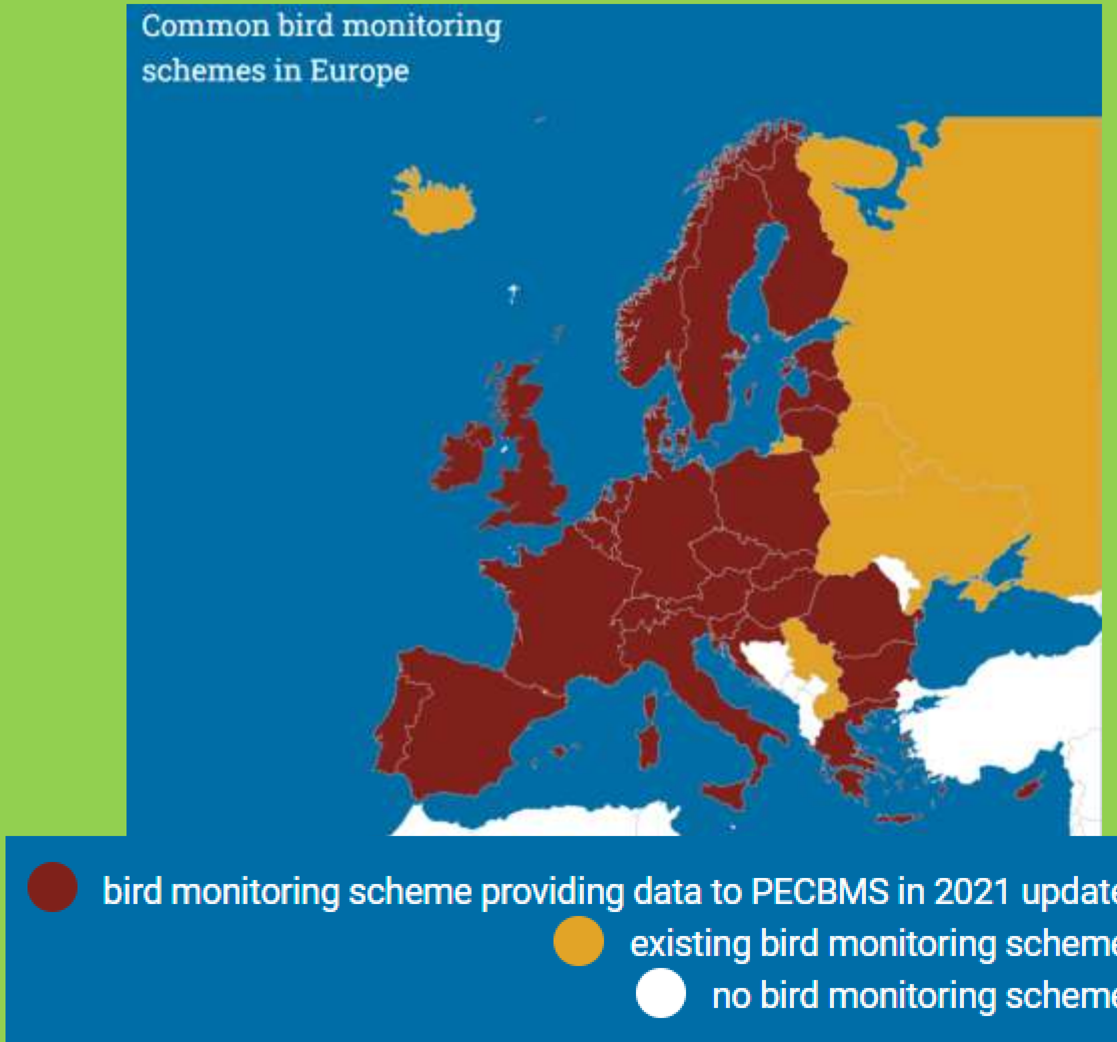
Geometric mean of annual indices of species use similar habitat

Indicator forest birds in Europe between 1980 and 2019



Pan-European Common Bird Monitoring Scheme (PECBMS) by the EBCC

Large coverage of Europe for 2021



https://pecbms.info/

Pan-European Common Bird Monitoring Scheme (PECBMS) by the EBCC

The PECBMS indicators have been accepted as

- Indicators for the EU´s Structural Indicator
- Indicators of Sustainable Development of the EU
- National versions of the Farmland bird indicators have also been approved as the Regulation indicators in the EU´s Rural Development Plans

Other international institutions, e. g, have used the indicators. Organization for Economic Co-operation and Development (OECD), or European Environment Agency (EEA), and have also been included in Living Planet Index (LPI).

https://pecbms.info/

Can we monitor biodiversity in Hungary properly with birds ? (plenty of discussion from 1997)

Hungary became member of the EU in 2004:

- What is the influence of the Common Agricultural Policy (CAP) on the farmland biodiversity in Hungary ?

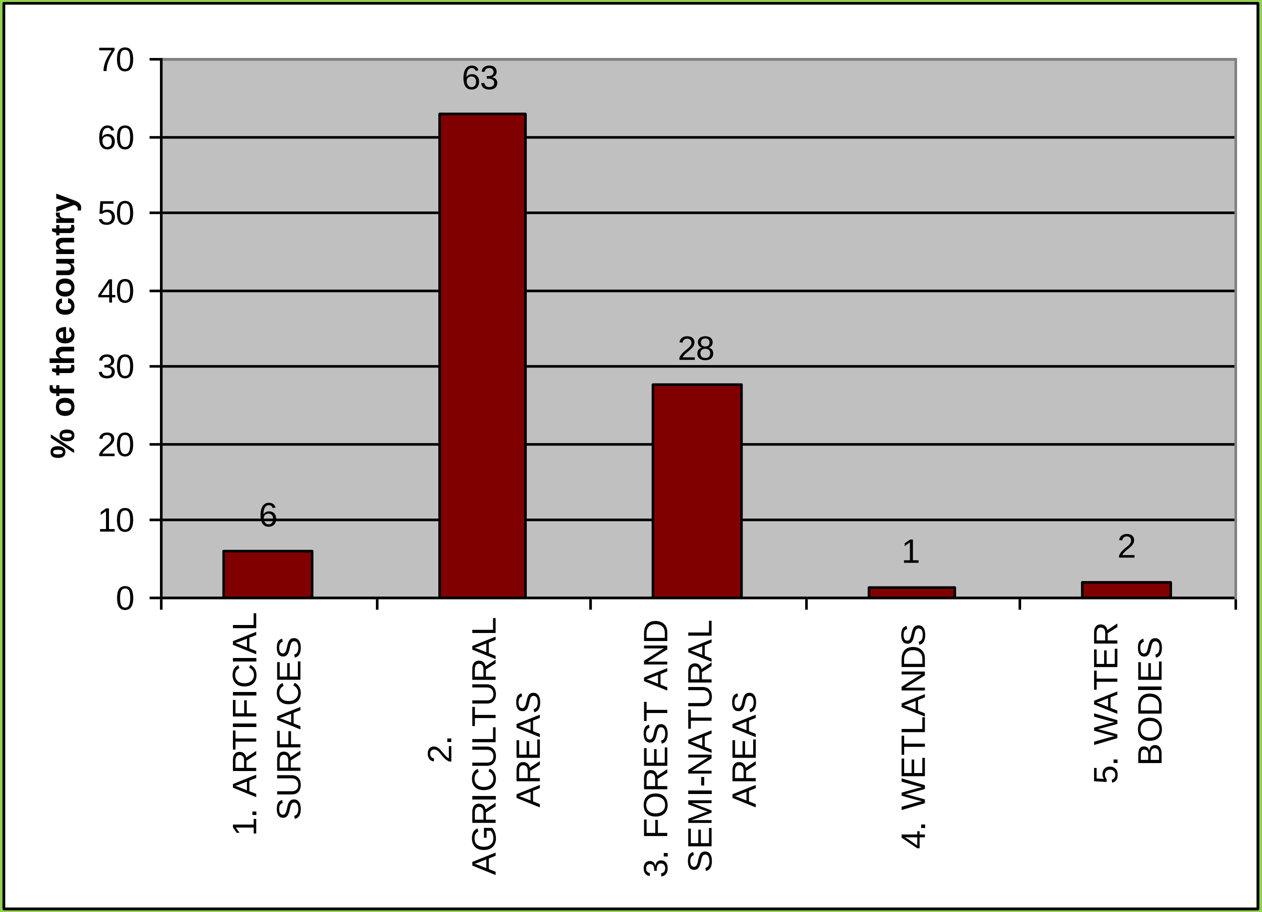
- How the agri-environmental schemes able to handle the known potential negative impacts of the CAP on the farmland biodiversity in Hungary?

Which kind of other factors (climate change, development,…etc) influence the Biodiversity ?

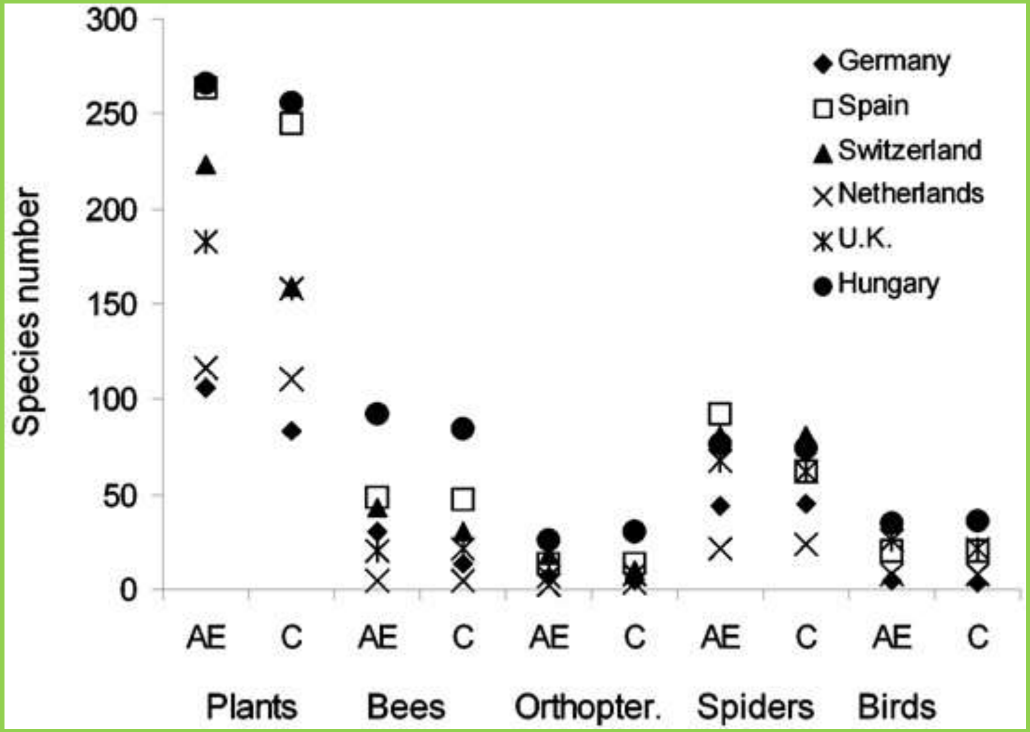
Distribution of habitats in Hungary (Corine)

94 000 sq km

~10 million people



Biodiversity of Hungarian farmland is among the highest in Europe



Detailed field investigations carried out in 2003, species richness and abundance of 10 different species groups . (AE:extensively grazed, C: intensively grazed semi-natural pastures)

Báldi, A. Batáry, P. Klein, D. 2013. Effects of grazing and biogeographic regions on grassland biodiversity in Hungary – analysing assemblages of 1200 species. *Agriculture, Ecosystems and Environment*

Monitoring of birds before 1997

- No relevant bird data from the main habitats
  - There wasn’t proper nationwide general monitoring scheme of common birds
- Bird monitoring focused on rare birds and mainly in natural habitats (Monitoring of Rare and Colonial birds, RTM)
  - Free choice selection of the studied areas
  - Not representative for the main habitats of the country
  - Limited sources for the start and running schemes

Important condition for an effective biodiversity monitoring

Need to know the answers for:

- Why ?
- What ?
- How ?

Focusing only collection of all kind of data of wild plant/animals without considering these questions during the planning could let to difficult to analyse and interpret the collected information about status of biodiversity

Biodiversity monitoring on large scale

Big challenge

- Regular data collection in large areas
- Sites of observations need to be representative for the main habitats and regions of the studied area
- **„Instrument” – the observers who can identify the species**
- Need to control factors influence the observation (date, time, weather, distance,…etc.)
- Importance of usage objective, standard methods
- Limited sources for start and long-term running

- **Only feasible by considering large number of voluntary people with proper identification skill with proper protocol for data collection, analysis and with coordination of their work!**

Challenge of biodiversity monitoring with voluntary people

- Different skill

- Enthusiastic start with often too large intensity – threat of fast „burnout”

- Continuously changing participants

- **However, committed and ready for even hard work**

- **Voluntary people can carry out field work when there is „gaps” in the sources of monitoring**

Challenge of biodiversity monitoring with voluntary people

Indispensable:

- Adequate sampling and surveying methods to the questions one want to answer with the scheme
- Easy to learn and use methods
- Monitoring center with proper staff and sources for long-term activity (in frame of NGO or GO): **tranning, coordination, information, motivation, data handling, control, analysis and feedback to the voluntary people**

- Application of proper, even less accurate sampling and survey methods ->> small bias and high accuracy because of large number of representative samples
- Less costly, but not free!, than monitoring with full time employees

https://pecbms.info/best-practice-guide/

Hungarian Common Bird Monitoring scheme since 1999

Mindennapi Madaraink Monitoringja (MMM)

Started with the help of RSPB and EBCC

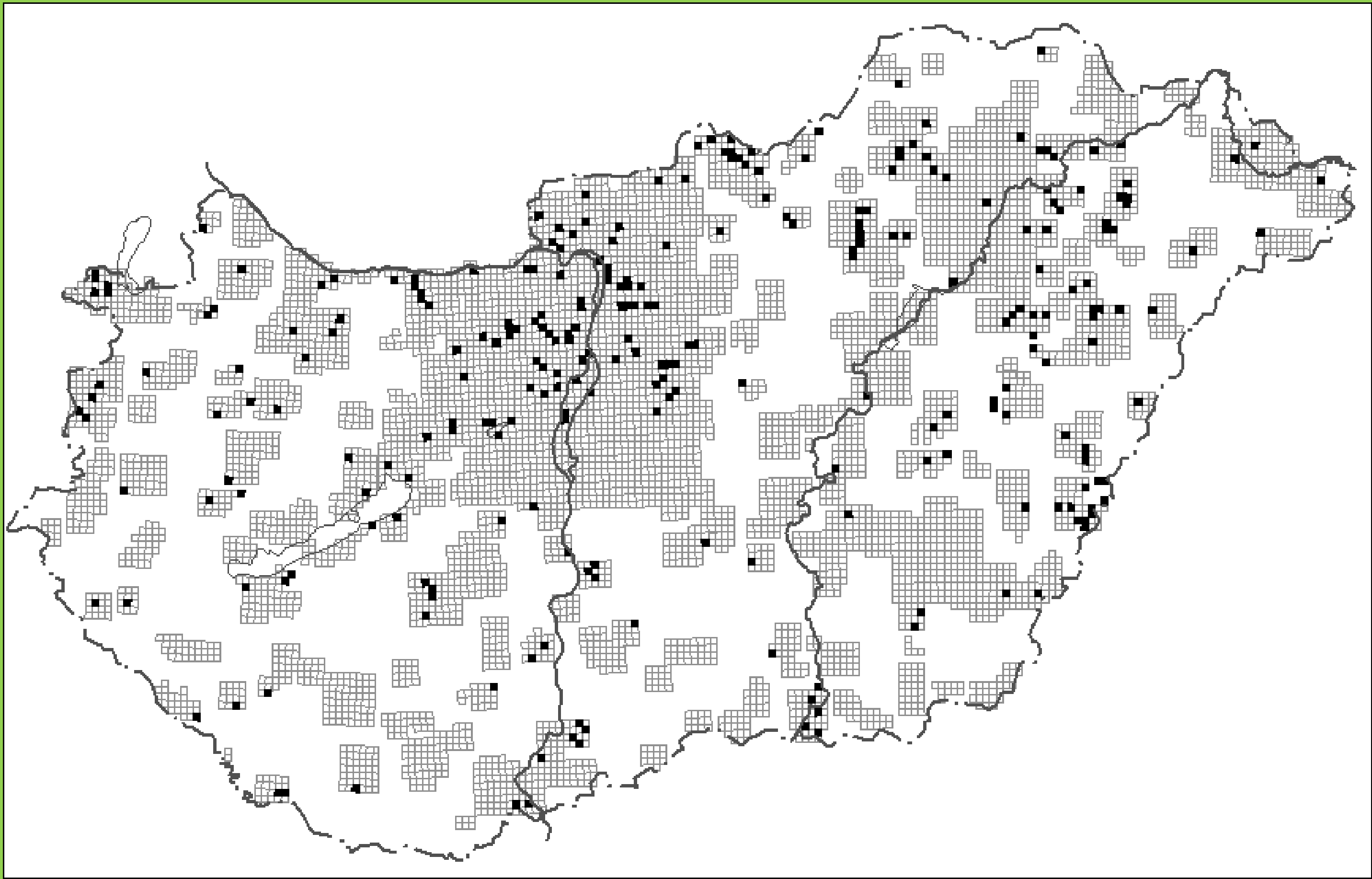
- Szép, T. and Gibbons, D. 2000. Monitoring of common breeding birds in Hungary using a randomised sampling design. The Ring 22: 45-55.

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

Sampling design

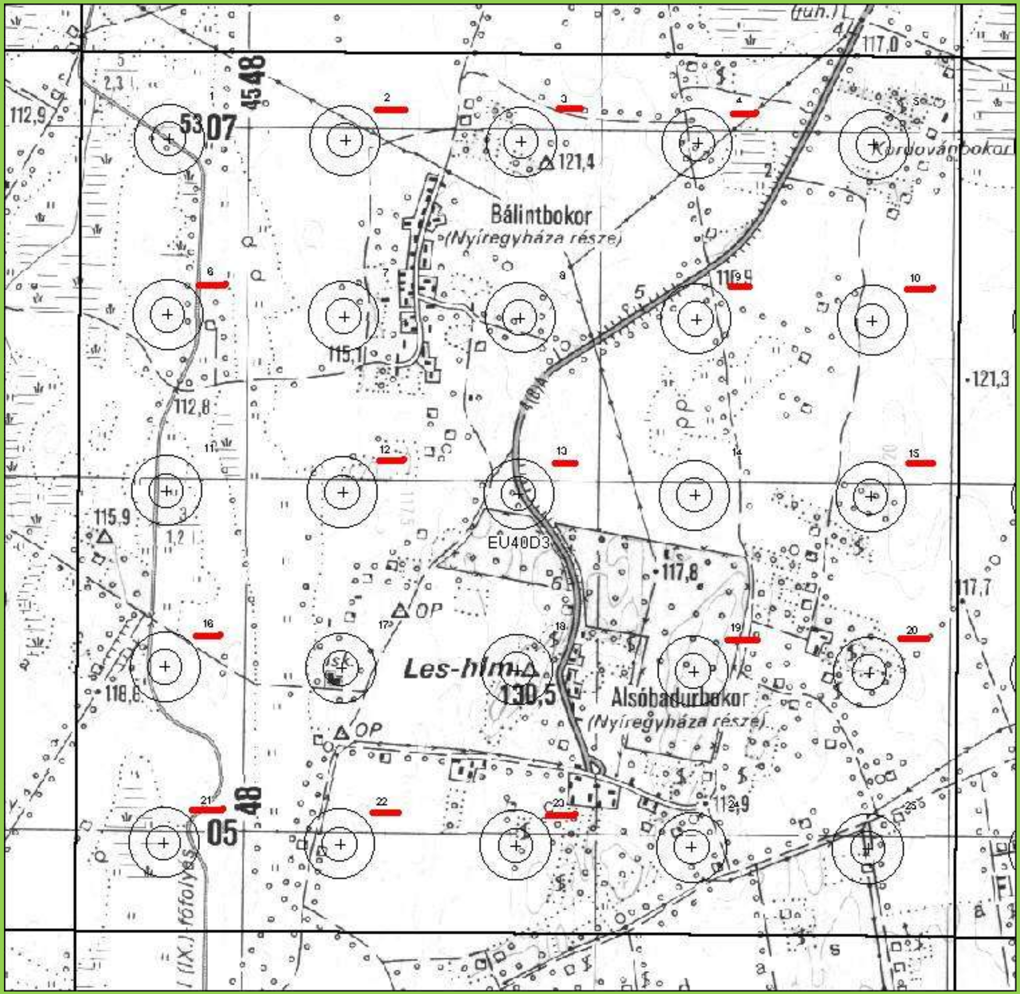
Semi-random selection of the surveyed 2.5*2.5km UTM squares

- 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



Point transect:
- 5-minute counting at all 15 points on two occasions during the breeding season
- Counts separatelly for 0-50m, 50-100m, 100-200 m areas

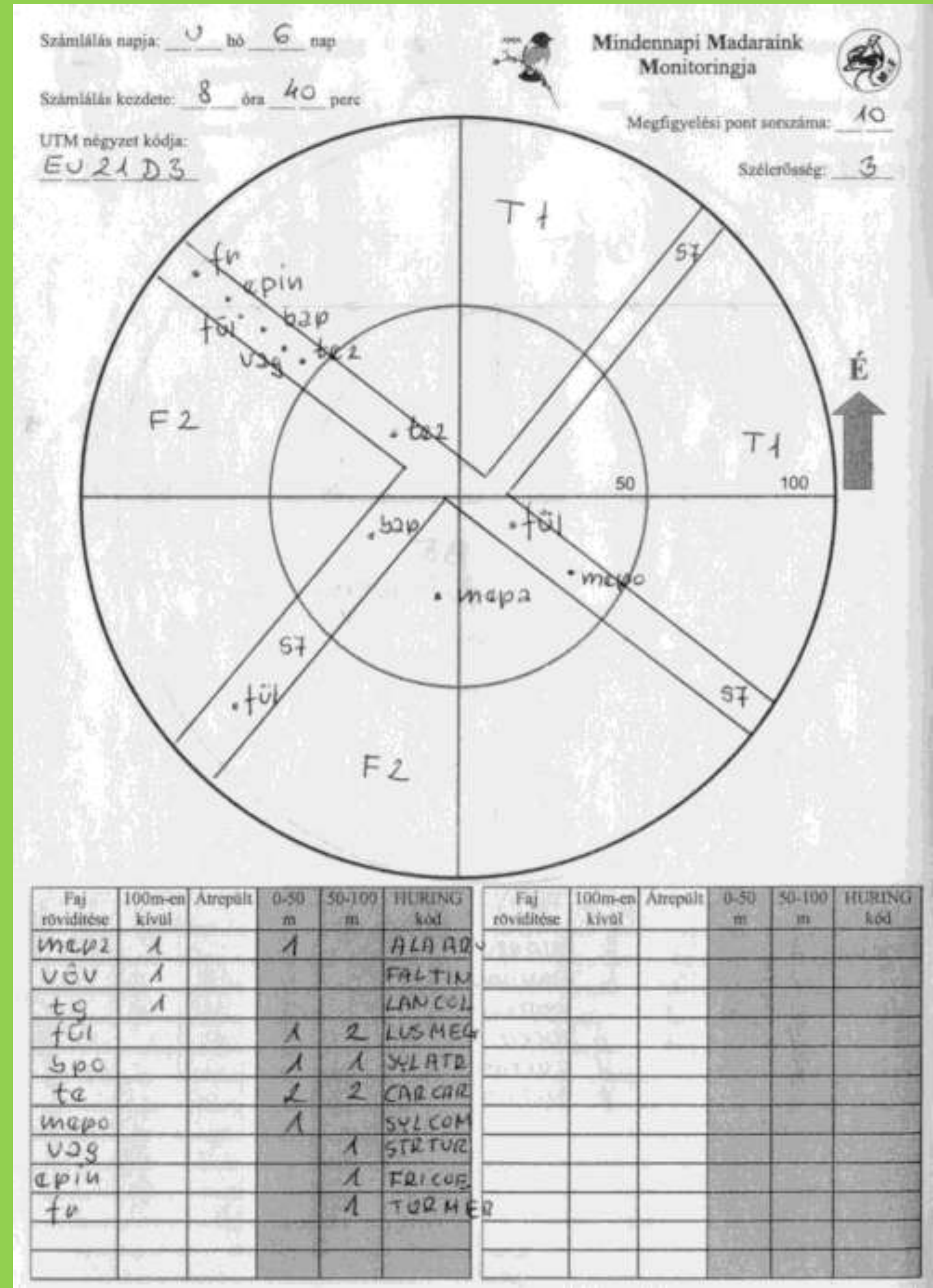
First survey: Between April 15 and May 10
Second survey: Between May 11 and June 10
A minimum of 14 days between the first and second survey

Survey conditions:
Conducted between **5:00 AM and 10:00 AM**

Wind strength between **0 and 2 on the Beaufort scale**

On **rain-free days**

The same person conducts both surveys within a year


Számlálás napja: V hó 6 nap
Számlálás kezdete: 8 óra 40 perc
UTM négyzet kódja: EU 21 D3
Mindennapi Madaraink Monitoringja
Megfigyelési pont sorszáma: 10
Szélerősség: 3

Faj rövidítése	100m-en kívül	Átrepült	0-50 m	50-100 m	HURING kód
mep2	1		1		ALA ARV
vöv	1				FAL TIN
tg	1				LAN COL
fül			1	2	LUS MEG
spo			1	1	SYL ATR
te			2	2	CAR CAR
mepo			1		SYL COM
vag				1	STR TUR
epin				1	FRI COE
fr				1	TUR MER

Faj rövidítése	100m-en kívül	Átrepült	0-50 m	50-100 m	HURING kód

Identification skill of the observers

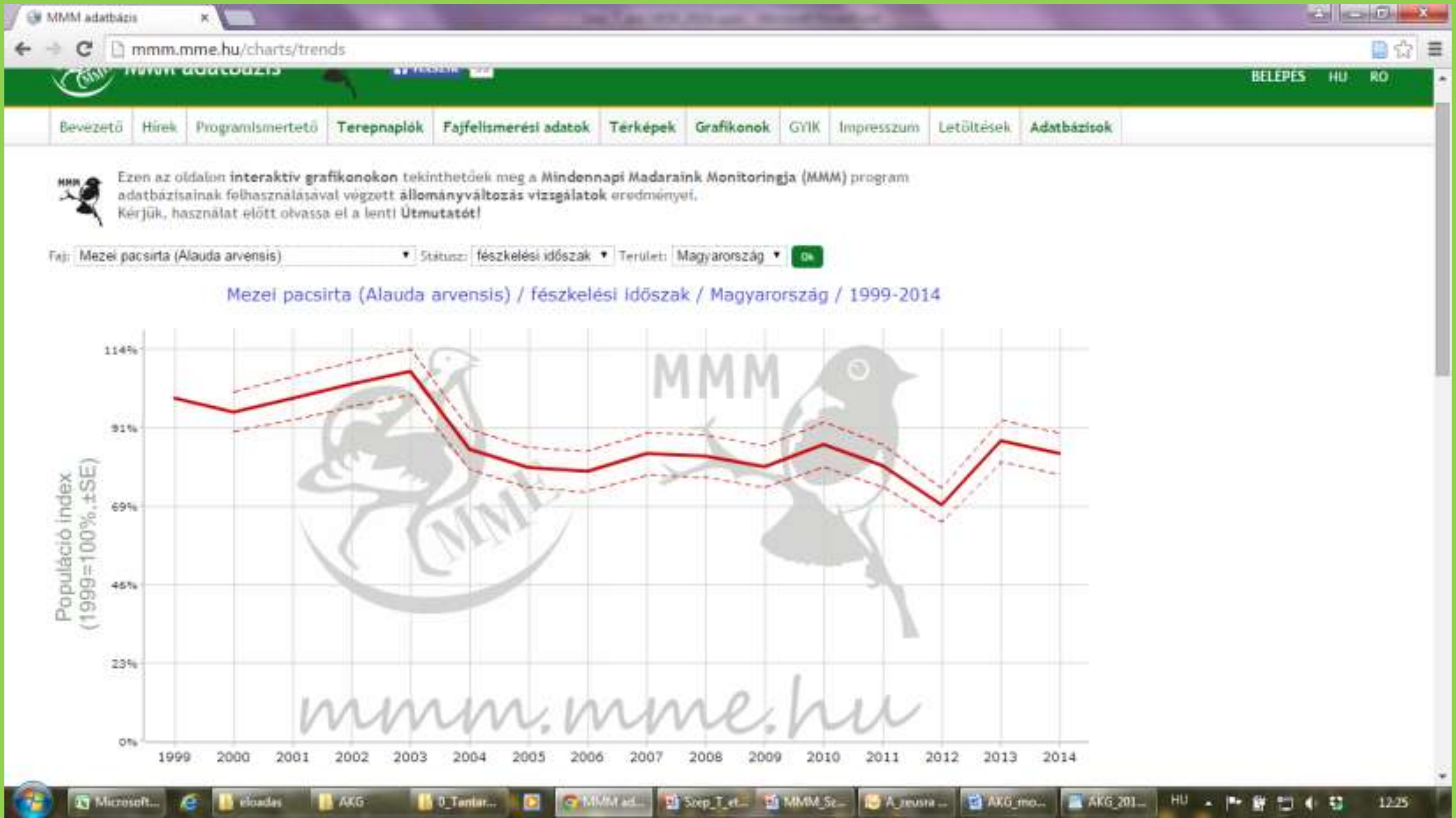
- Annual survey of the species identification skill of the observers for each species occurring in Hungary
  - „How can you identify the given species?”
    - only by view
    - only by sound
    - by view and sound
    - I’m uncertain to identify

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

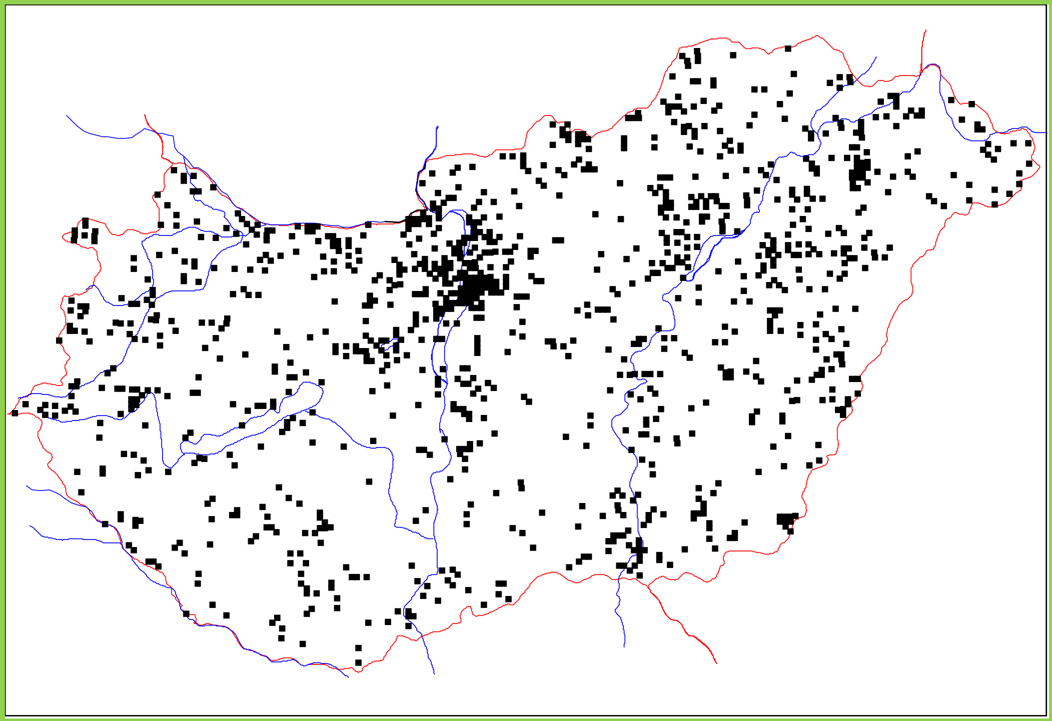
On-line database

http://mmm.mme.hu

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



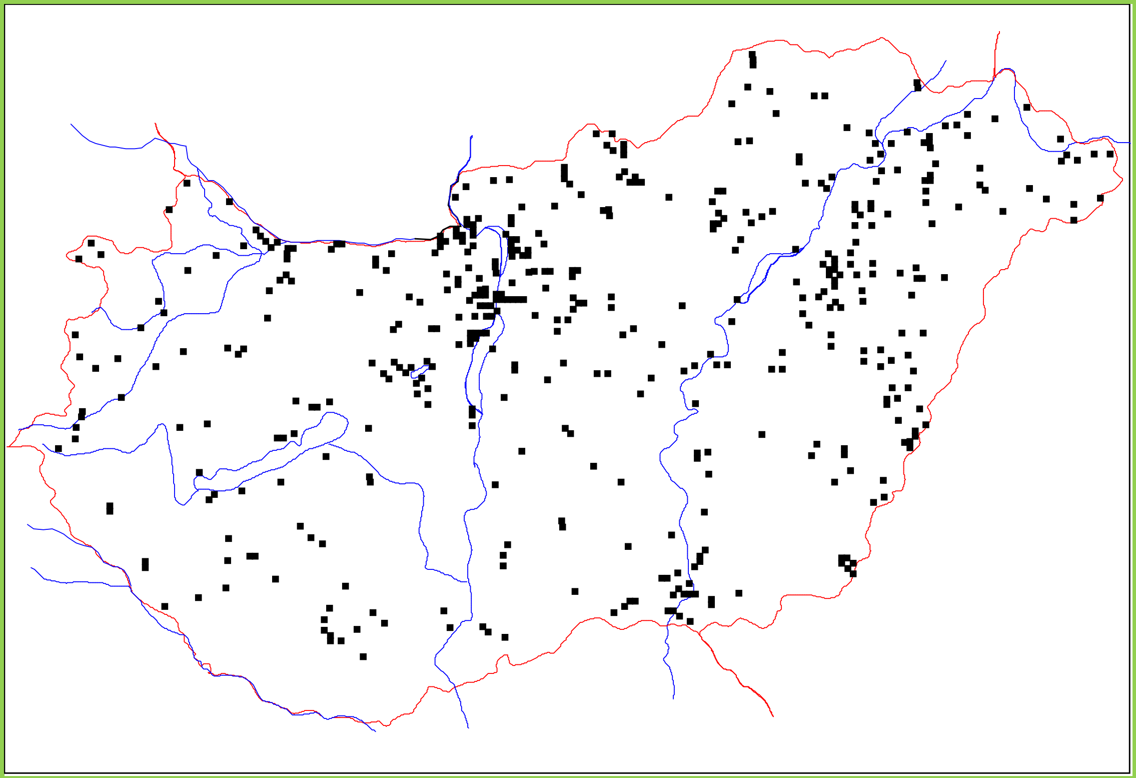
Surveyed UTM squares between 1999-2024 during the breeding season



Surveyed UTM squares

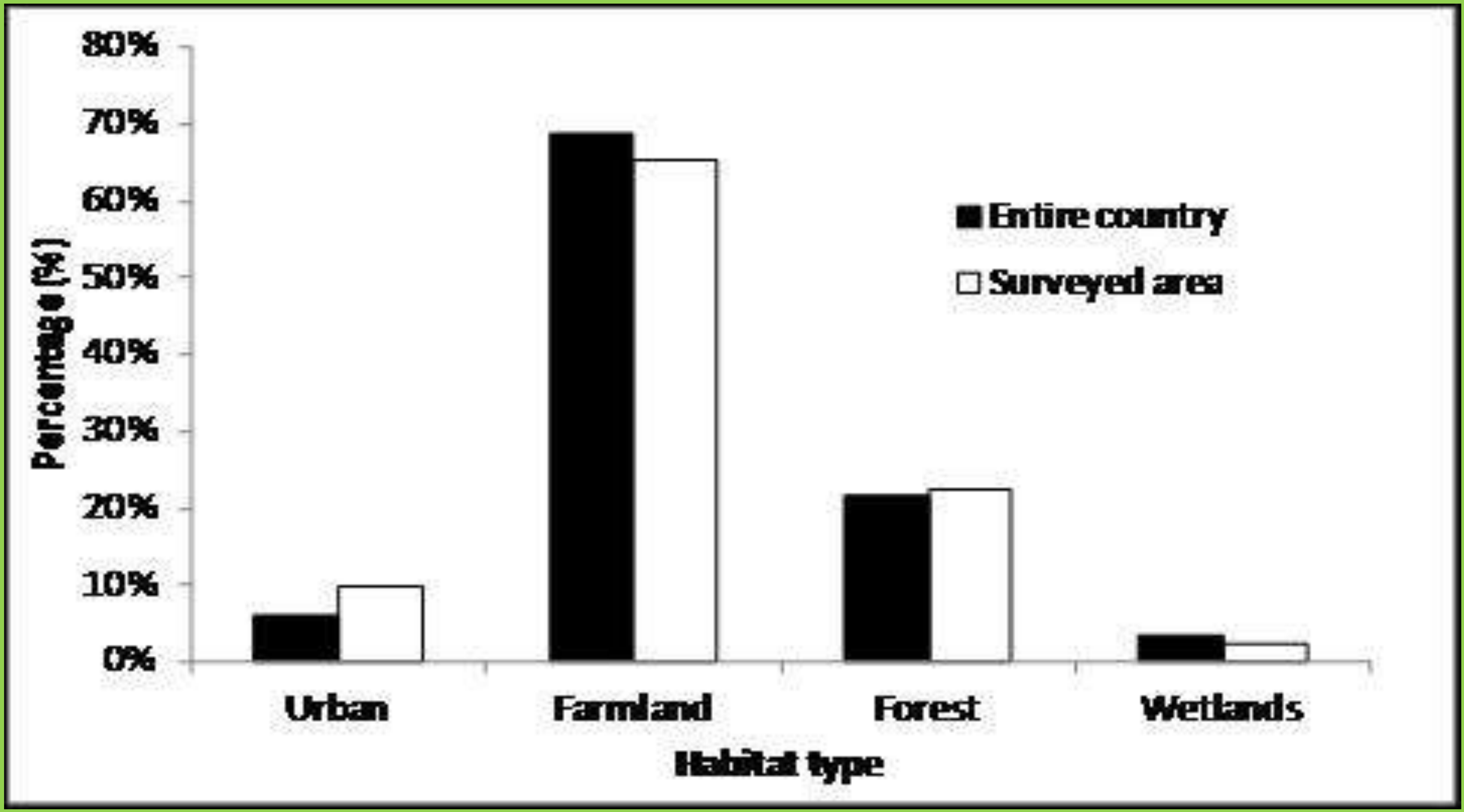
- More than 1300 squares surveyed minimum in two years
- More than 1000 participating observers
- One of the largest database on common birds in Central-Eastern Europe, based on random sampling design, ~60 million records (UTM, point, species, date, number)
- 200-300 UTM surveyed annually (~2% of the country territory)

Surveyed UTM squares between 2000-2024 during the wintering season (January)

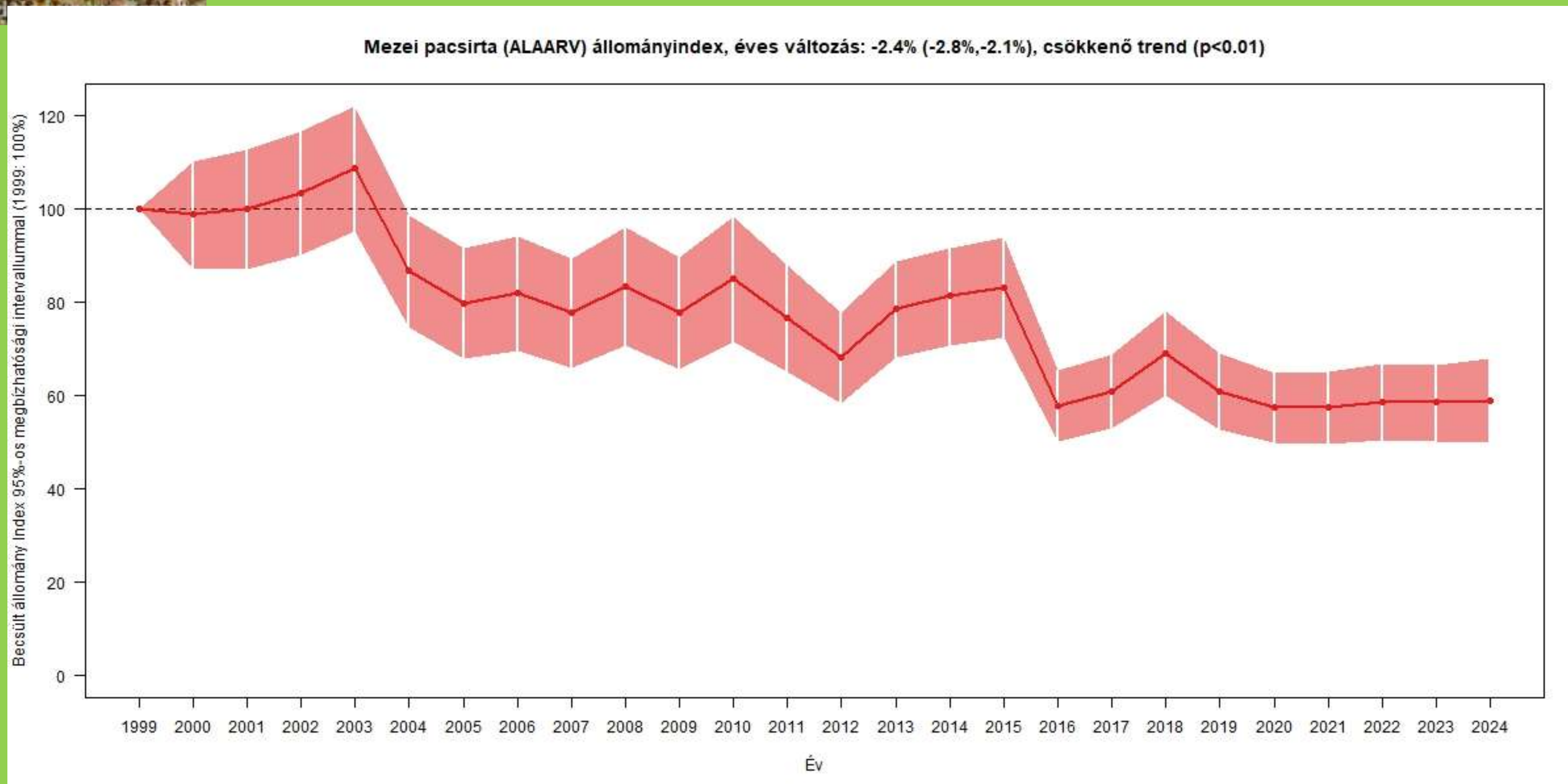


- Standard survey during the wintering season for monitoring occurence and abundance of species
- Use of similar field protocol as during the breeding season (but: only one visit in January, during daylight period)

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



Size of the country: 93 000 km^2

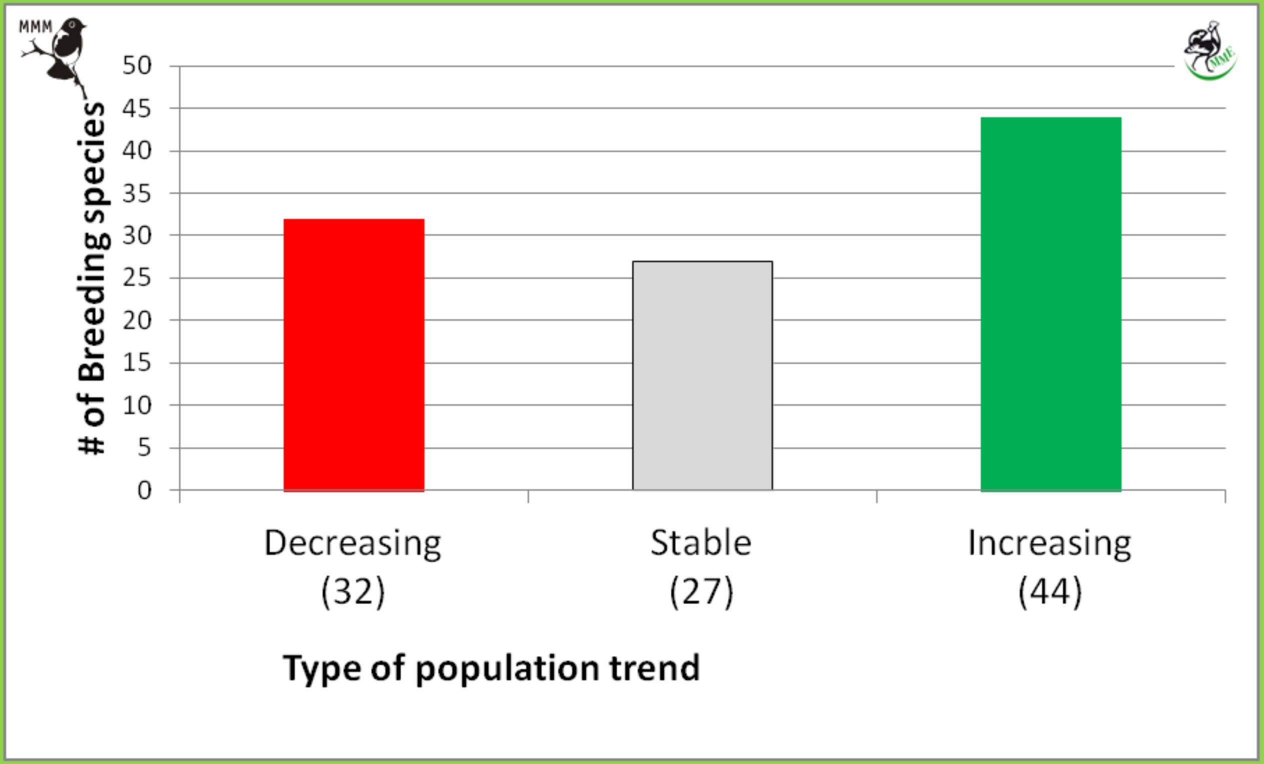


Population index (1999:100%)

Skylark (Alauda arvensis)
Change 1999-2024: -46% (min: -41%, max: -51%)*
Change 2013-2024: -29% (min: -26%, max: -40%)*

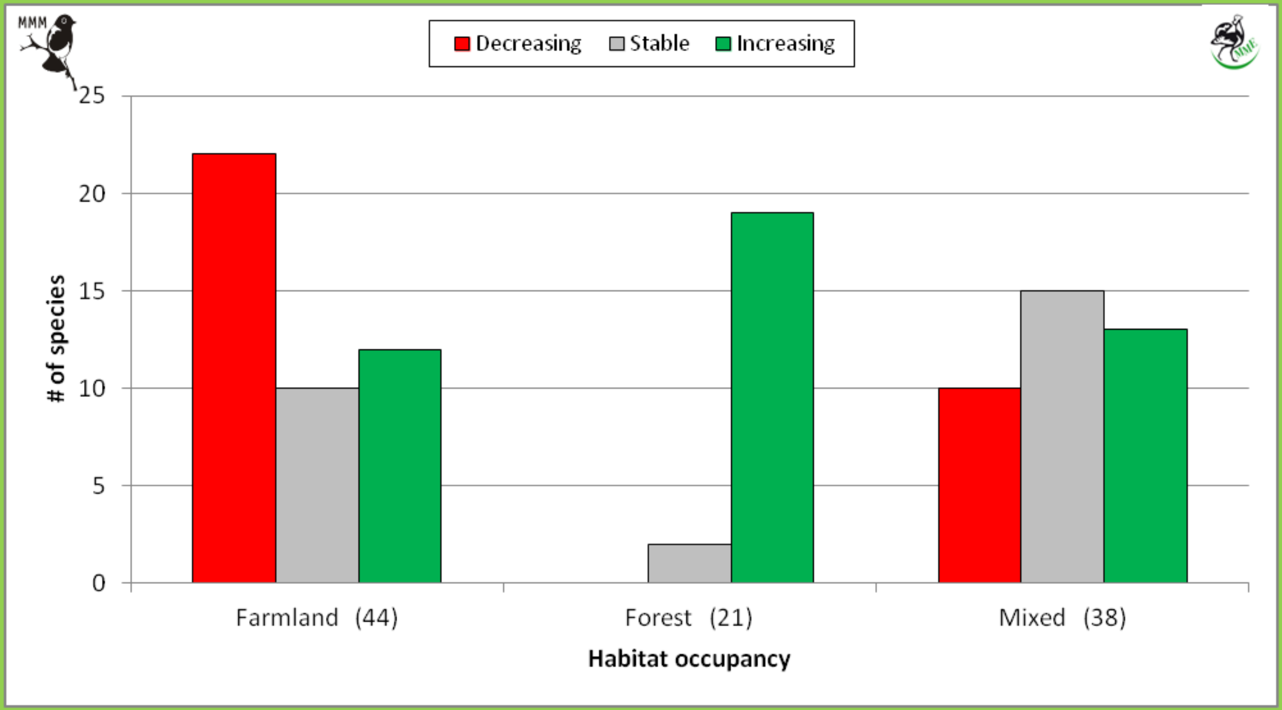
Year

Mindennapi Madaraink Monitoringja (MMM), 1999-2024



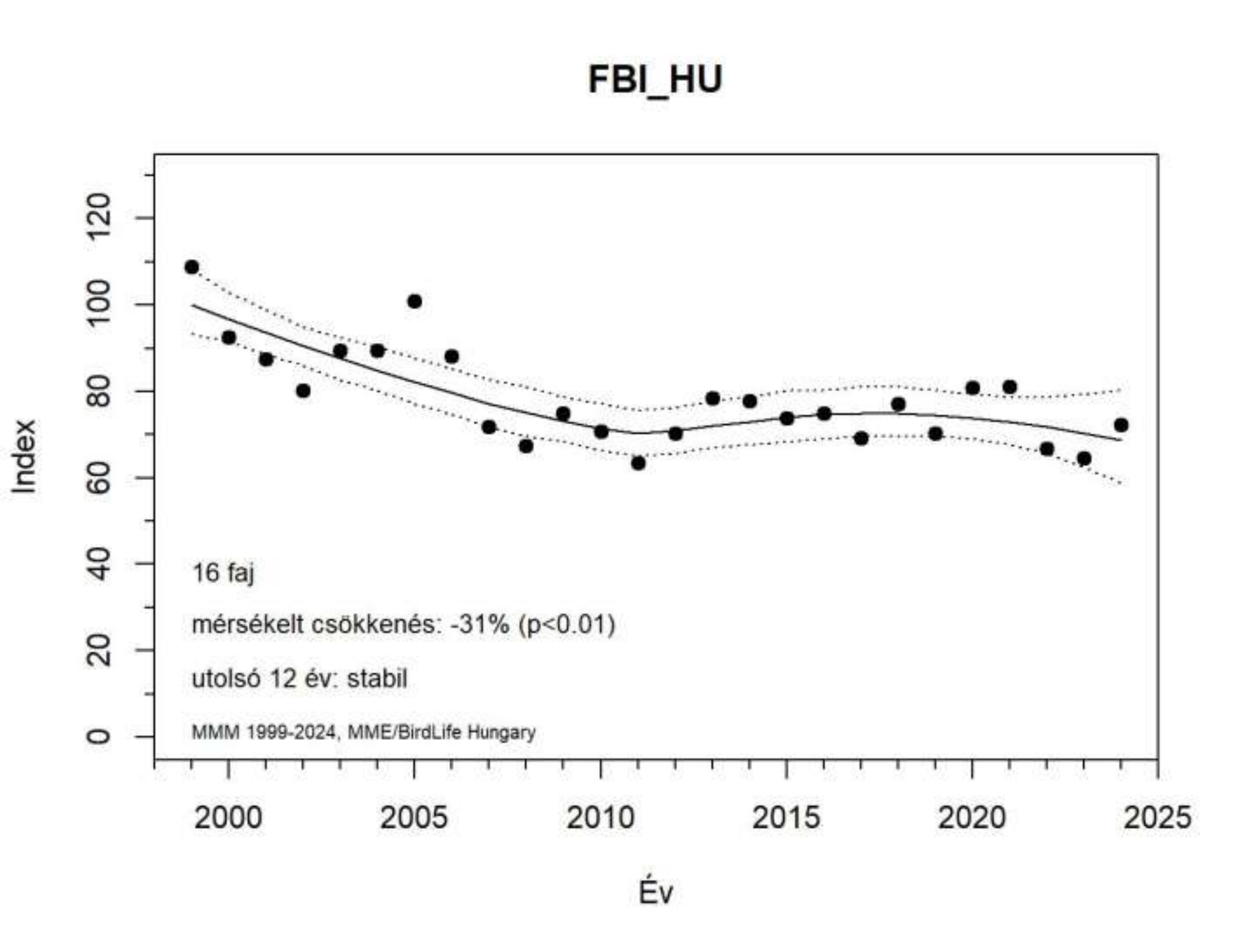
The population trend is known for 103 domestic breeding bird species (49% of the 211 domestic breeding species) between 1999 and 2024.

Species using agricultural habitats – Showing the most decline between 1999 and 2024.

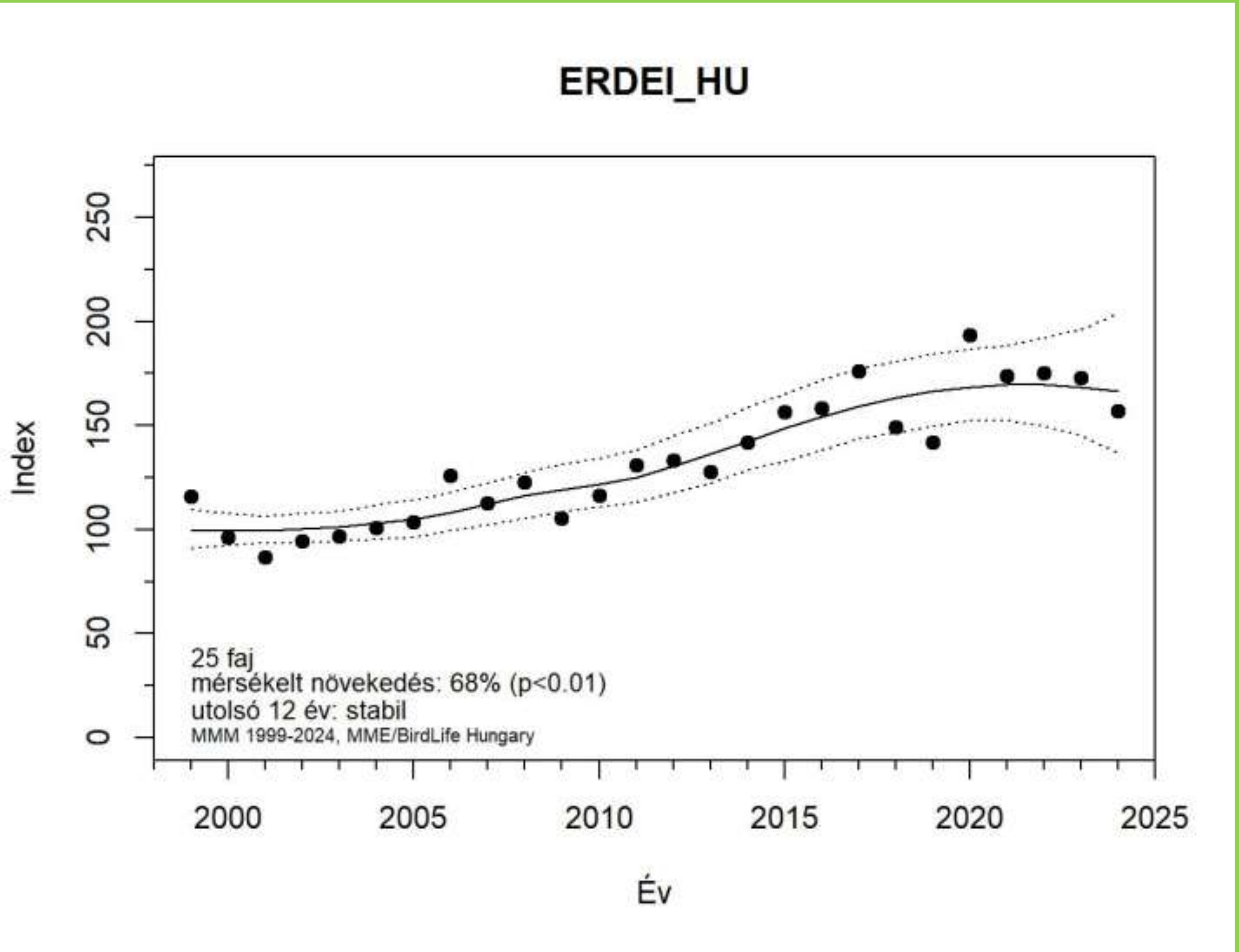


1999-2024

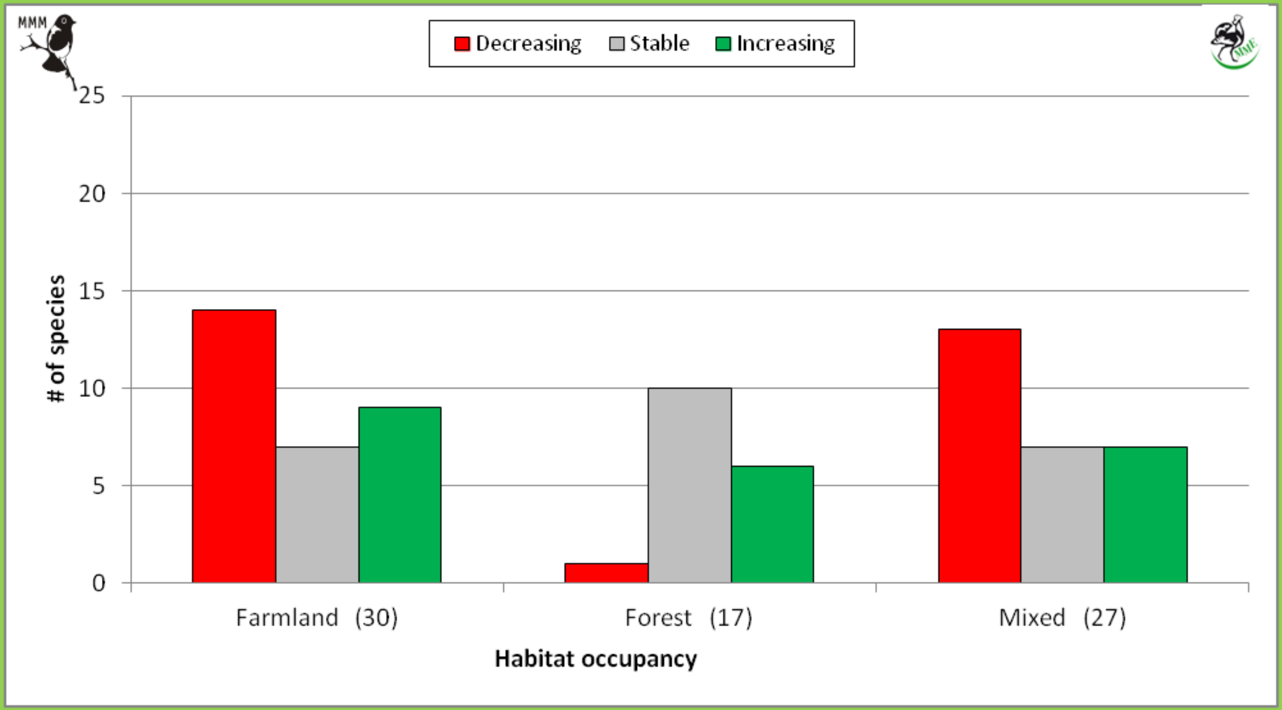
The population of bird species associated with agricultural habitats has decreased by approximately 31% over the past 26 years, but it remained stable during the 2013-2023 period.



The population of bird species associated with forest habitats has increased by approximately 68% over the past 26 years, but it has remained stable during the 2013-2024 period.



Between 2013 and 2024, the decline is no longer limited to species characteristic of agricultural habitats.



2013-2024

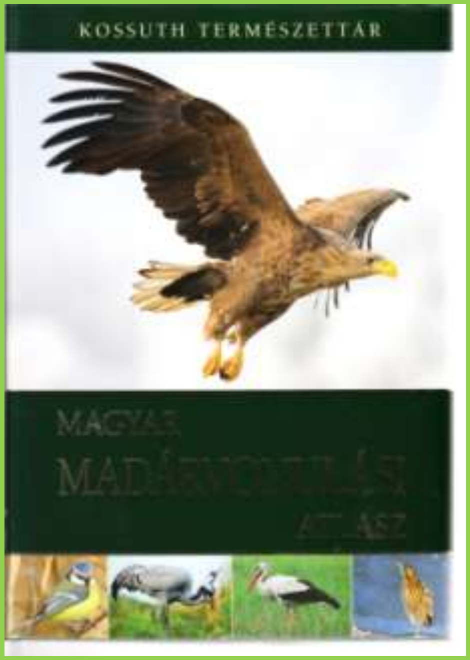
Classification species on migration strategy

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

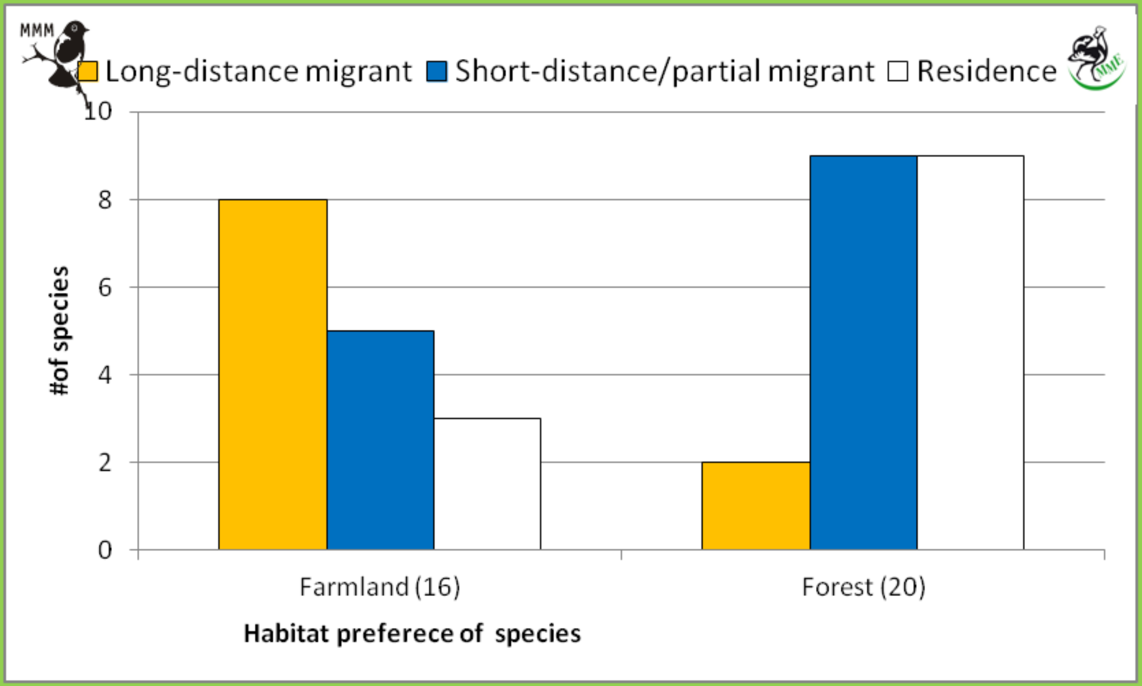
– Resident – spend entire year in the breeding area

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

– Long-distance migrants – migrate over the Sahara

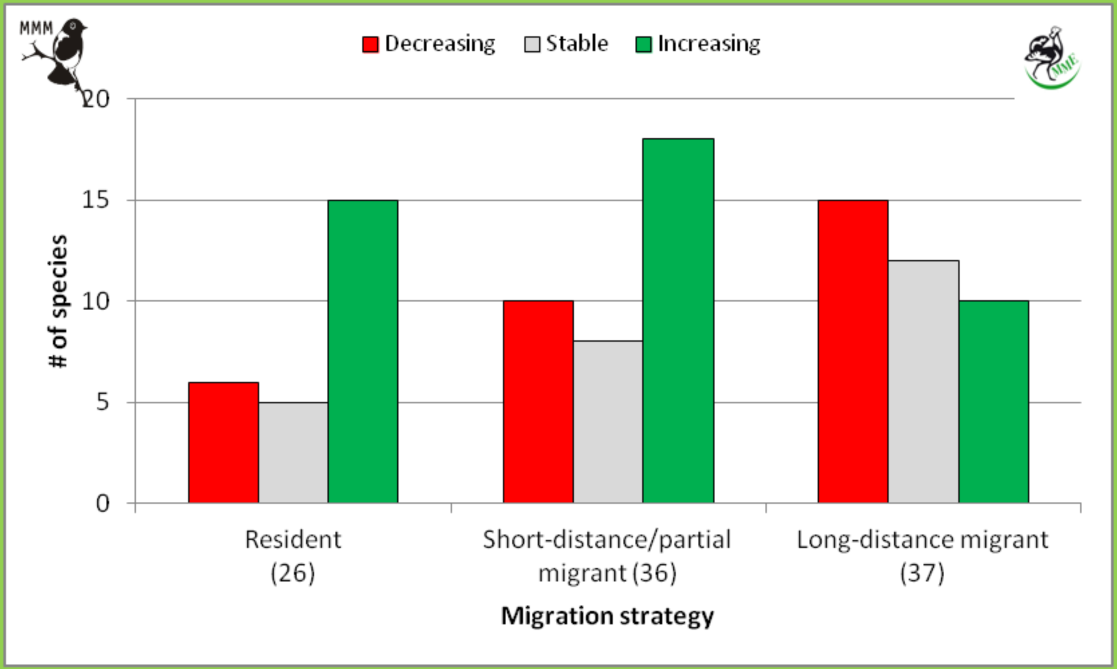


Significant difference in the migration characteristics of species associated with agricultural and forest habitats.



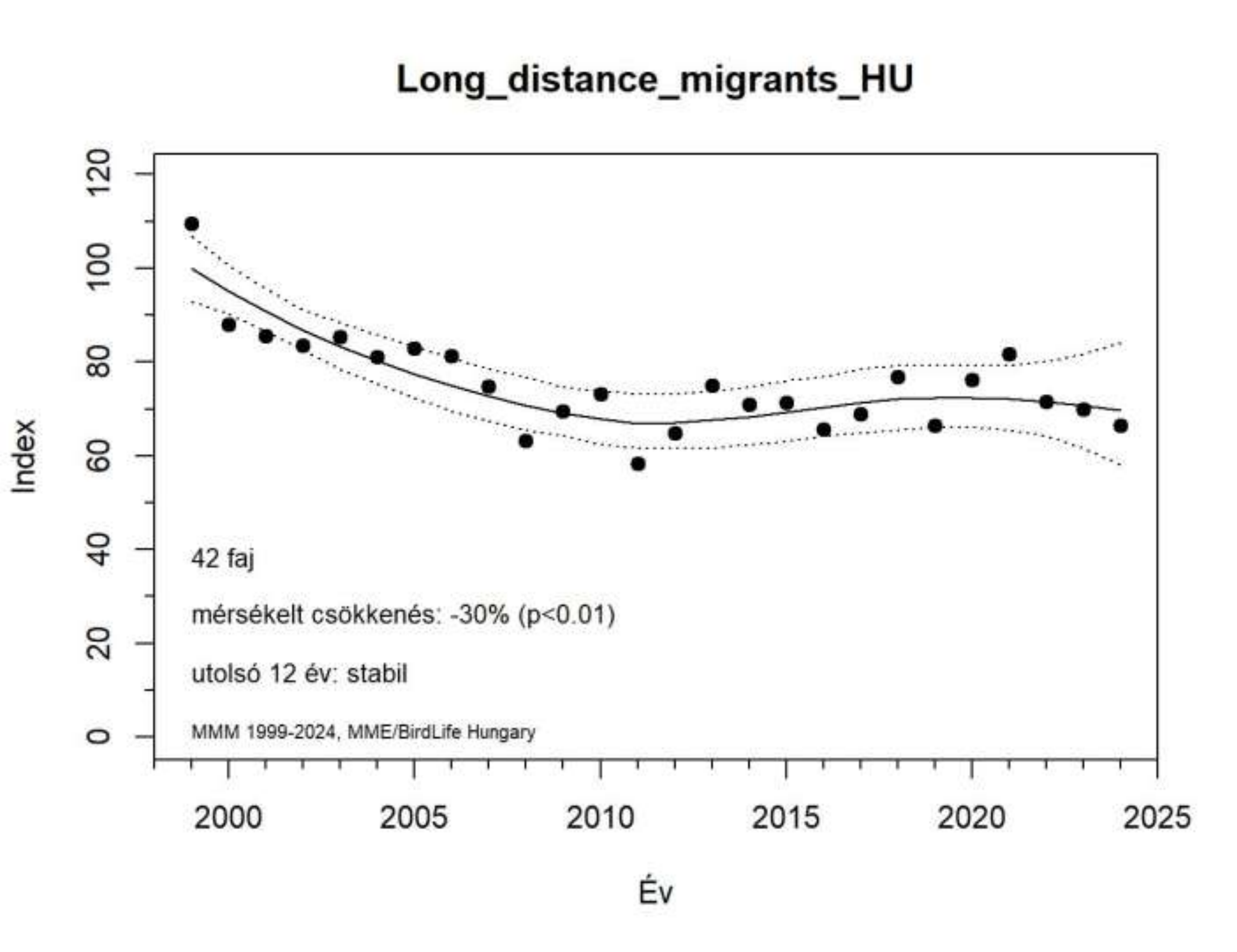
Among the species associated with agricultural habitats, there are more long-distance migrants

Long-distance migratory species – showing the greatest decline between 1999 and 2024

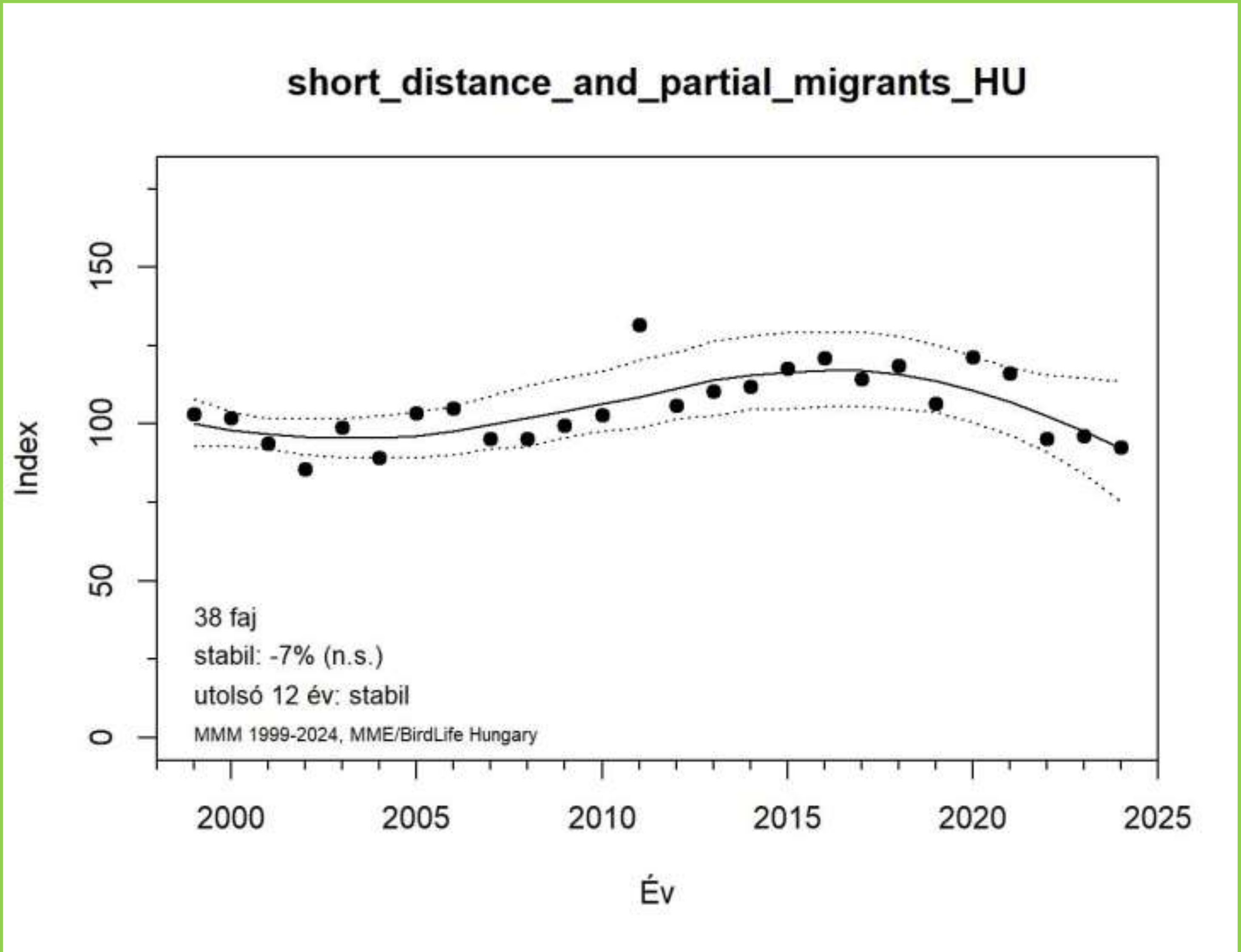


Migration strategy and breeding population trend types in Hungary from 1999 to 2024

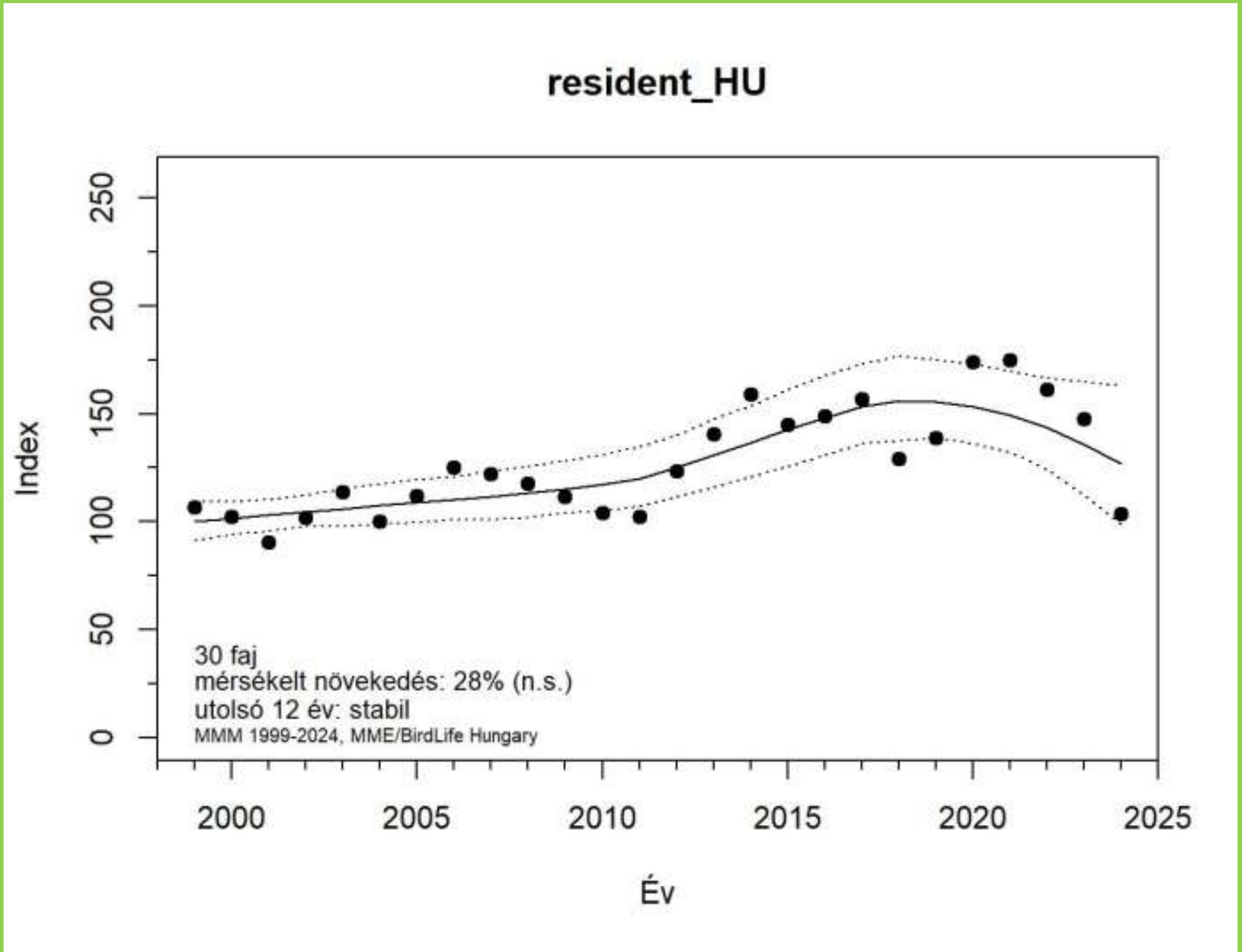
The population of long-distance migratory bird species has decreased by approximately 30% over the past 26 years, but it remained stable during the 2013-2024 period



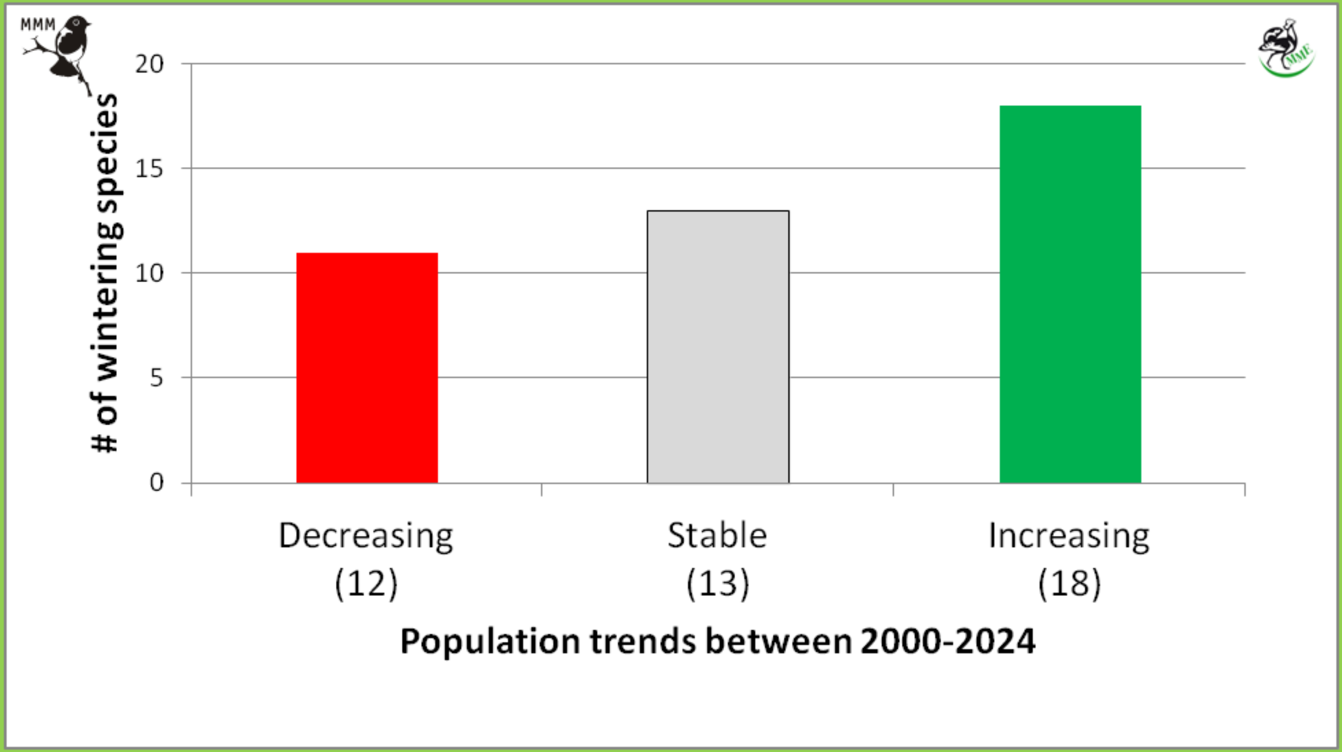
The population of short-distance migratory bird species may have slightly increased until around 2015, but it remained stable during the 2013-2024 period.



The population of resident bird species has increased by approximately 28% over the past 26 years, but it remained stable during the 2013-2024 period

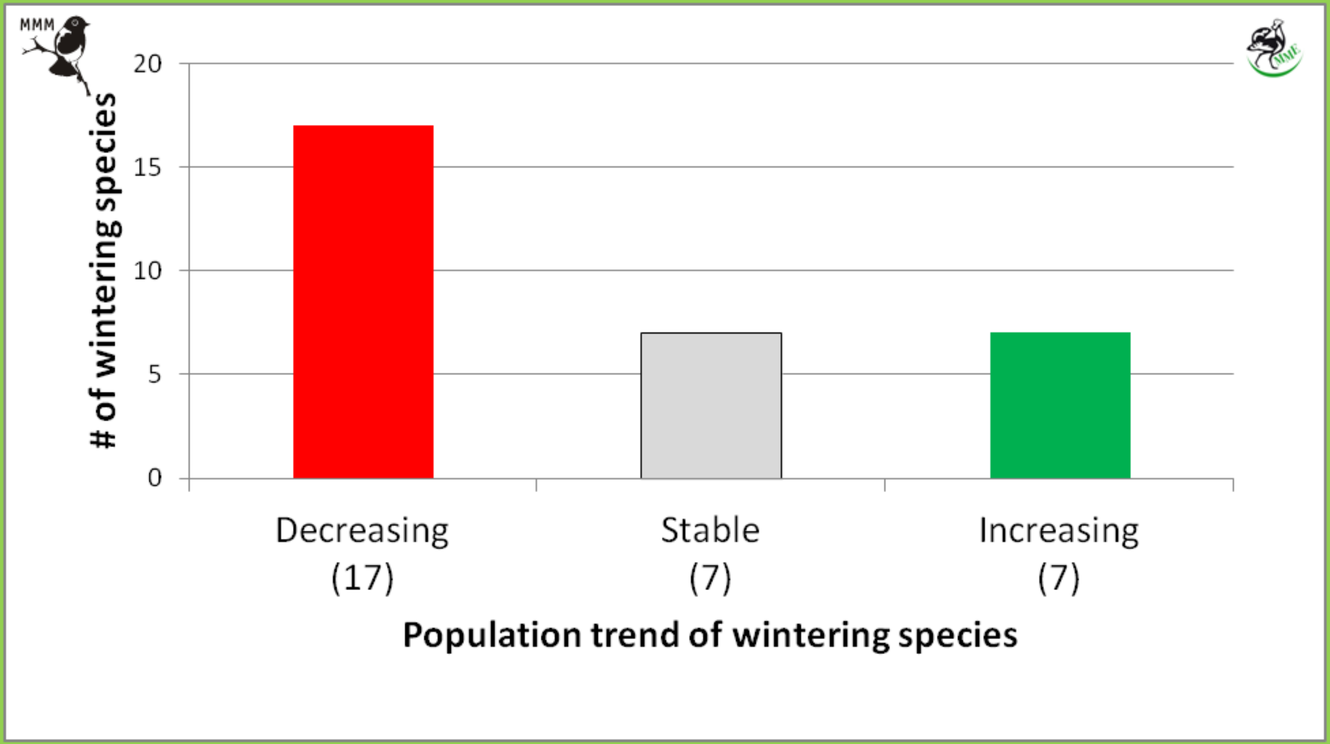


The majority of species wintering in our country have shown an increase between 2000 and 2024.More growing populations – More favorable wintering conditions



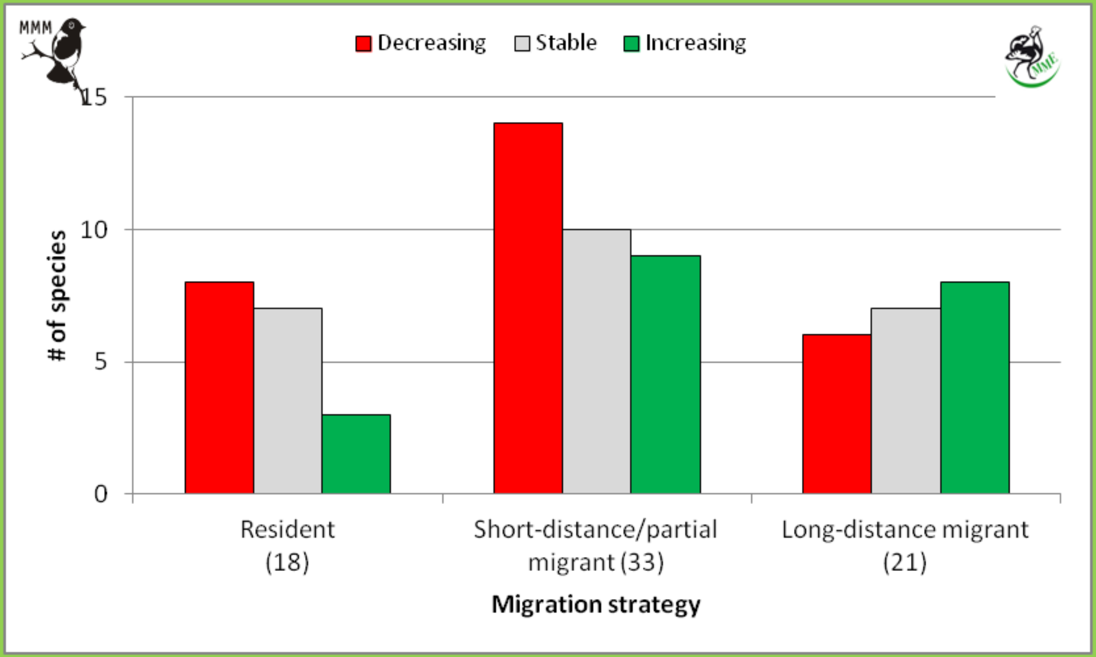
2000-2024

The majority of species wintering in our country have already shown a decline between 2013 and 2024.Decline in resident/wintering (?) populations



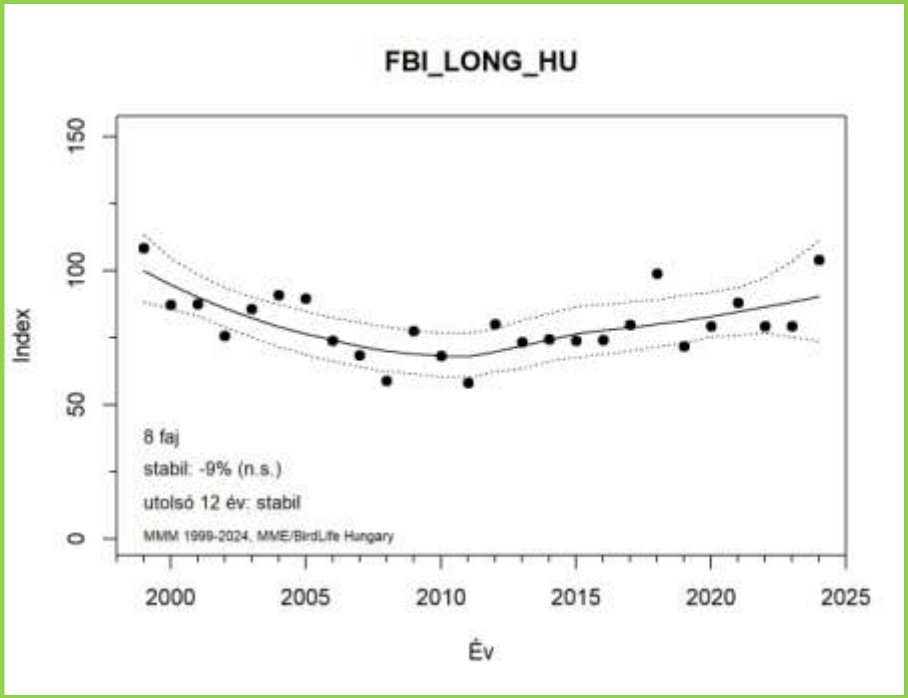
2013-2024

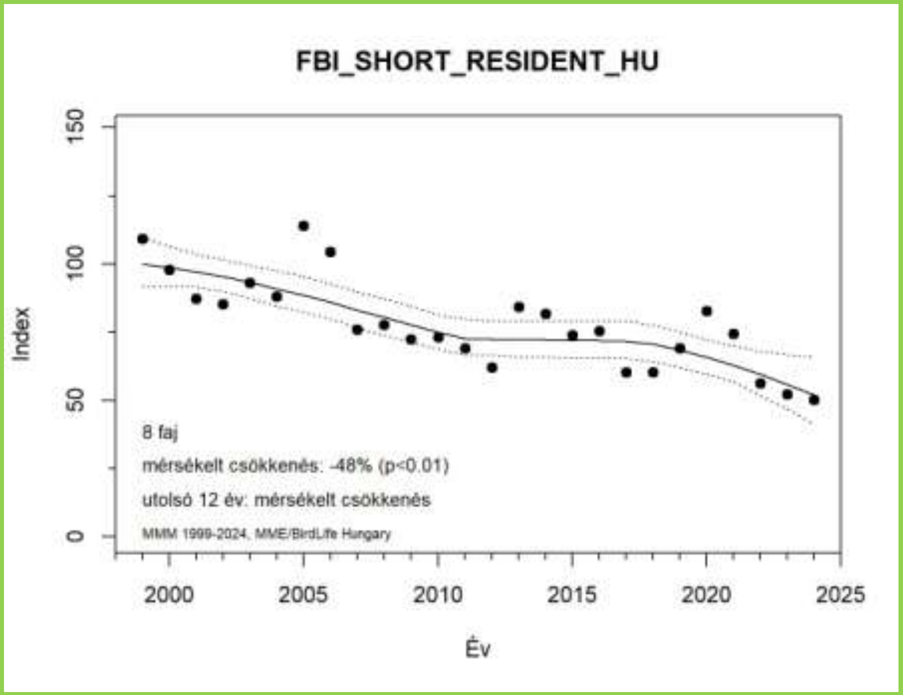
Between 2013 and 2024, the species showing a decline are mainly no longer the long-distance migrants



Migration strategy and breeding population trend types in Hungary from 2013 to 2024

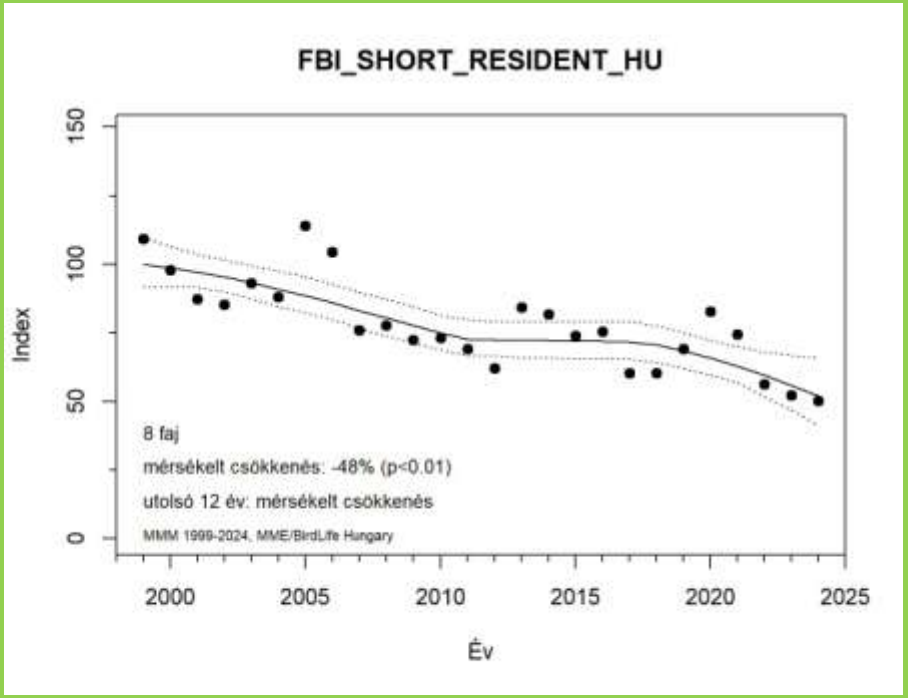
Among the bird species associated with agricultural habitats (FBI), the populations of short-distance migrants/residents have decreased by approximately 48% over the past 26 and 12 years, in contrast to the long-distance migrants.



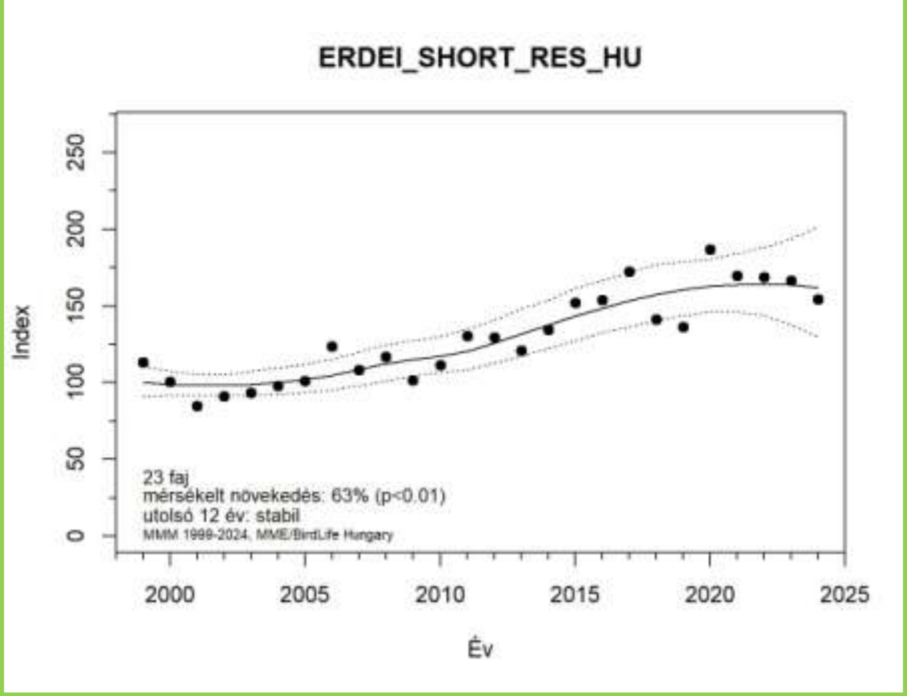


a- long-distance migrants *b- short-distance/residens*

The populations of short-distance migrants and residents have only decreased in bird species associated with agricultural habitats (FBI), in contrast to those using forest habitats, where the population has increased by approximately 63% over the past 26 years

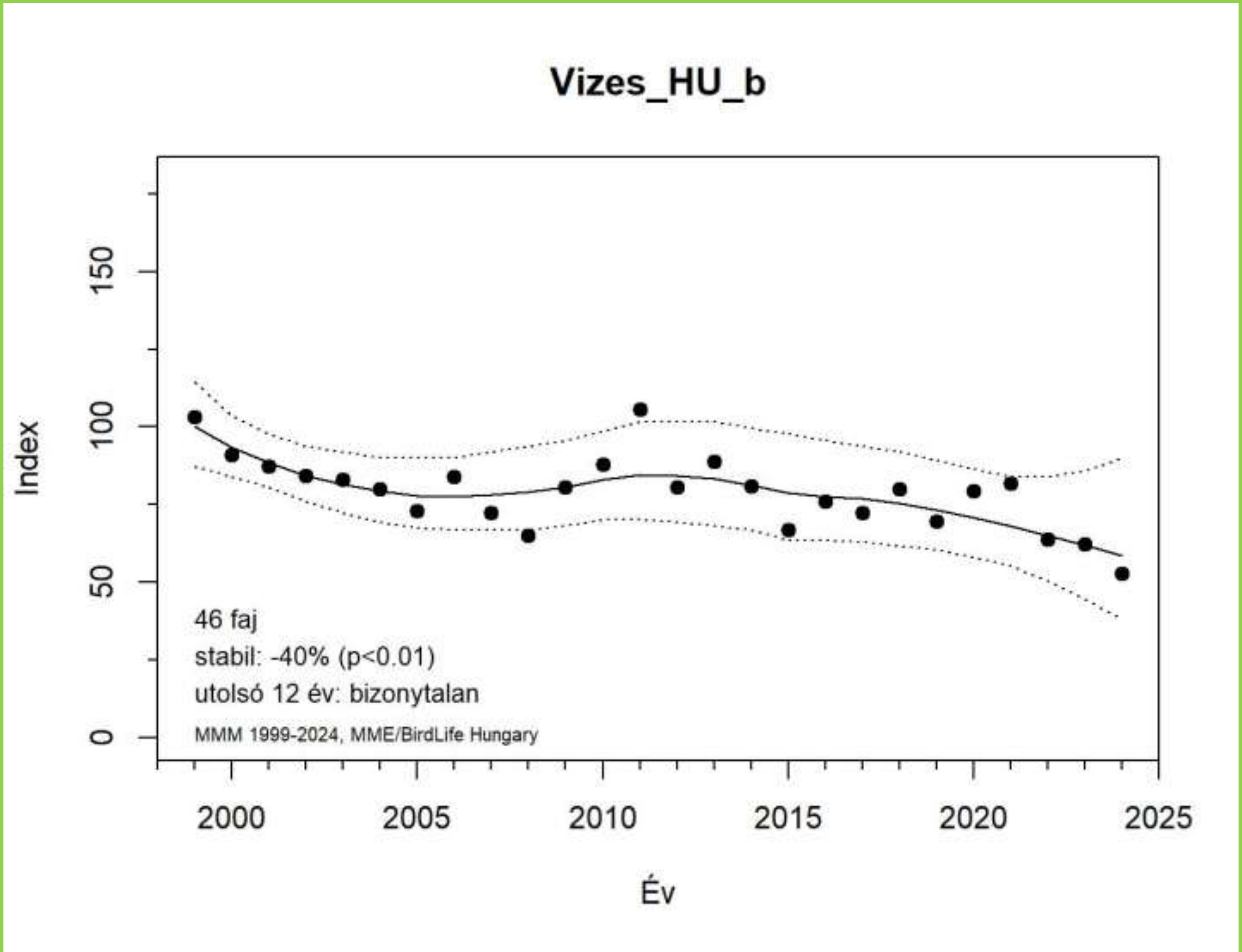


a- Agriculture habitats



b- Forest habitats

The population of species preferring wetland habitats has decreased by approximately 40% over the past 26 years, with an uncertain trend observed during the 2014-2023 period



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

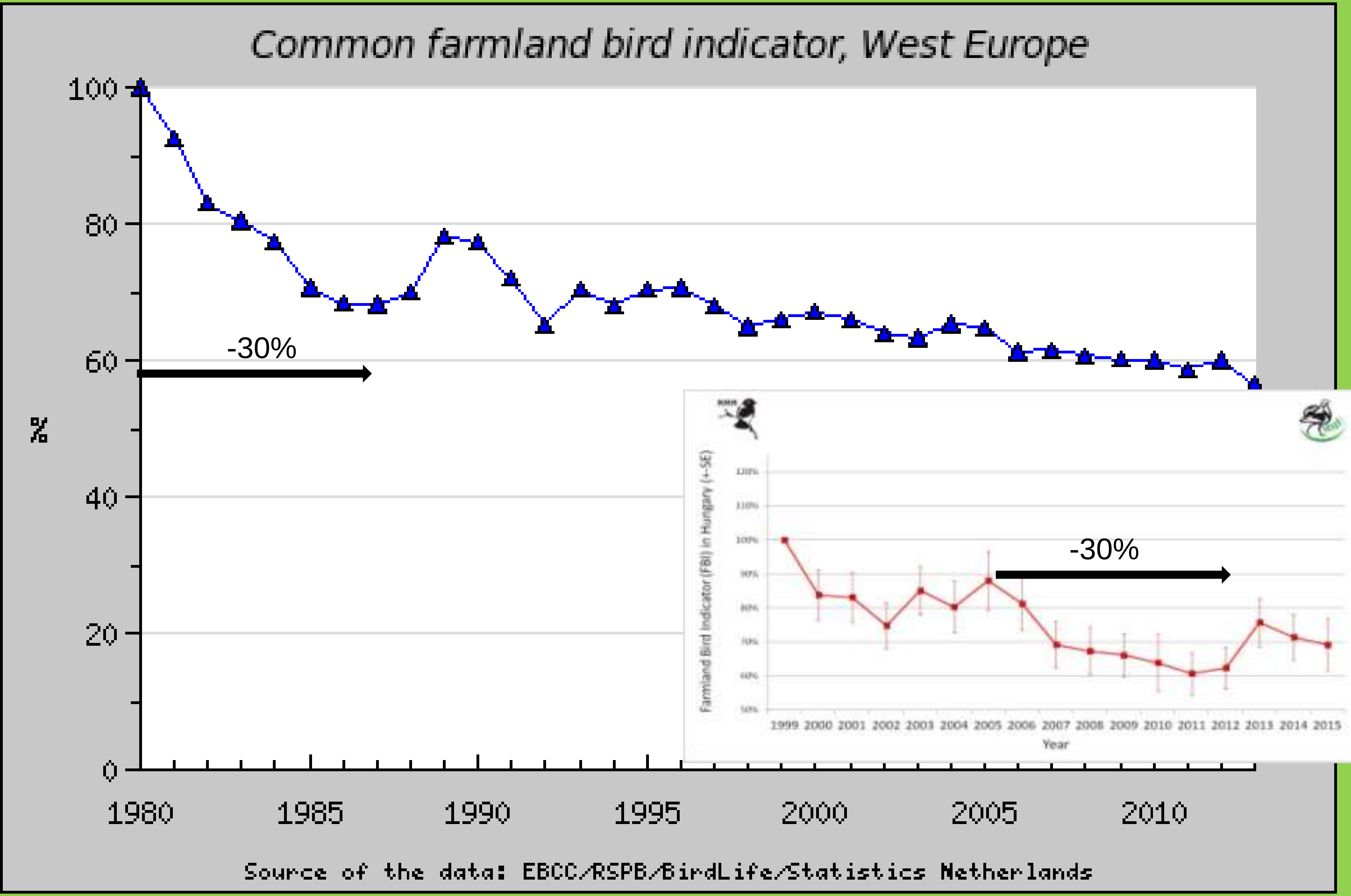
- Farmland biodiversity show marked decline since EU CAP has implemented in Hungary!

- 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

FBI in Western Europe and in Hungary



Decline of FBI in Hungary during 7 years (2005-2012) since join to EU is similar to the level of decline in Western Europe during 7 years following start of CAP (1980-1987)!

Option to detect the effects of the agri-environmental schemes (AES) using farmland bird indicator (FBI) on the scale of the country

- Proper population data from the surveyed 1009 pieces UTM squares before and after the start the CAP (2004) in Hungary

- Opportunity to identify the surveyed farmland UTM squares on the base of CORINE landcover database

- Opportunity to measure coverage of AES in each surveyed farmland UTM squares

- Opportunity to estimate population trends of farmland species and FBI for groups of farmland UTM squares with similar AES coverage

  - Opportunity to compare large scale trends of FBI in farmland areas with different AES coverage

Agri-environmental schemes (AES) in Hungary

Existing 19 AES grouped in four types on the base of the main type of farmland habitats it run:

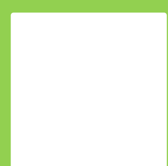
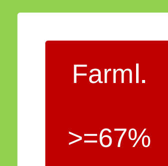
- Arable related AES
- Grassland related AES
- Fruit and grape related AES
- Reedbeds related

How the coverage of AES influence the FBI in farmland areas Hungary during 1999-2014?

We considered the **591** pieces of 2.5*2.5 km UTM squares (UTM)

• monitored with standard protocol of MMM during 1999-2014 at least in two years (Σ 1003 pieces)

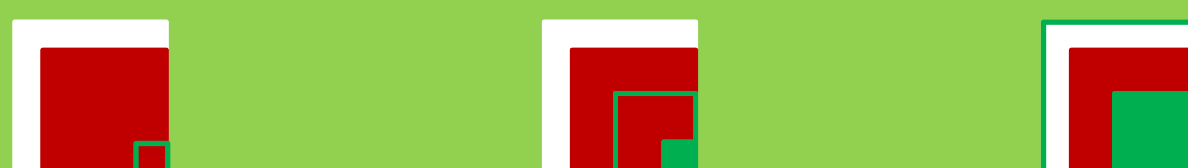
• dominant part of the UTM area (>66.6%) covered with farmland habitats,on the base CORINE CLC50

1003 pc. UTM  ====>>> 

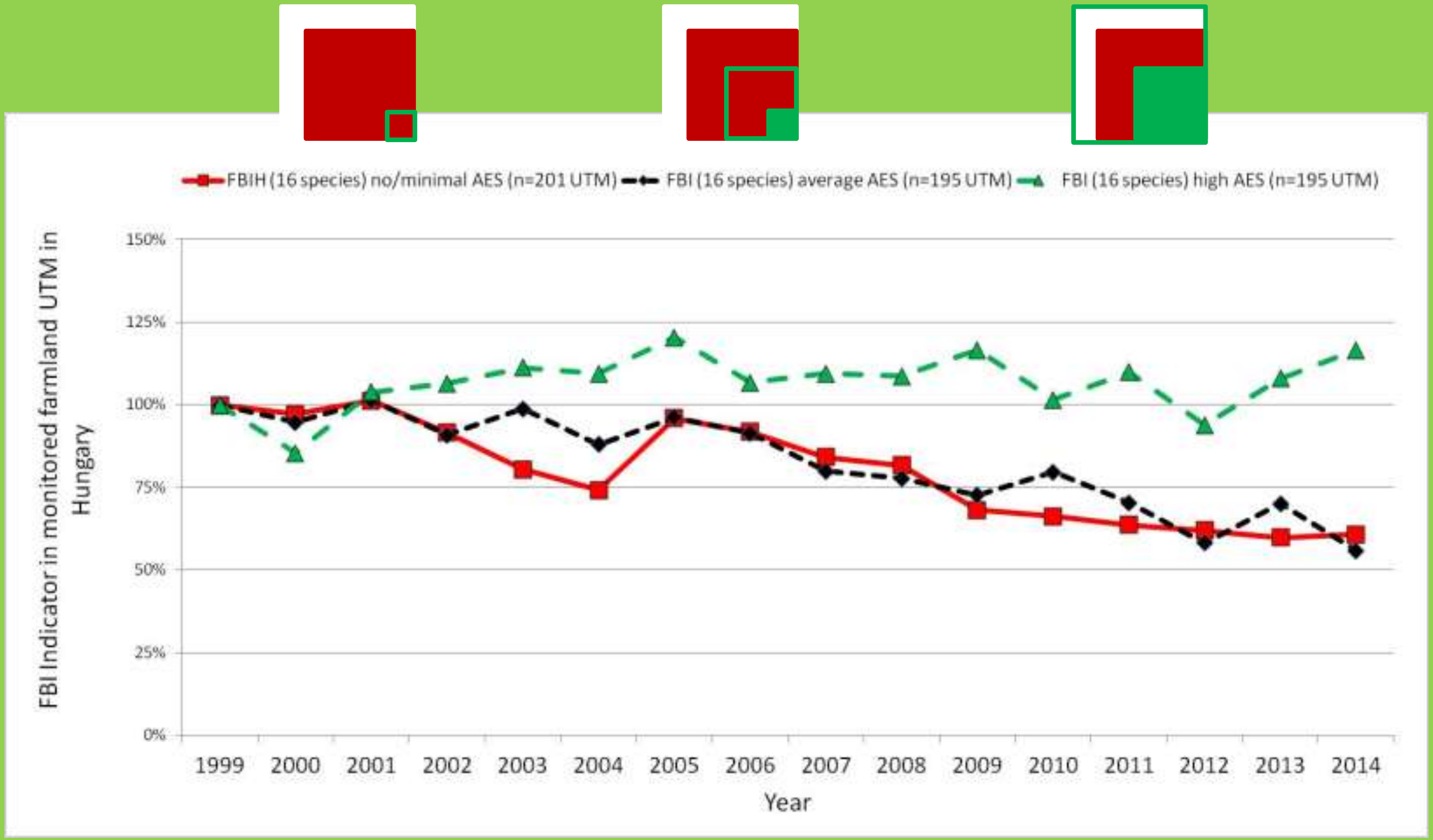
591 pc. farmland UTM

The 591 pieces of farmland UTM grouped to three similar size groups (percentiles) on the base of covarege of four types of AES in the area of the given UTM

	n=201	n=195	n=195
AES intensity	**no/minimal**	**average**	**high**
<u>Σ AES area</u> / UTM area	<4.31	>=4.310% and <=28.219%	>=28.219%



FBI of farmland areas with different coverage of Agri-Environmental Schemes in Hungary, 1999-2014



- The FBI did not show trend in farmland areas where the coverage of AES in the UTM was higher than 28.2% ($P=0.227$)
- Areas with no/minimal/average AES coverage (<28.2%) showed significant decline (slope: -0.028, SE=0.003, $P<0.001$)

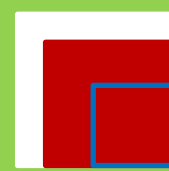
How the coverage of AES influence the FBI in farmland areas with low level of protection coverage Hungary during 1999-2014?

We considered the **445** pieces of 2.5*2.5 km UTM squares (UTM)

- Monitored with standard protocol of MMM during 1999-2014 at least in two years (Σ 1003 pieces)
- Dominant part of the UTM area (>66.6%) covered with **farmland** habitats,on the base CORINE CLC50
- Coverage of **NATURA 2000 areas** of the UTM was less then 33.3%

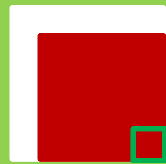
591 pc. farmland UTM

====>>>

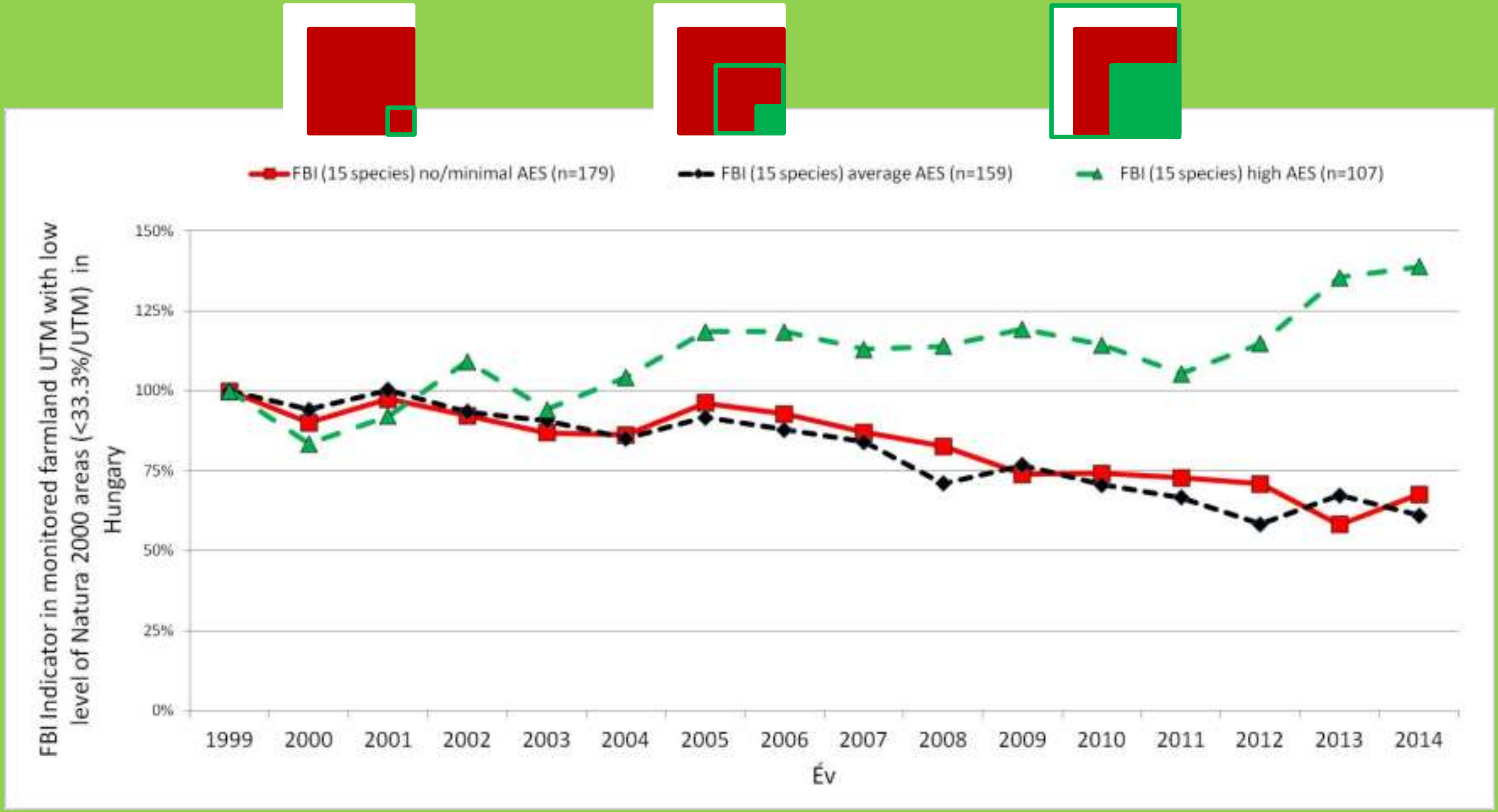


445 pc. farmland with low protection UTM

The 445 pieces of farmland UTM low level of nature protection formed three groups with similar size on the base of covarege of all kind of AES in the area of the given UTM

	n=179	n=159	n=107
AES intensity	**no/minimal**	**average**	**high**
<u>Σ AES area</u>	<4.31	>=4.310% and <=28.219%	>=28.219%
UTM area			

FBI of farmland areas with low level of protected areas with different coverage of Agri-Environmental Schemes in Hungary



- The FBI showed increasing trend in areas where the coverage of AES in the UTM was higher than 28.2% even the level of NATURA 2000 areas is low (slope=0.025, SE=0.005, P<0.001)
- Other areas had decreasing trends (slope =< -0.023, SE<=0.003, P<0.001

Conclusion

- CAP related processes has basic role in the large and fast decline of farmland biodiversity measured by FBI in Hungary

- Extension of agri-environmental schemes, mainly related to the grassland, had detectable role in maintaining or improving farmland biodiversity

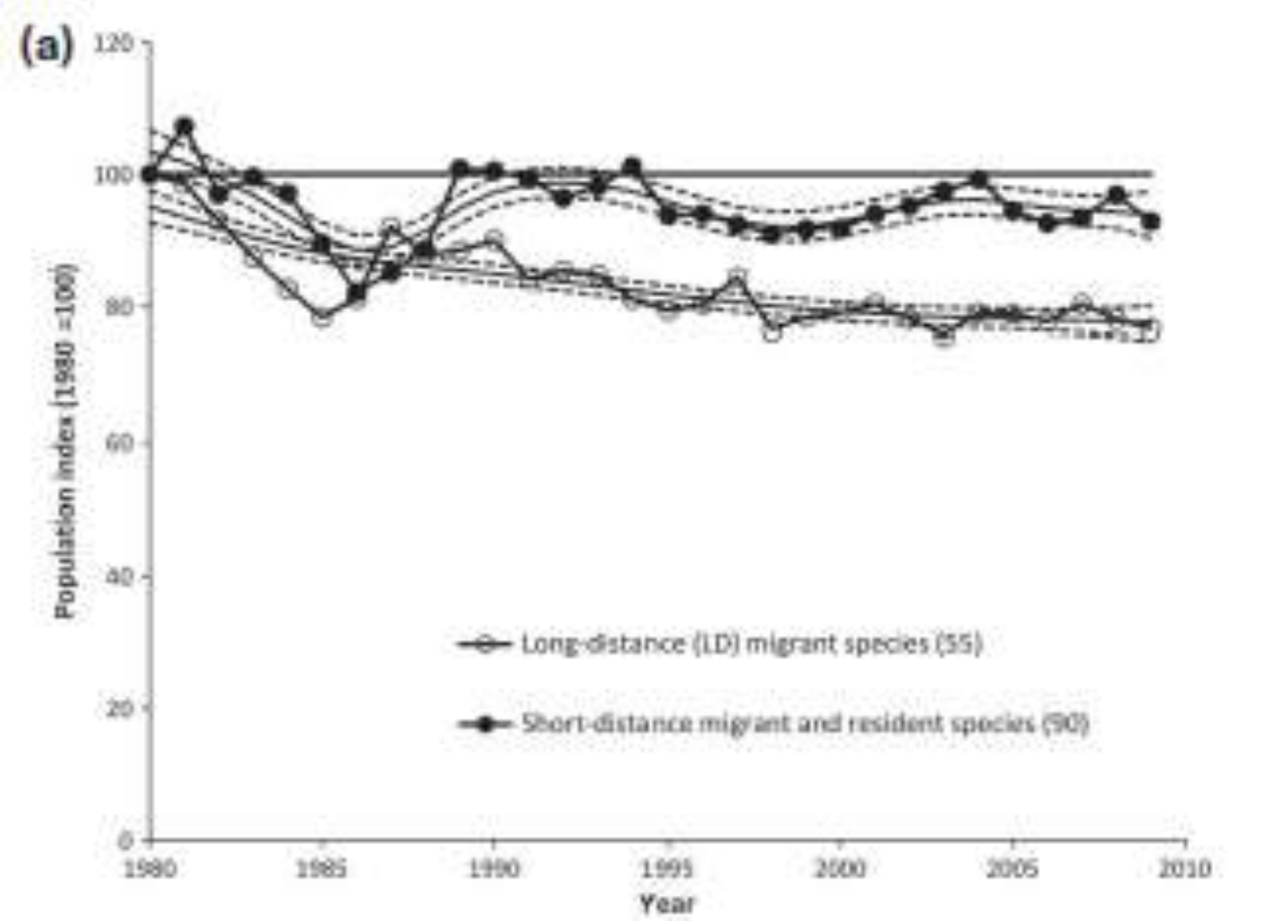
- Recent AES of intensively farmed habitat did not halt the decline of the farmland biodiversity

- Further increase of extension and efficiency of AES would need ….<-> but …
- FBI could help to measure the efficiency of AES in large spatial scale

Long distance migrants in Europe

There is growing evidence that long distance (Afro-Palaearctic, (A-P)) migrants are in decline throughout Europe, with declines often being more pronounced than those of either short-distance migrants or sedentary (Sanderson et al. 2006, Vickery et al. 2014)

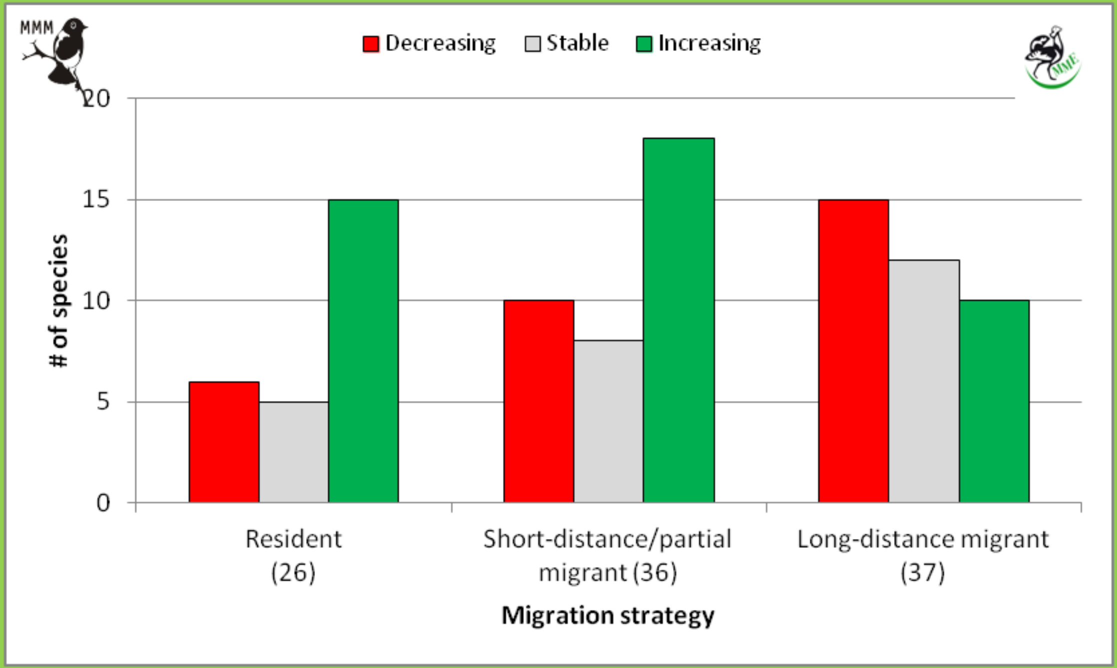
These declines are of growing conservation concern in both scientific and political arenas



Long distance migrants in Europe and in Hungary

Long distance (Afro-Palaearctic) migrants are in decline throughout Europe, with declines often being more pronounced than those of either short-distance migrants or sedentary (Sanderson et al. 2006, Vickery et al. 2014)

Different trends are detected in Hungary among long distance vs. others species - Common Bird Monitoring (MMM) using random sampling since, 1999-2024



Szép T., Nagy K., Nagy Zs., Halmos G. 2012. Population trends of common breeding and wintering birds in Hungary, decline of long-distance migrant and farmland birds during 1999–2012. – Ornis Hungarica 20(2): 13–63.

Study of Bird Migration, long-term study of Sand Martin in Hungary

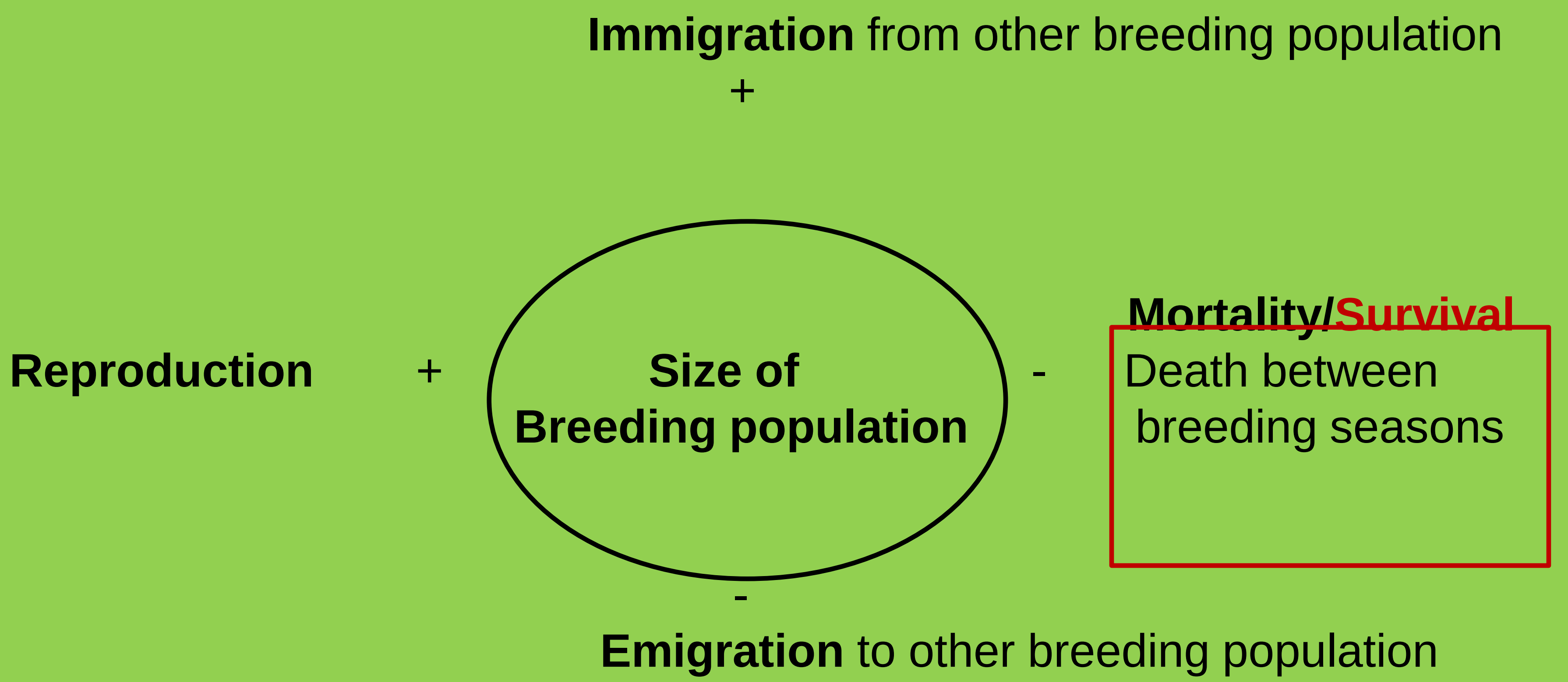
Tibor Szép
Environmental Institute, University of Nyíregyháza & MME/BirdLife Hungary

How it is started?

- Several studies showed large population decline of several long distance migrants following drought in the Sahel in the second half of XX. century
    - Whitethroat (Sylvia communis) (Berthold 1973, Winstanley et al 1974)
    - Sand Martin (Riparia riparia) (Kuhnen 1975, Cowley 1979)

1986: What is the role of the distant migration/wintering areas on the breeding population in Europe, how can we measure it?

Survival rate – most direct proxy to detect influence of migration/wintering event



Why Sand Martin?

Weight 12-13 g

Socially monogamous

Insectivorous

Wintering areas, south from the Sahara

Long-distance migratory species

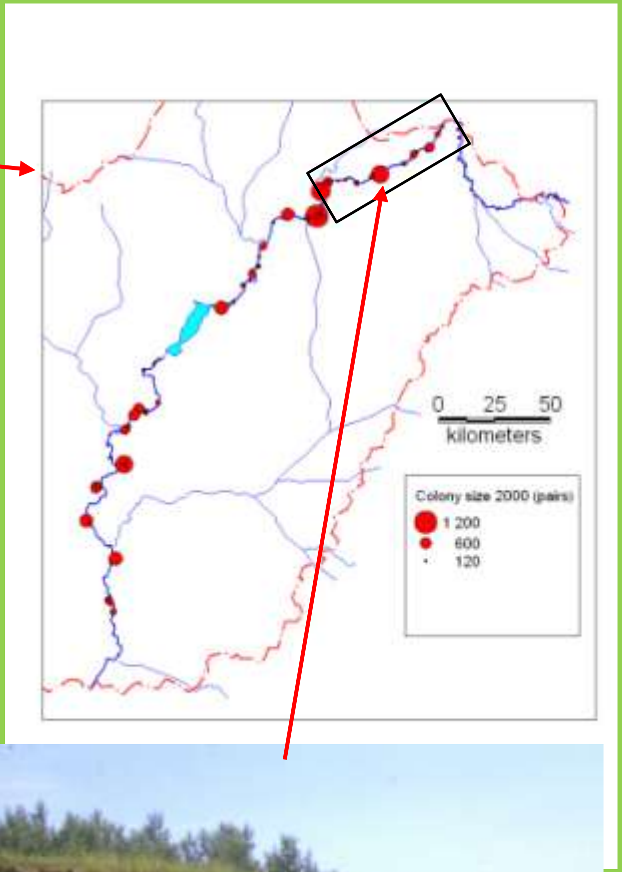
Bre(e)d in large colonies in Hungary in natural habitat

Easy to catch in large numbers without adverse effect – usage of capture-recapture methods

Easy to survey breeding habitats and populations

Opportunity for censusing breeding habitats, colonies and its sizes along the river

Start of integrated monitoring of Sand Martin along Tisza river, Eastern Hungary, 1986-1994

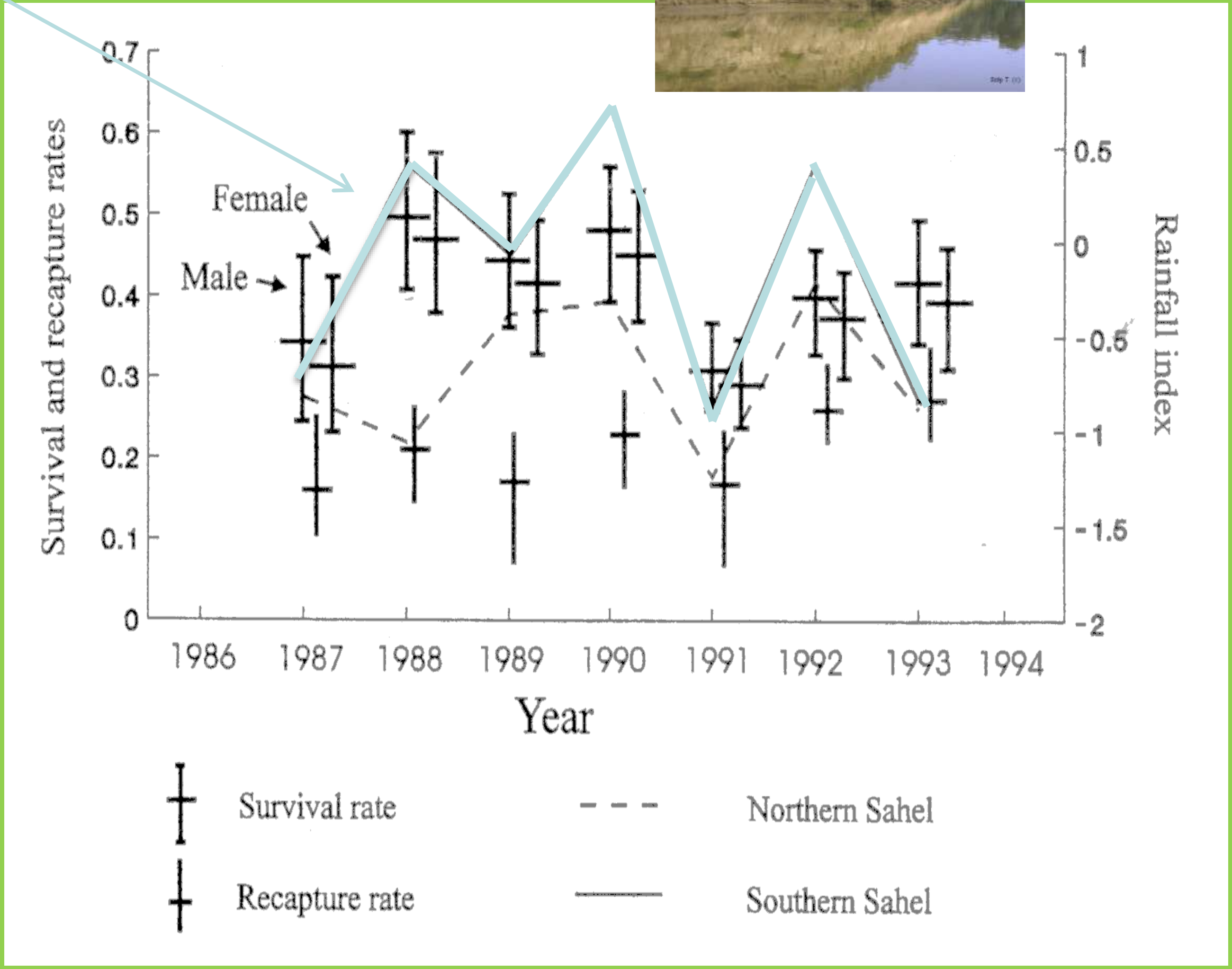


- Annual survey of
  - **breeding habitat**, perpendicular walls
  - **breeding colonies** along the 70km long section of the river

- **Ringing adult and fledged juveniles** at the largest colony at Tiszatelek colony during the fledging period (June-July)
  ~ 1000-2000 ind./year

- Survival rate highly depend on the rainfall (Sahel, Western part) condition in Africa (*Szép 1995, Ibis*), one could model the survival rate with Sahelian rainfall for short term (1986-1994, Tiszatelek colony)

Sahelian rainfall index



Development of integrated monitoring of Sand Martin 1994-

Annual survey of the ~600 km long Hungarian section of the river, since 1990

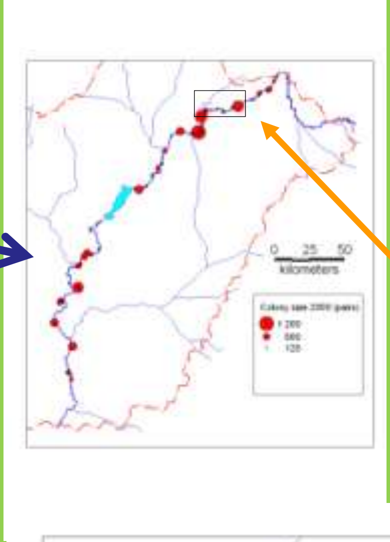
Regular ringing of all riverside and sand pit colonies in an standard studied area, along a 40km section of the river (Tokaj-Tiszatelek), since 1994

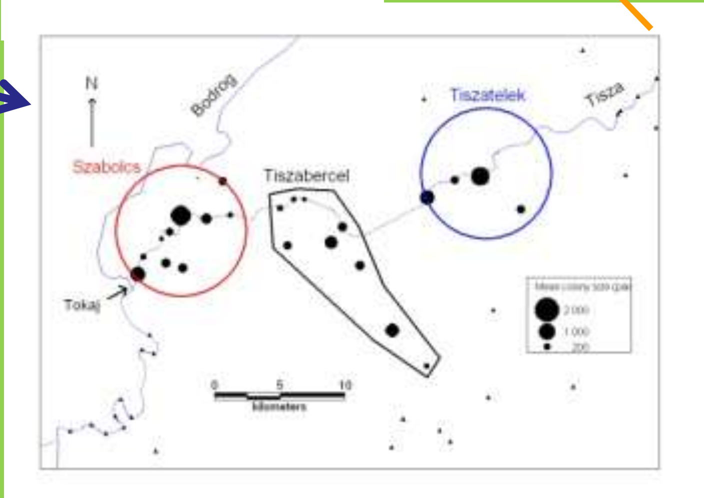
~2000-6000 ringed ind./year

~260-1300 recaptures/year ringed during former years

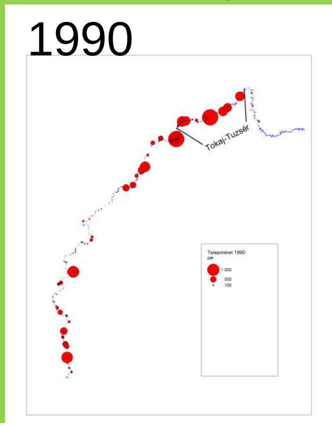
Regular survey of breeding success at randomly selected section(s) of colonies in the studied area using videoendoscope, since 1995

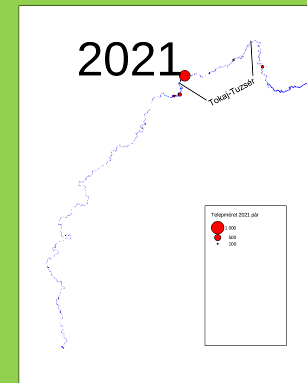
(~800-2000 burrows/year)

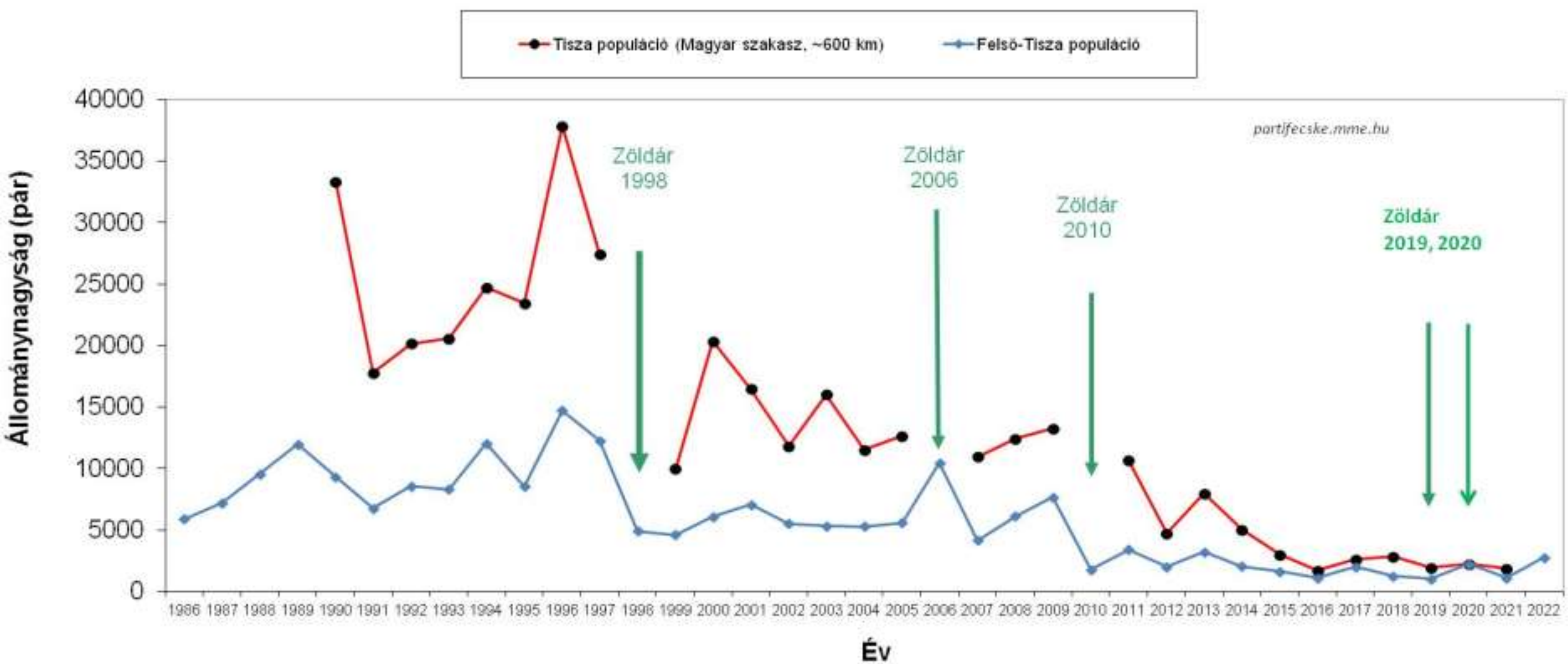




Population along the Hungarian section of river Tisza (600 km) Strong decline, in 2022 only 5% of the population of 1990 remainded





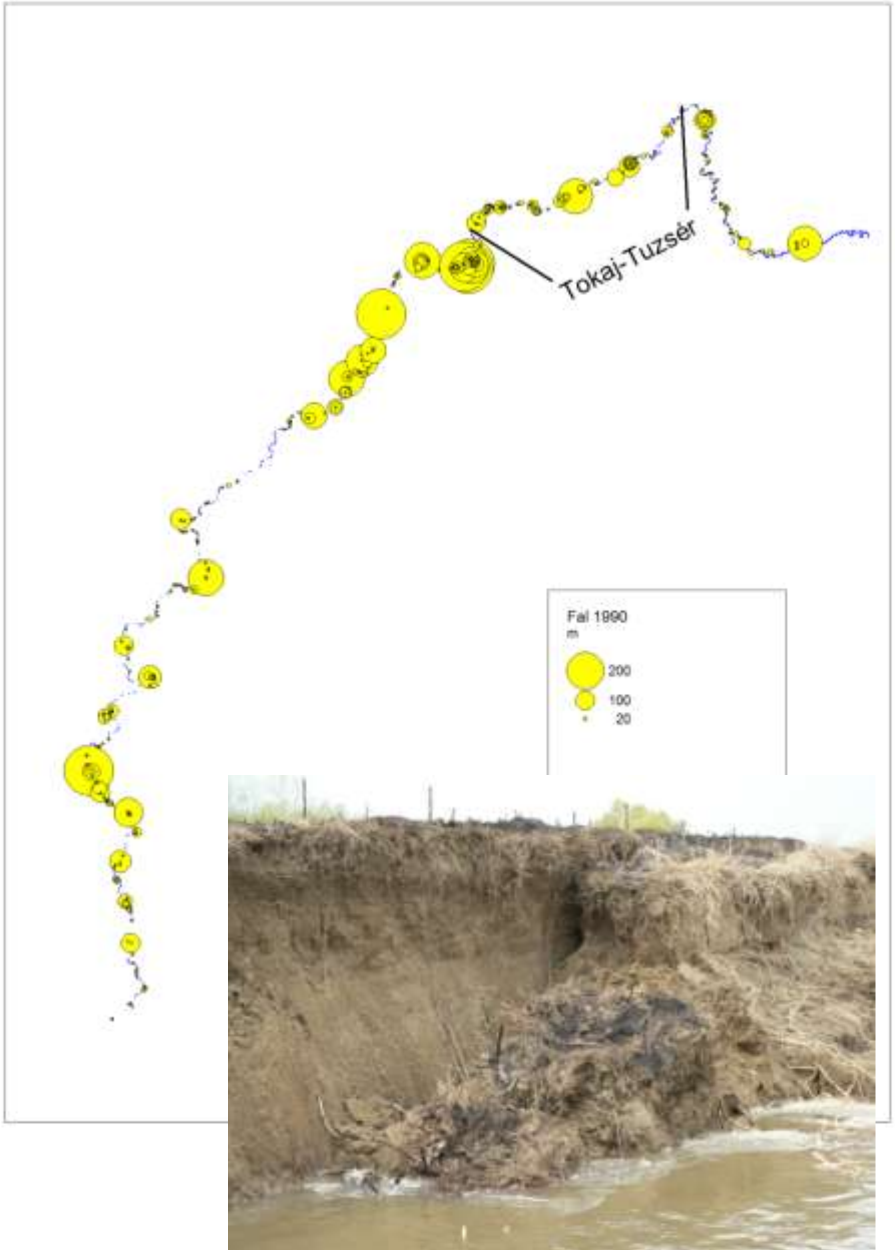


„Green flood" - Flood during the breeding season

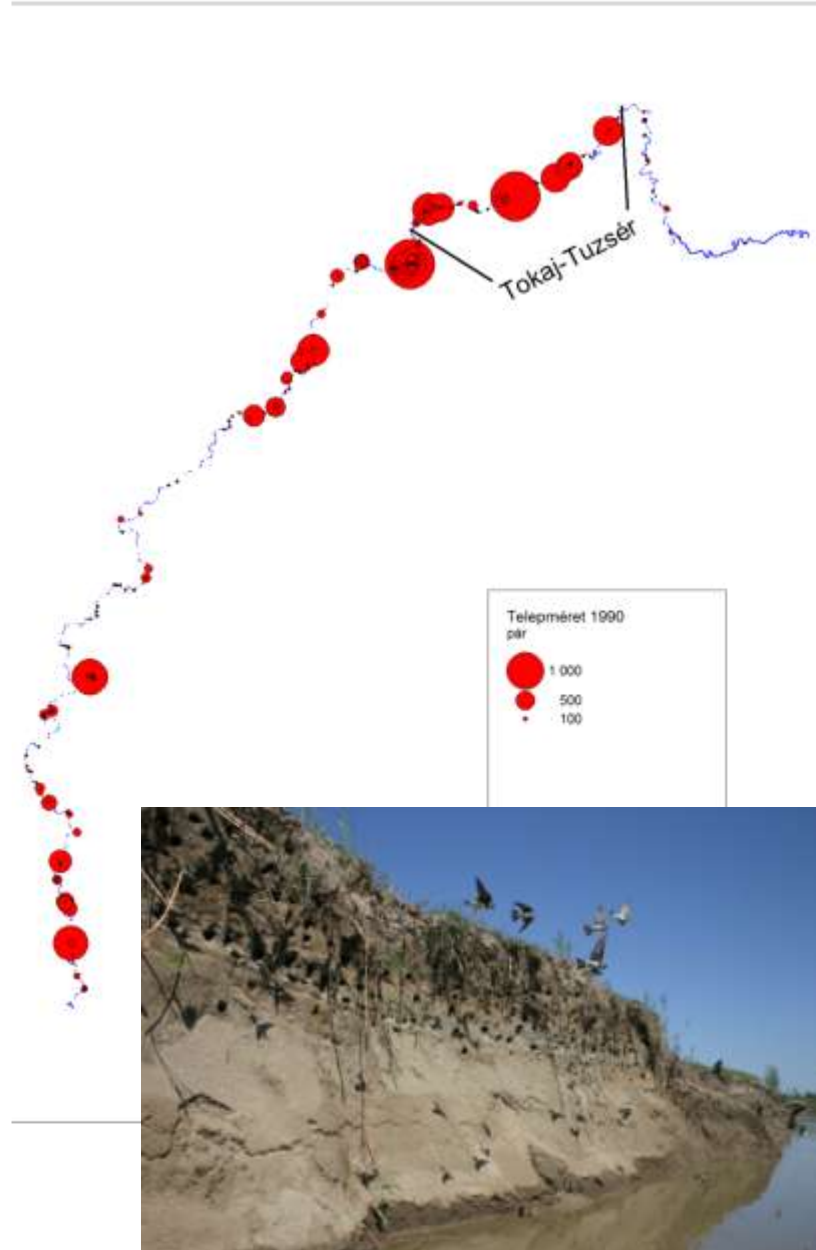
- Destroy > 80% of first clutch of the population breed along the river
- 1998, flood occured before the fledging (middle June)
- 2006, flood occured during the incubation (end of May)
- 2010, flood occured during the incubation (second half of May)
- 2019, flood occured during the incubation (second half of April)
- 2020, flood occured during the incubation (end of June)
- Flood in the breeding season occured formerly every ~7-10 years during the last 100 years

1990

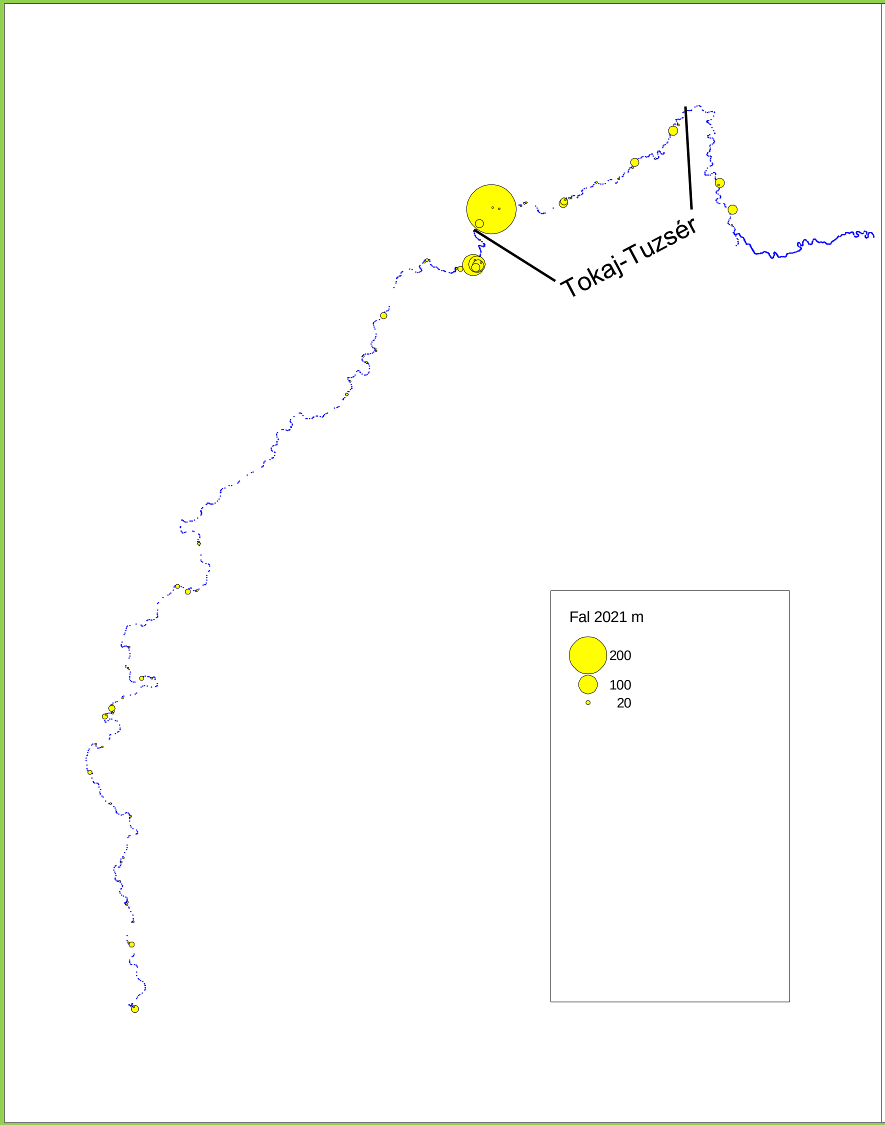
Potential breeding walls and its sizes



Breeding colonies and its sizes



2021


Tokaj-Tuzsér
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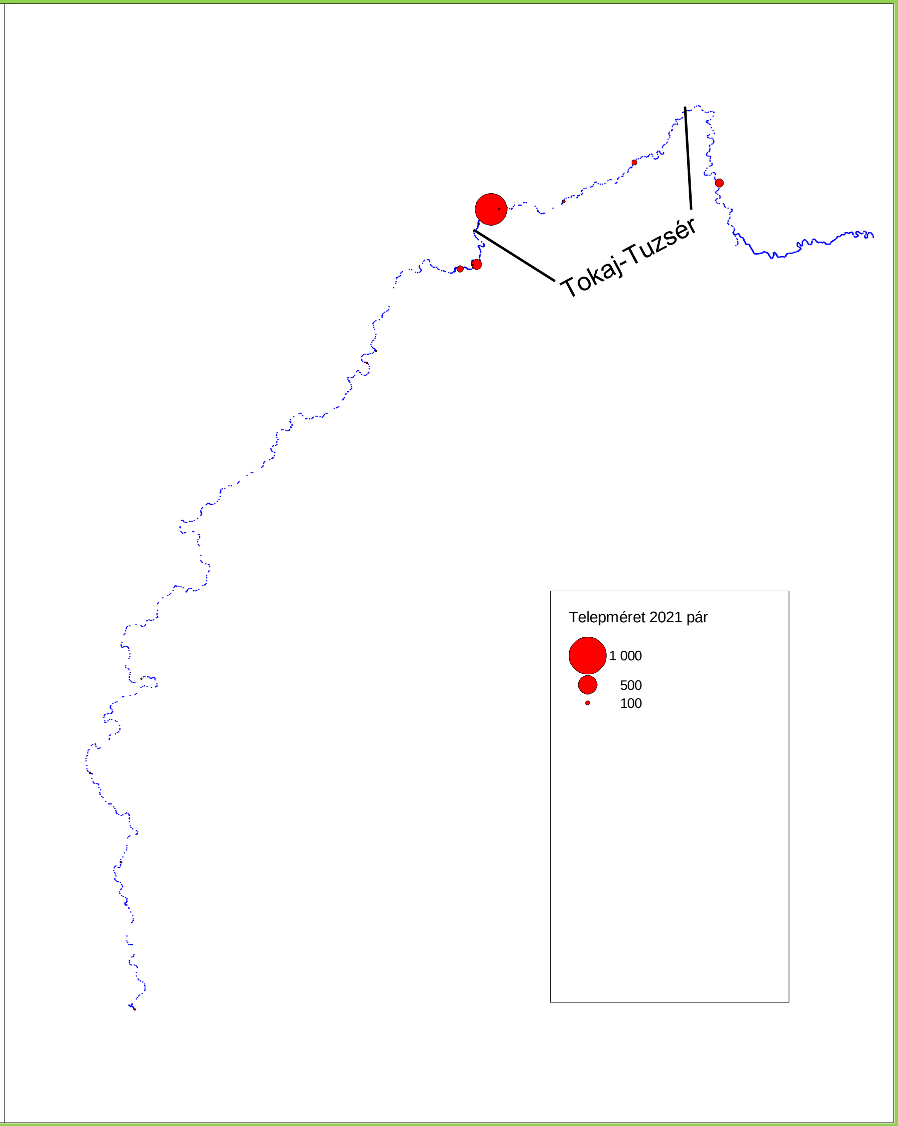
200
100
20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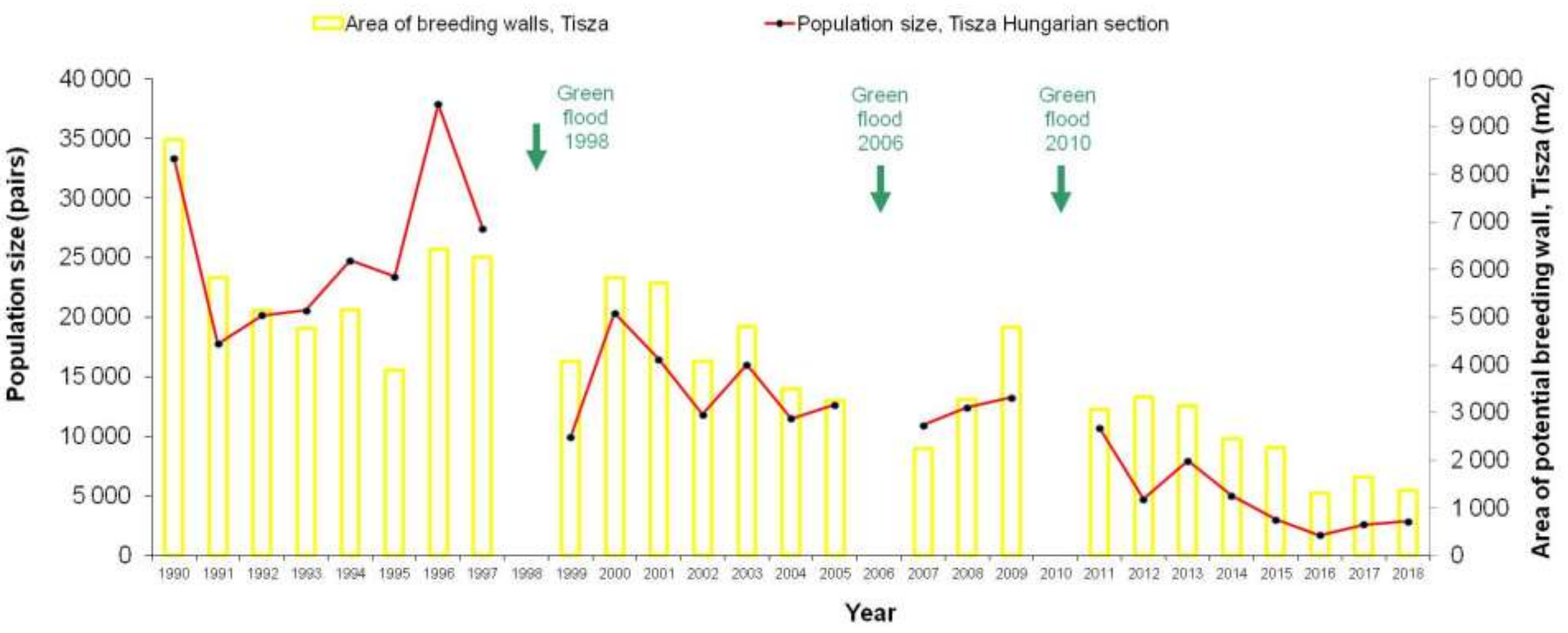
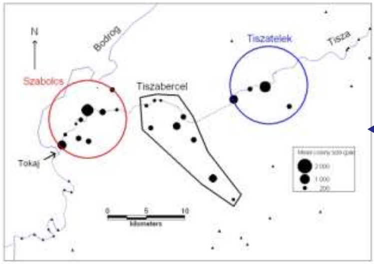
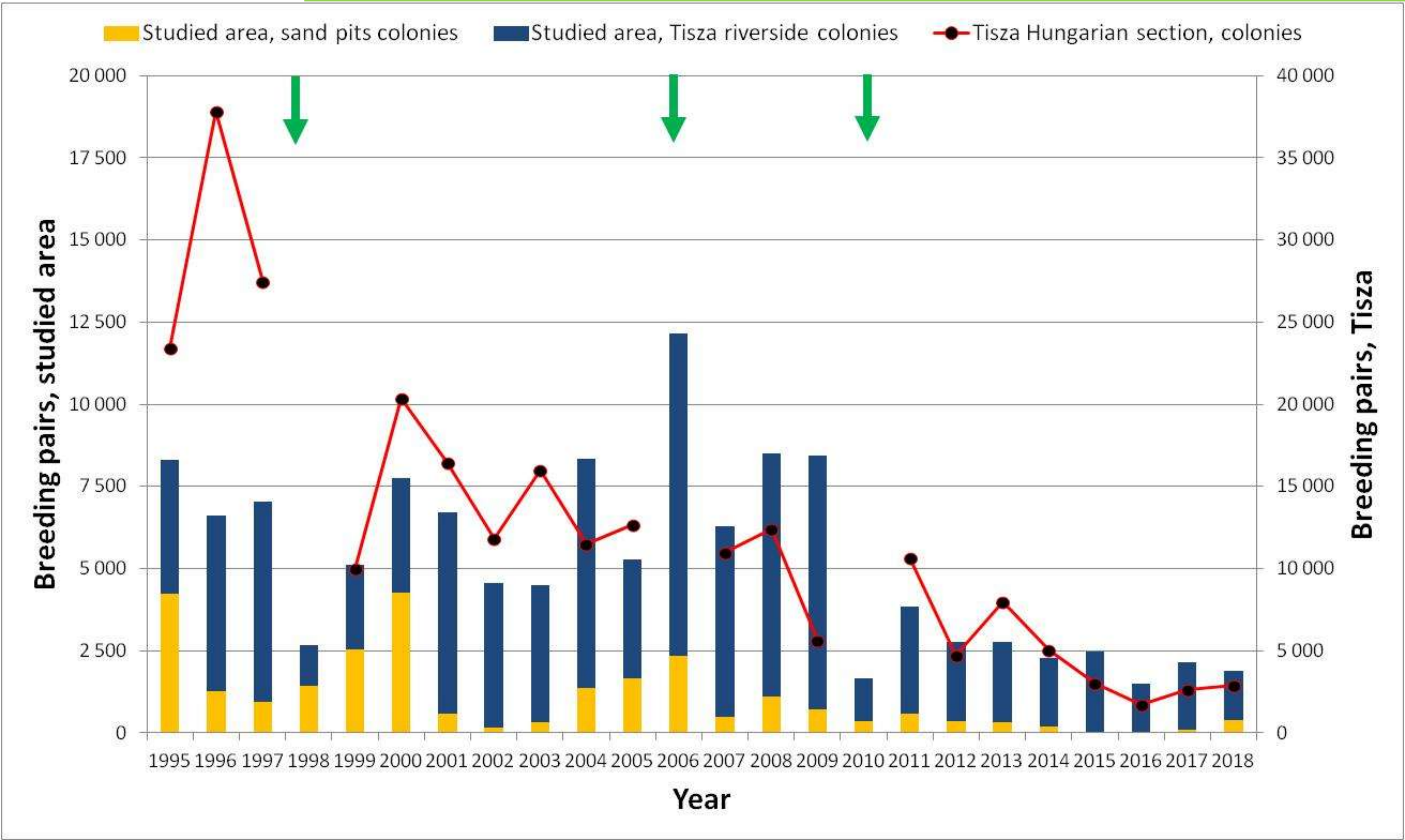
Telepméret 2021 pár
1 000
500
100

Annual total area (m^2) of the potential breeding walls decreased during 1990-2018 along the river ($R=-0.842$, $P<0.001$, $N=26$)





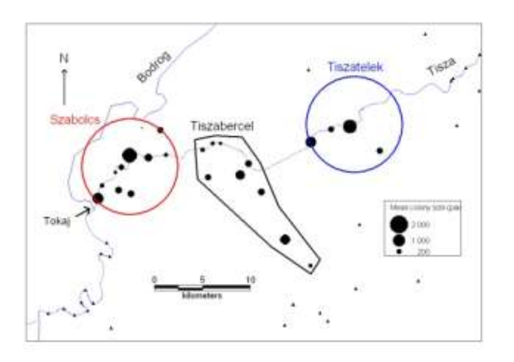
Population size
in the studied area vs. Tisza Hungarian section
Large decline has started after 2010

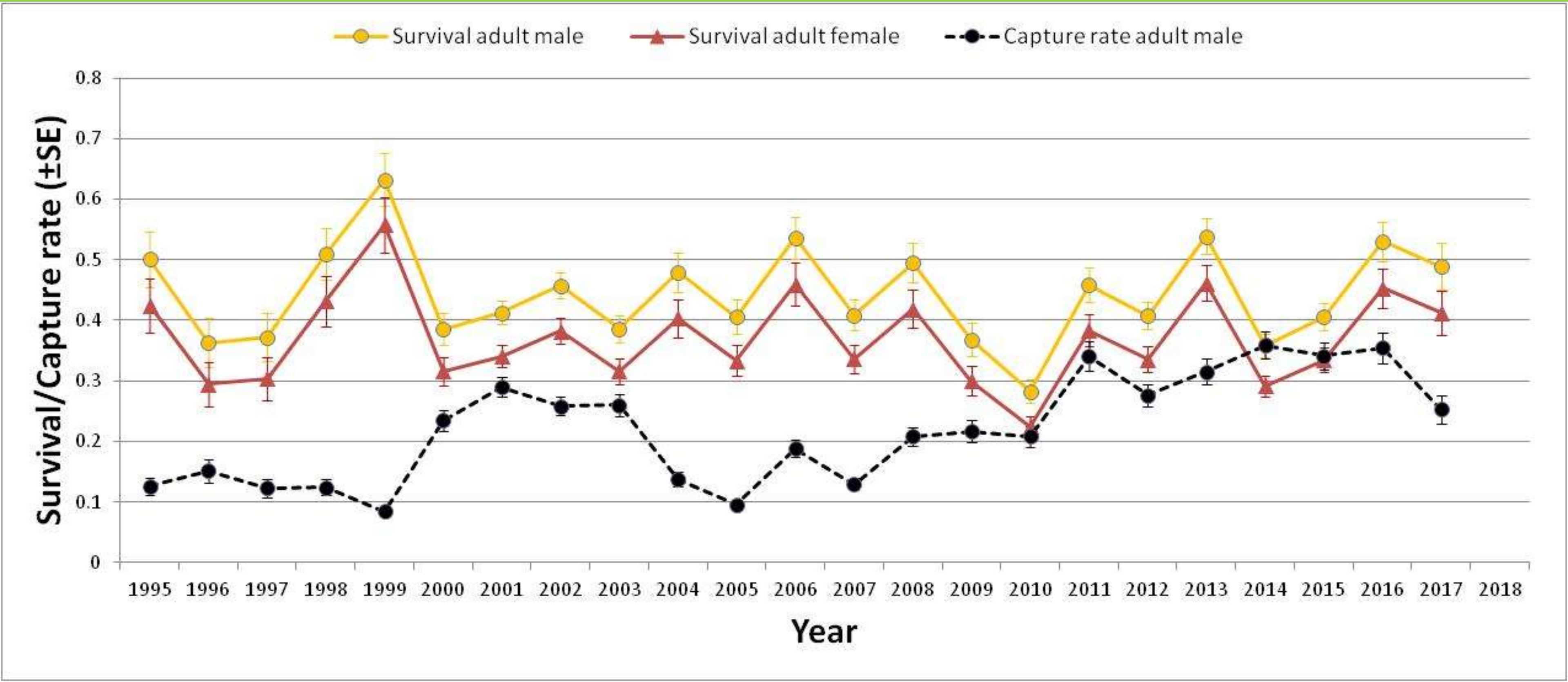


Highly fluctuating annual survival rate on the base of long term data in the studied area (1994-2018)

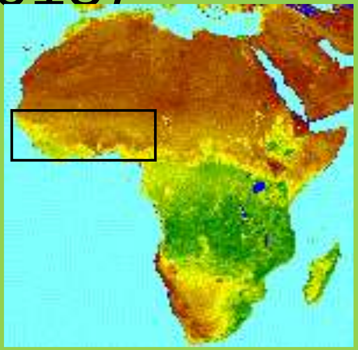
General CJS model fit (χ^2=219.717, df= 204, P=0.214, c-hat=1.077, RELEASE)

- **Best model: Phi(sex+t), P(sex+t)** (QAICc Weigth= 0.977, MARK)
- **Adult female has lower survival, higher permanent dispersal (?!)**
- **Large annual fluctuation, ~ 0.4 mean survival rate**
- **There is no significant trend in the survival rate of adults** (R= -0.031, P=0.888, N=23)

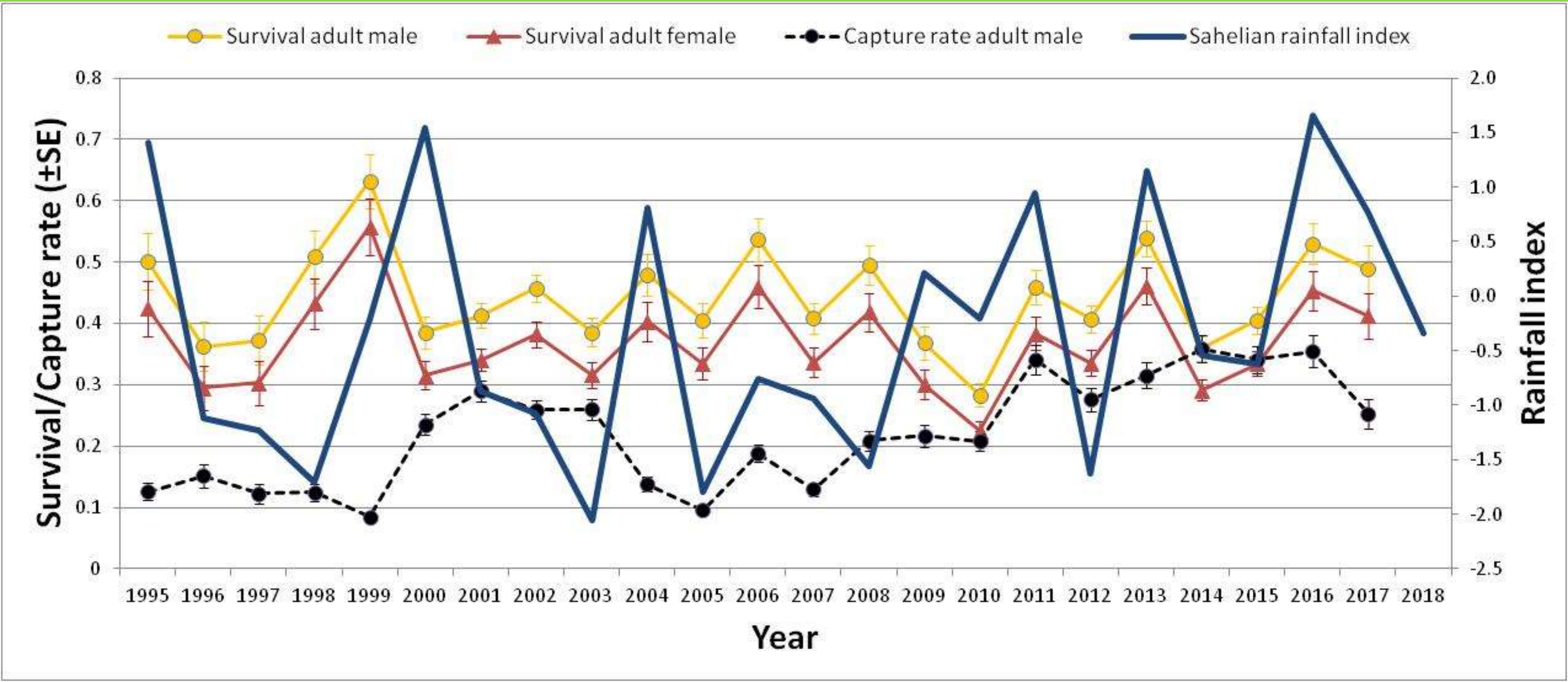




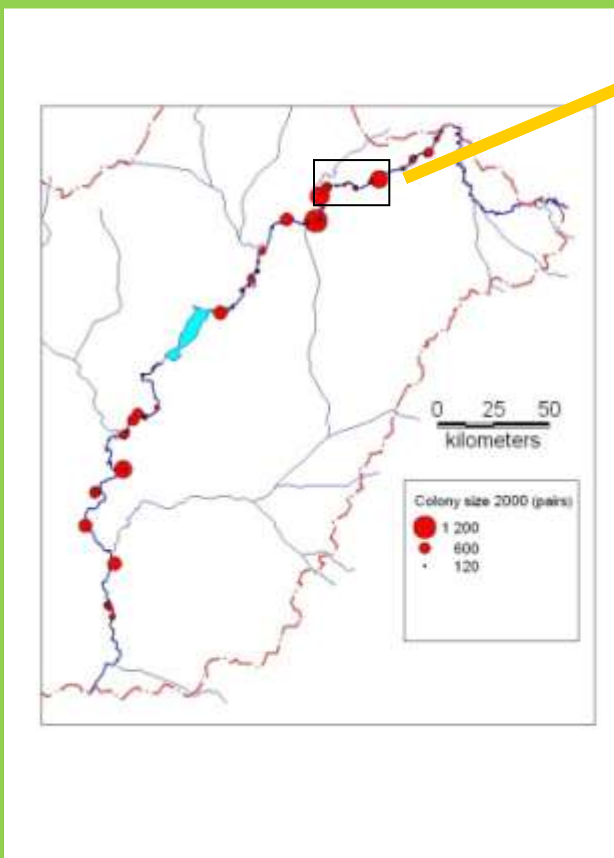
Highly fluctuating annual survival rate on the base of long term data in the studied area (1994-2018)

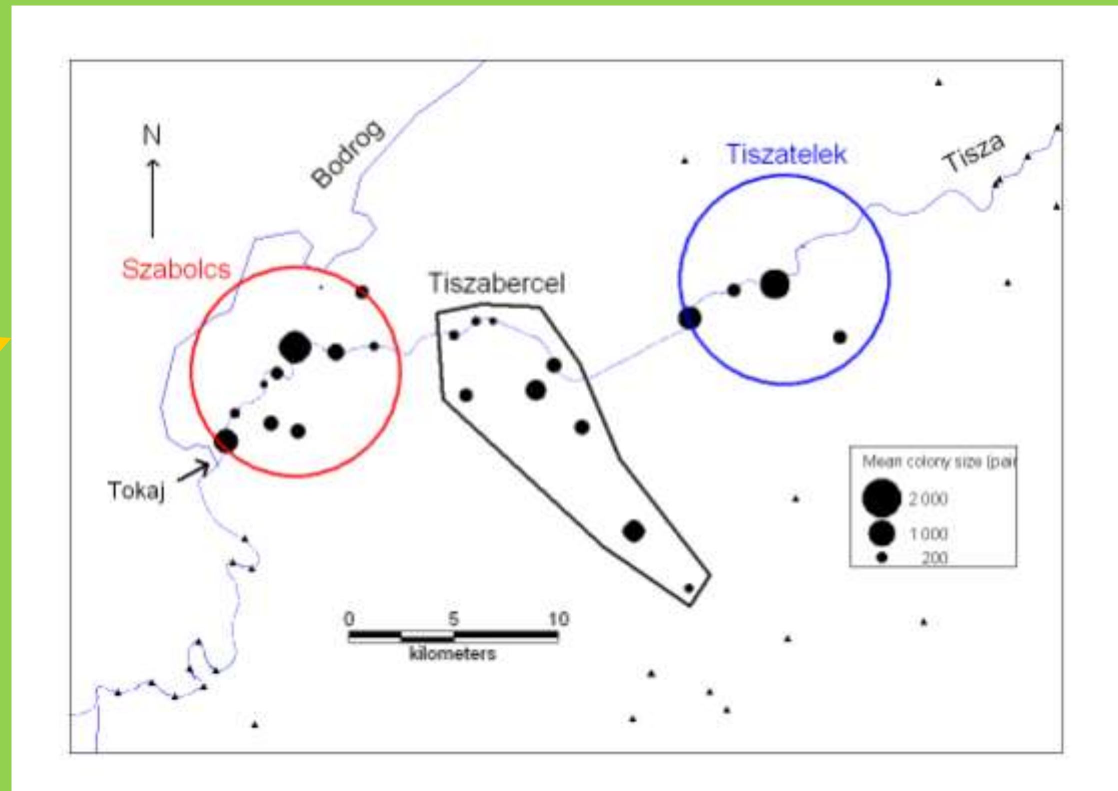


- **Sahelian rainfall could not model the annual survival rate long term,** LRT: Phi(sex+t), P(sex+t) vs. Phi(sex+Sahelian rainfall), P(sex+t) (χ^2=725.712, df= 22, P<0.001)
- **Usage of different wintering areas**
- **Carry-over effects of breeding/migrating areas and periods**



Studied regions along the Upper-Tisza between 1994-2011



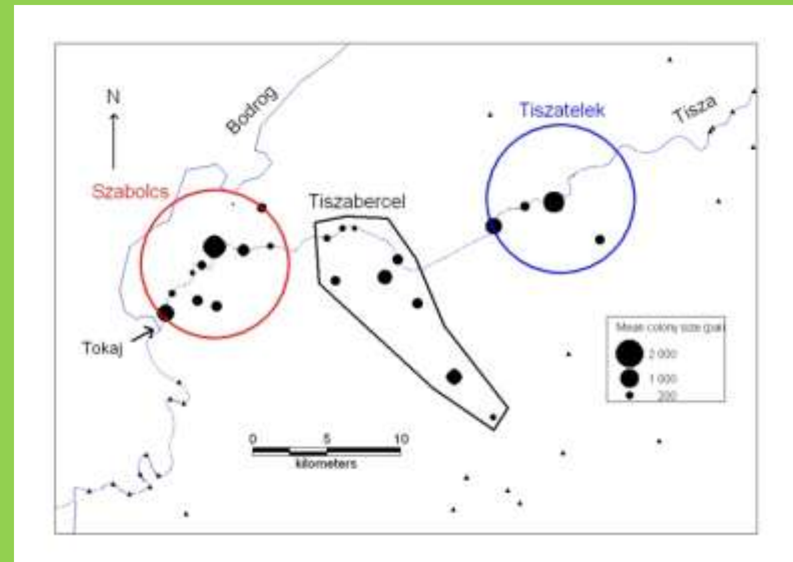


- Three separated regions along the river, 300 km^2 large area
  - **Szabolcs**
  - Tiszabercel
  - **Tiszatelek**

Model selection – adults

$\Psi_{f.to.t+s}\ F_{f.t.+s}\ p_{to.t.m+s}$

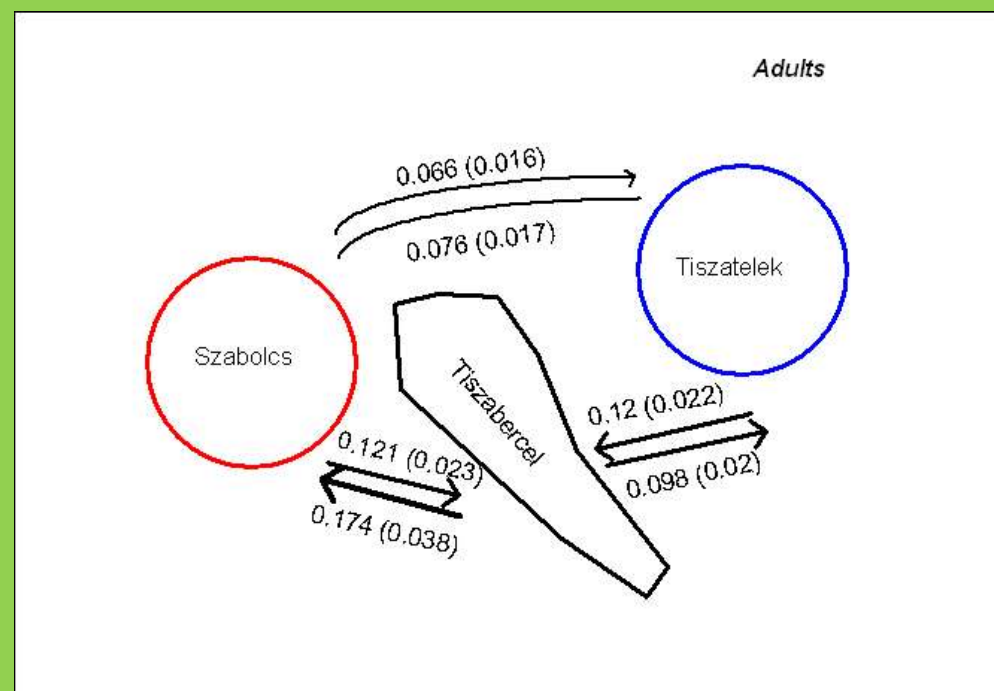
model with the lowest AIC for adults



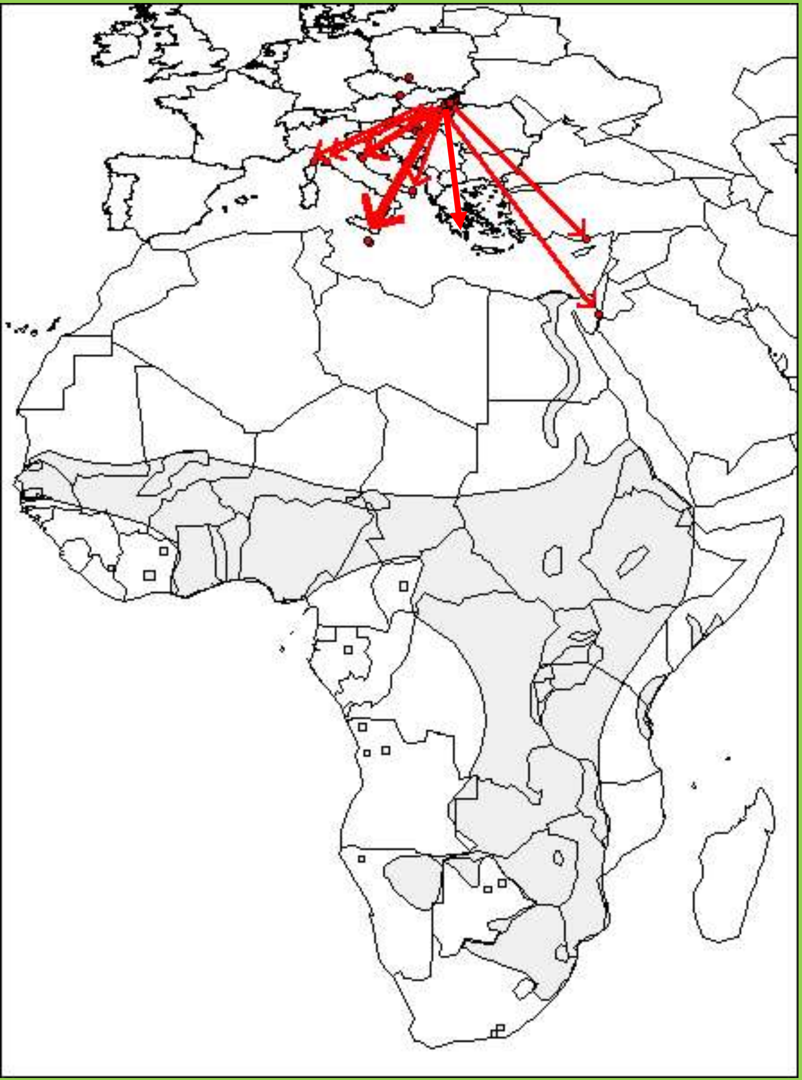
Movement rate (Ψ)

- Vary among regions and years with interaction

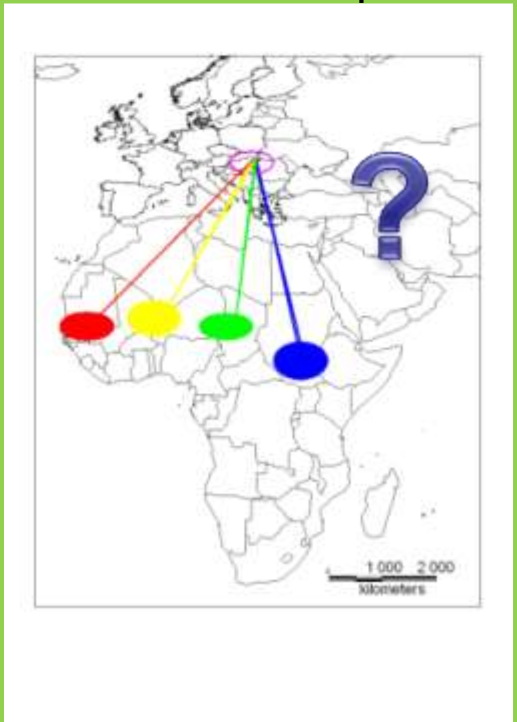
- High percent of adults remain within their region



Limited or no information about the all migration and wintering areas of sand martin breeding in Eastern Hungary until 2013

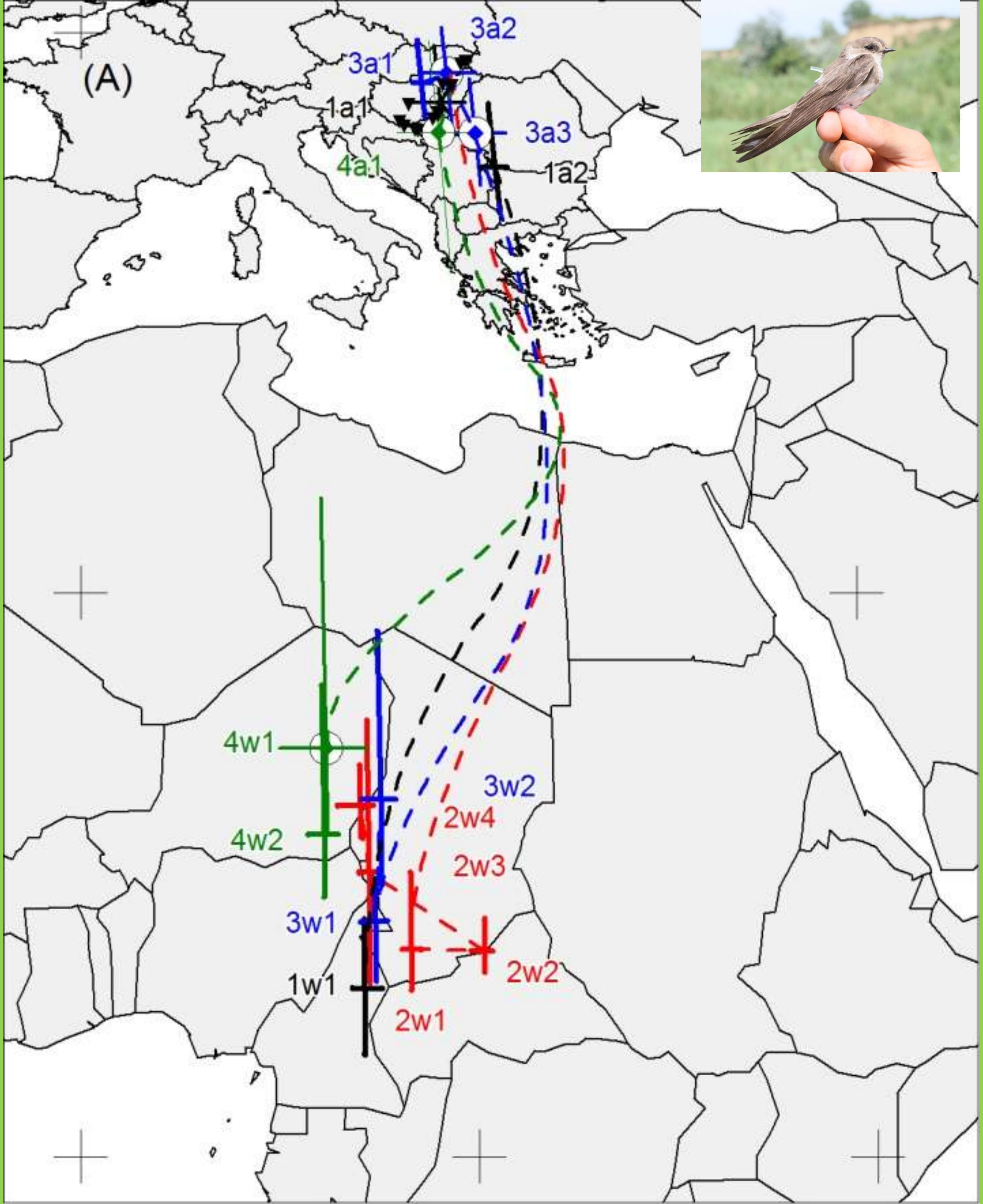


- ~170 thousand ringed breeding birds since 1985,
  - No any African recoveries/recaptures !



Application of geolocators in cooperation with Swiss Ornithological Institutes (2012/13) – first success !!!

Szép, T., Liechti, F., Nagy, K., Nagy, Zs., Hahn, S. 2017. Discovering the migration and non-breeding areas of Sand Martins and House Martins breeding in the Pannonian basin (central-eastern Europe). Journal of Avian Biology 48: 114-122



Data of 4 birds with geolocator about migration/wintering of Sand Martin

Autumn migration:

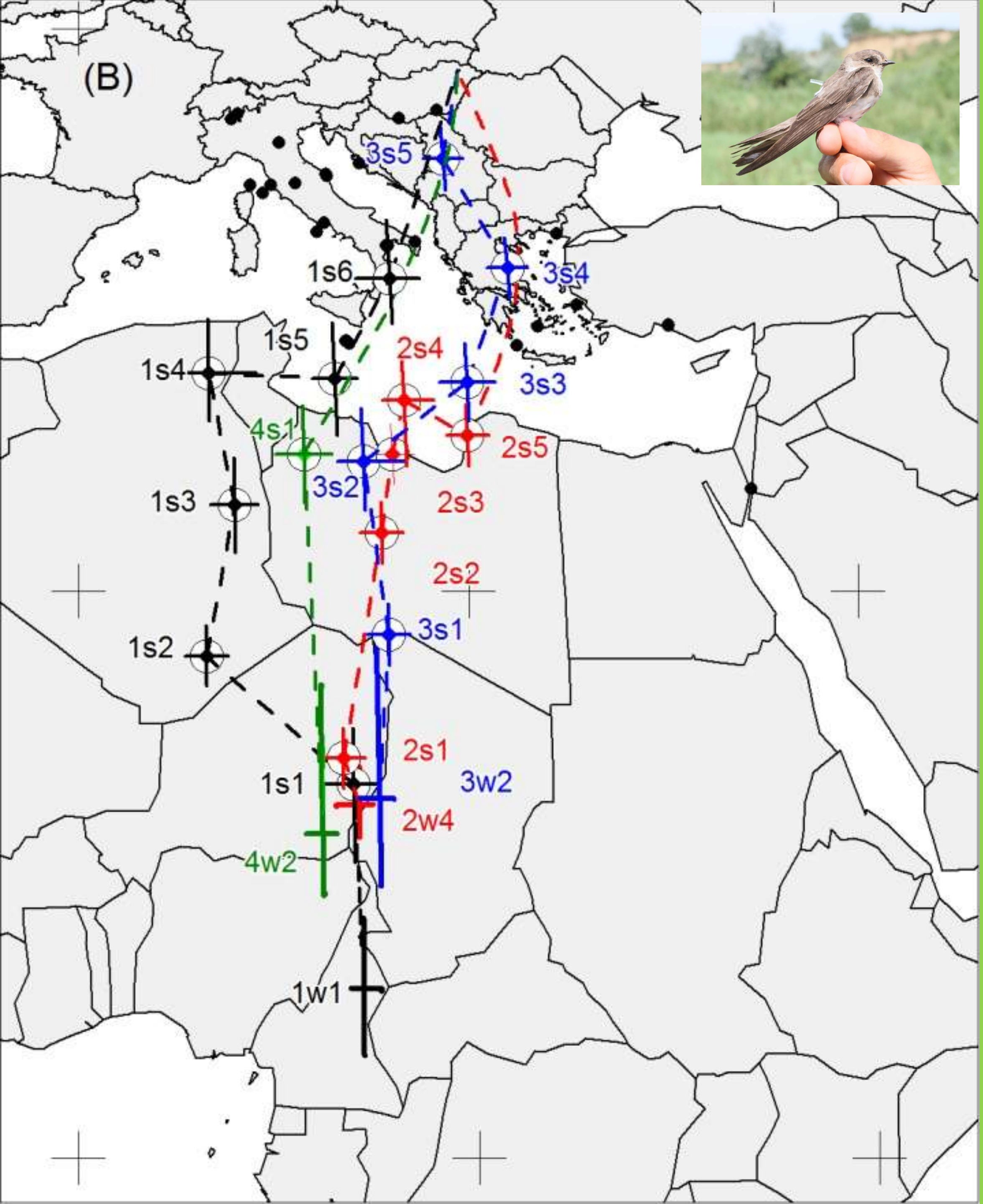
Limited information about the post breeding and autumn migration period

(equinox)

Importance of Greece at the start

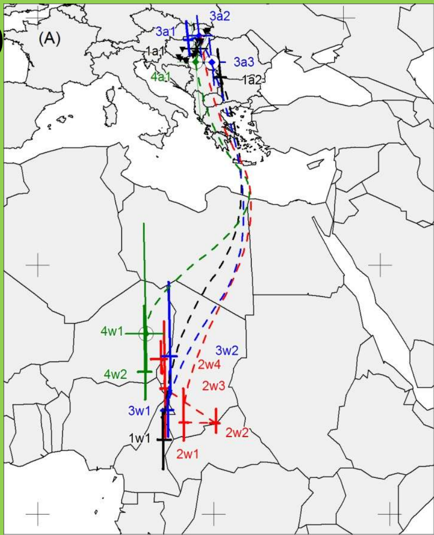
Wintering area:

- All individuals used the Lake Chad basin



Spring migration:

- Start in April-May
- First detailed data about areas, length (~ 14 days) and speed of spring migration (400-800 km/day)
- 5-6 stop-over sites with ~ 1.5 days interval during ~4000-5700 km long migratio



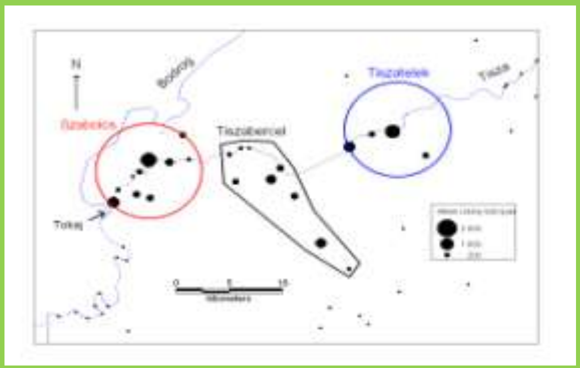
Recent project using geolocators, 2017-2020

- 100-100 geolocators deployed in 2017 and in 2018
  (Migratech, 14 months lifespan, measure light in wide range – option to use template fit)

-Opportunity to investigate in details the entire non-breeding period

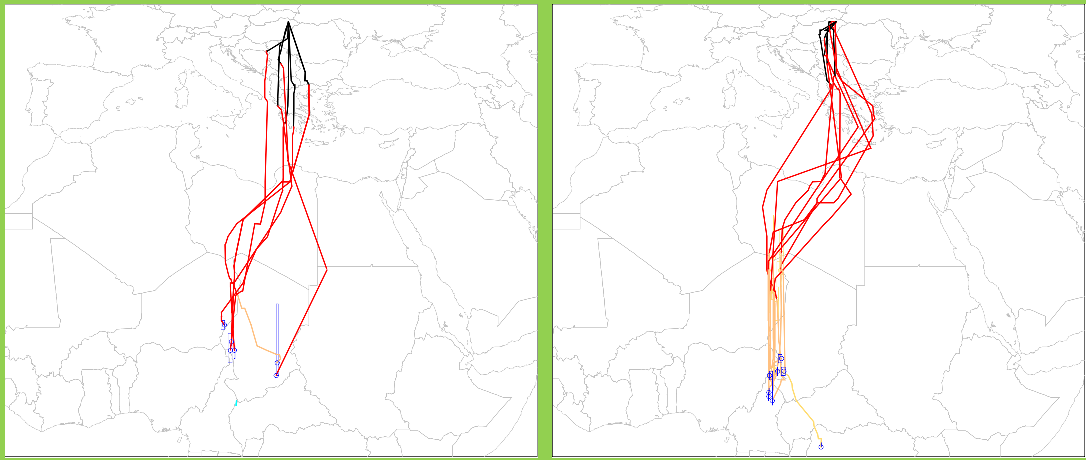
Sand Martin is a long-distance migrant species

Study area in Hungary

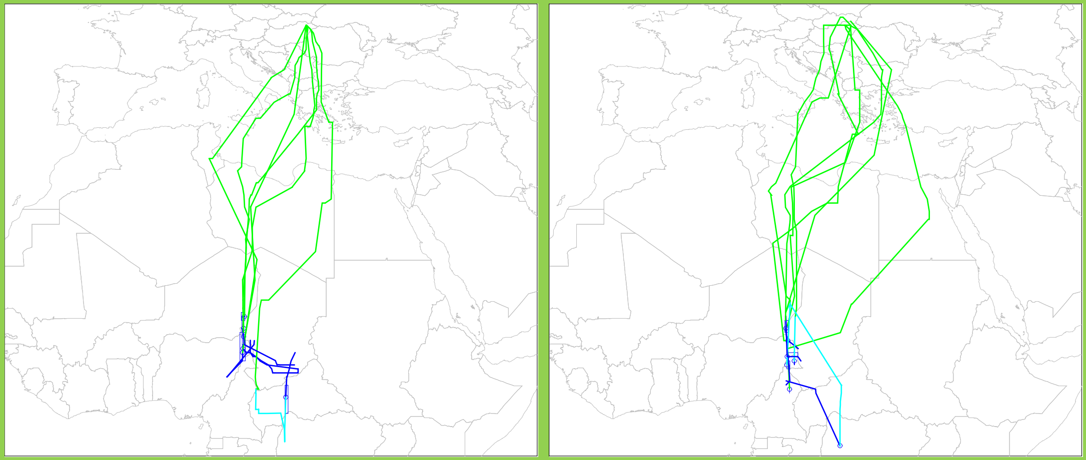


- 6 recaptured individuals in 2018
- 8 recaptured individuals in 2019

Autumn migration in 2017 and 2018 by geolocators

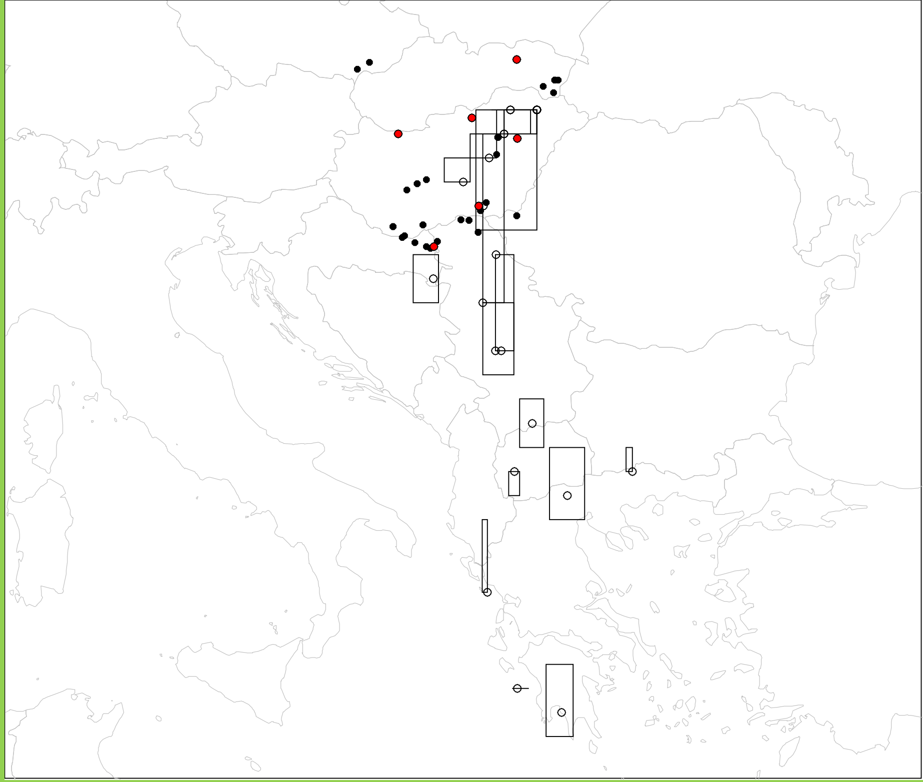


Spring migration in 2018 and 2019



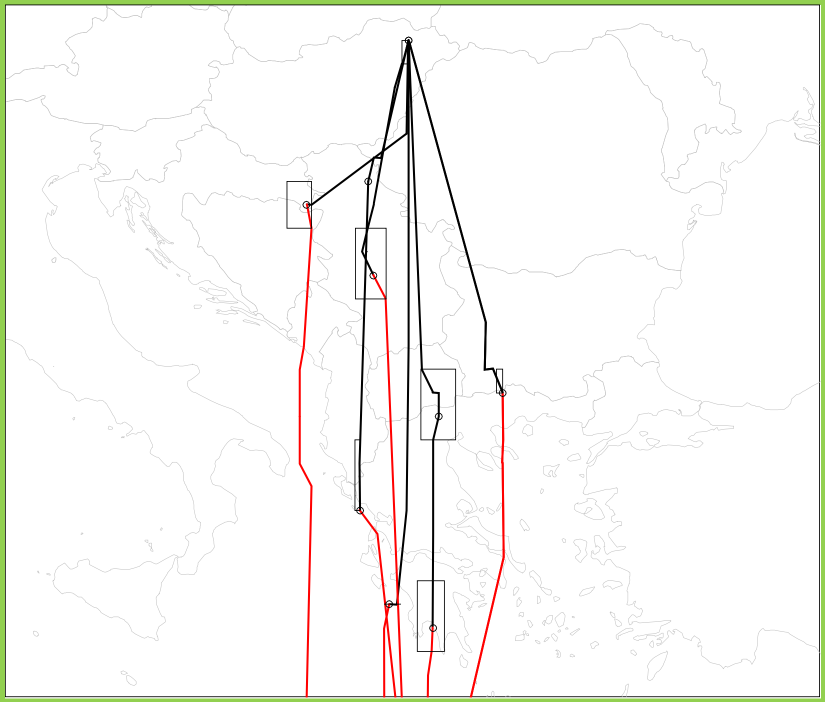
Autumnal pre-migratory period

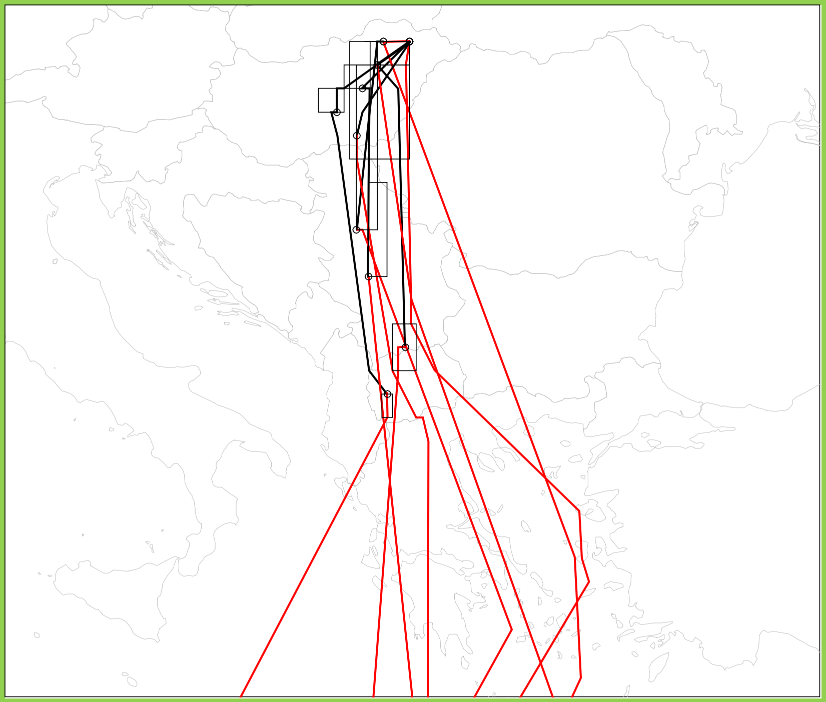
Identified autumnal pre-migration areas during 2017-2018 by geolocators and sites of recaptured individuals between 10th July and 7th September, belong to the studied population. (black circles: median position of the post-breeding/pre-migratory stationary areas, black dot: recaptured before 2017, red dot: recaptured during 2017-2021).



The average length of the autumnal pre-migration period was 55.607 day (SD = 9.063, range 42.8 - 68.7 day, n = 14), from which the individuals stayed in stationary areas in total an average 50.236 days (SD = 9.253, range 36.2-62.7 days, n = 14), used an average three stationary areas (range 1-5) from which they used an average two stationary areas (range 1-3) at least a week long before start of the autumn migration.

Autumnal pre-migratory period



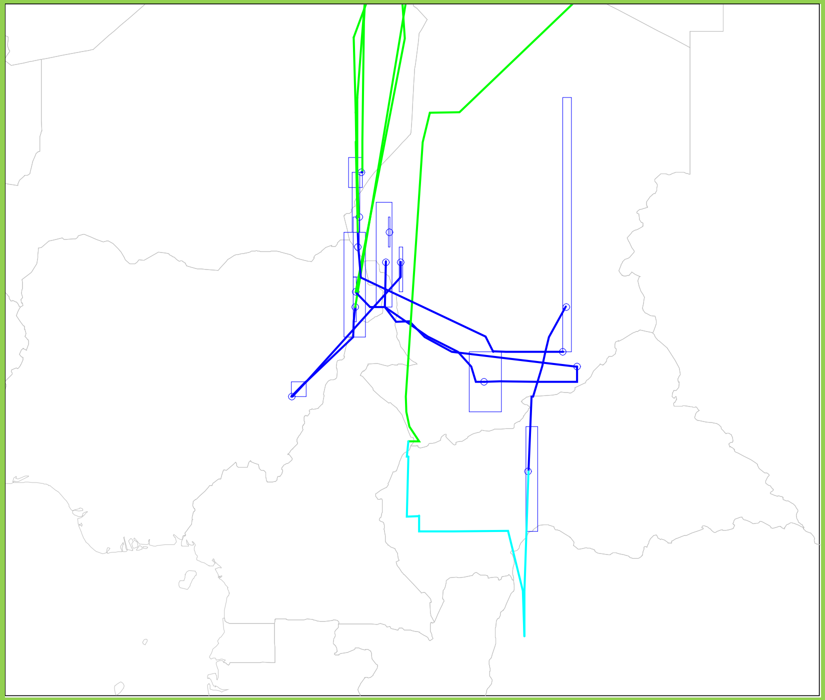


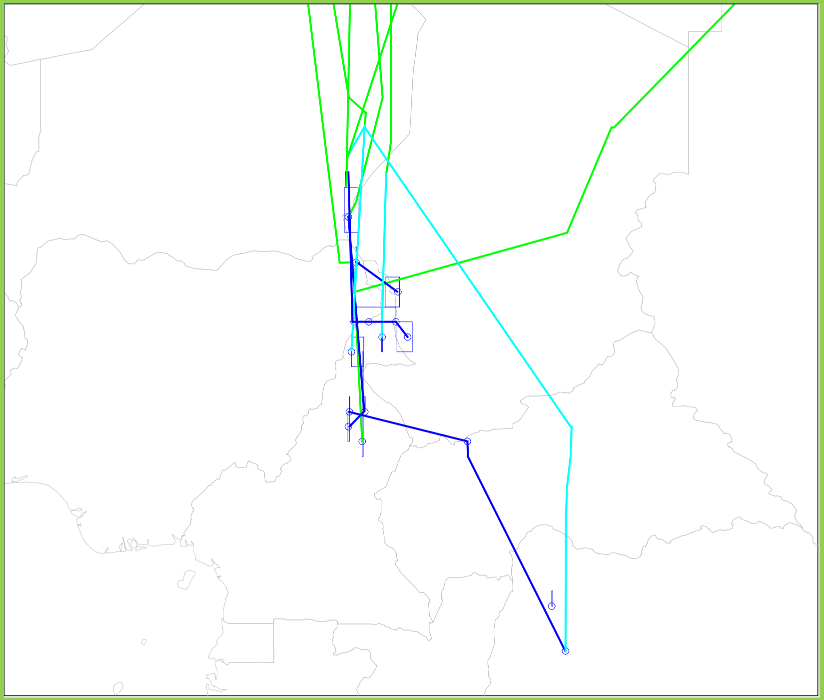
Stationary areas and movement among it during autumnal pre-migratory period, left: 2017, right: 2018. (black: autumnal pre-migration areas and movements, red: movement after start of the autumn migration).

Autumn migratory period

The average speed of movement during autumn migration until reaching the first stationary area used for at least one week in the sub-Saharan non-breeding region was 470 km/day (SE = 129, range 216-745 km/day), it was significantly higher than during the autumnal pre-migration period (Wilcoxon = 6, $P < 0.001$).

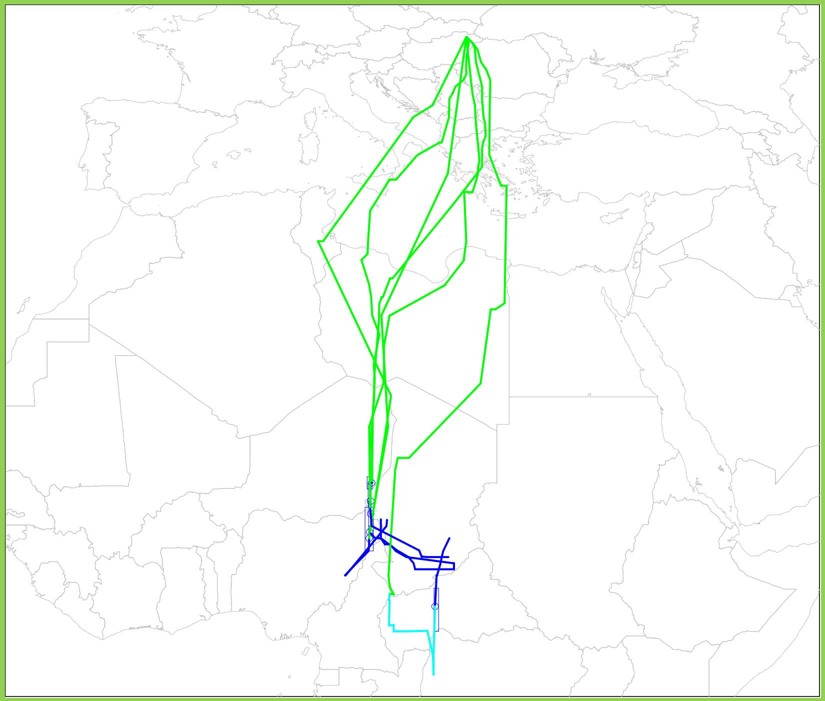
Wintering period

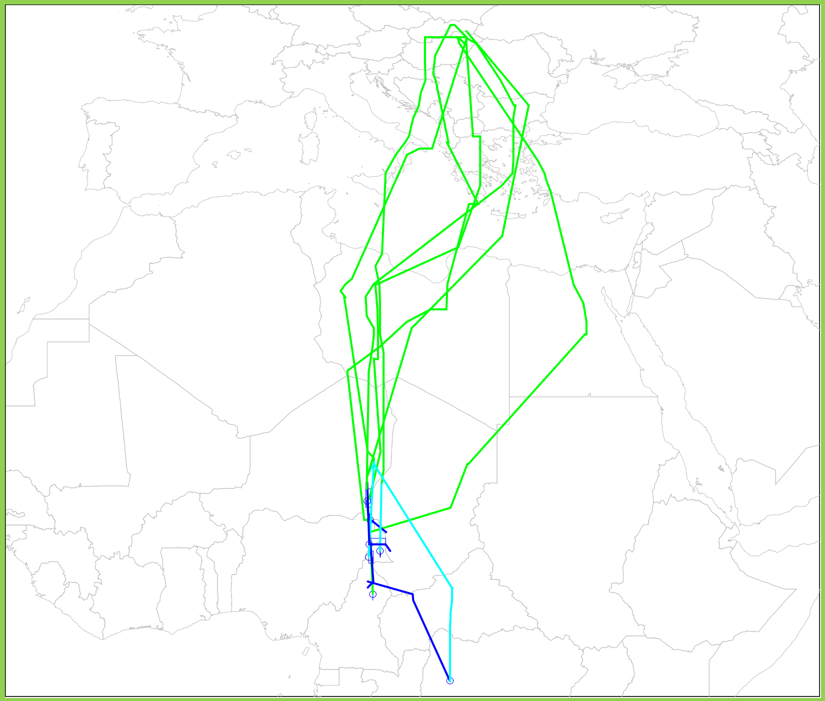




The studied individuals dominantly used the Lake Chad basin as the main non-breeding residence area (Fig. 5), similar to the other two former studies of this population (Szép et al. 2017, Hahn et al. 2021), there were only four individuals (29%) which used different areas in eastern direction (two in SE Chad/Central African Republic) and southern east direction (two in NW Congo).

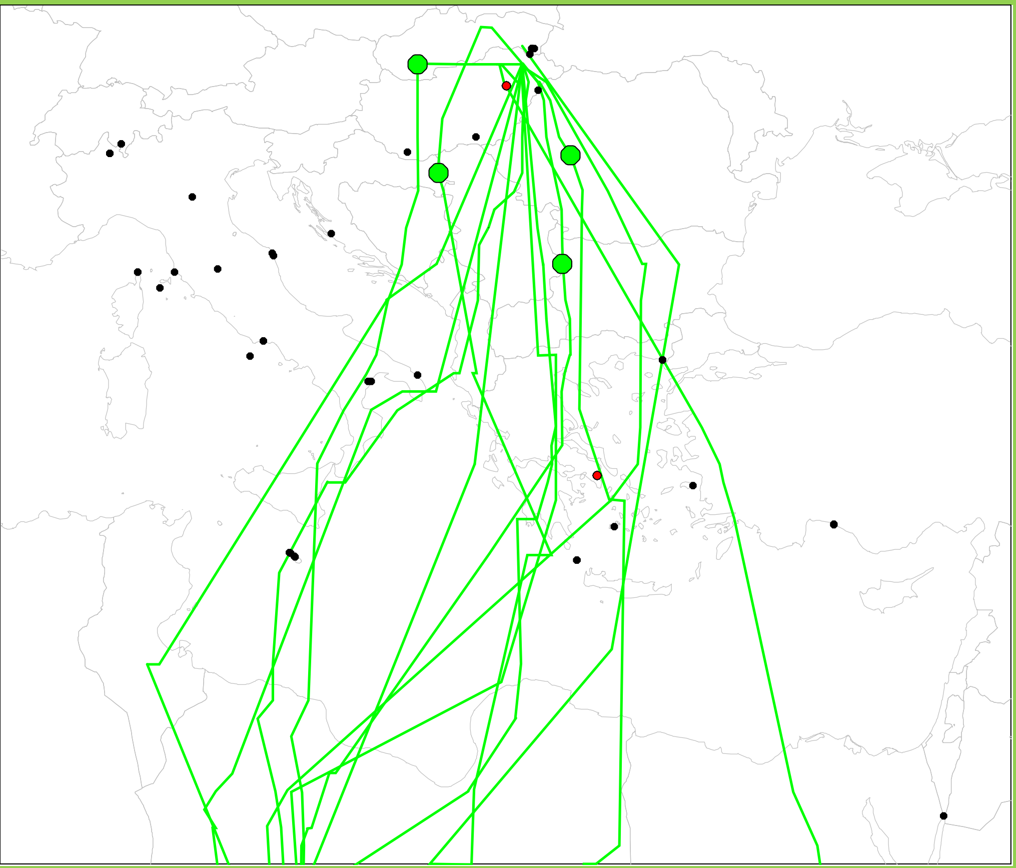
Spring migration period

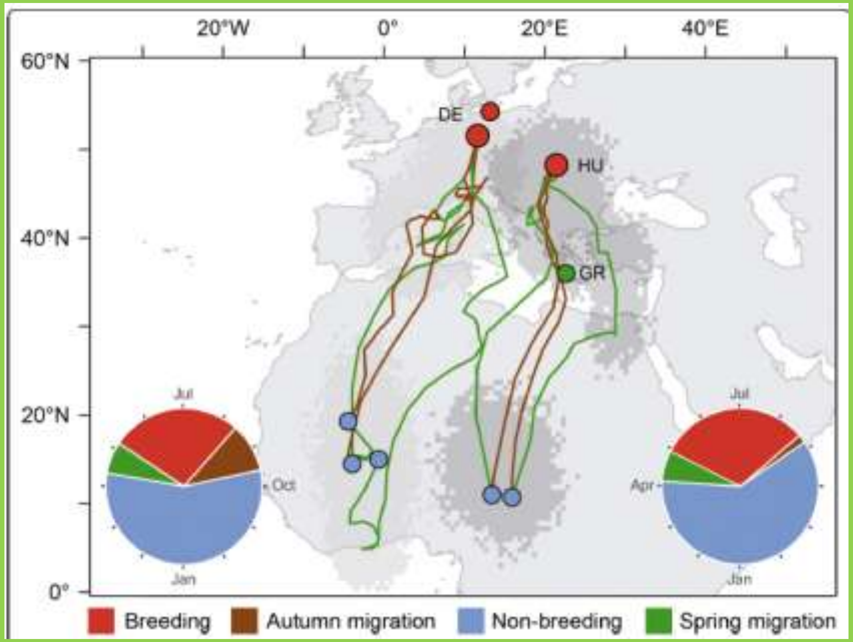




The length of the season until arrival to the final breeding area where the pairing detected was an average 14.3 days (SD = 4.858, range 7.6-23.9 days, n = 13), the birds stayed in stationary areas in total an average 4.731 days (SD=2.623, range 1-9.7 days, n =13), used an average 2.85 stationary areas (SD=1.068, range 2-5) and moved an average 4,136 km among stationary areas (SD = 437, range 3395-4136 km) in this period with an average 484 km/day speed (SD = 182, range 245-763 km/day) which speed did not differ significantly from the speed of the autumn migration across barriers (Wilcoxon = 81, P = 0.878)

Spring migration

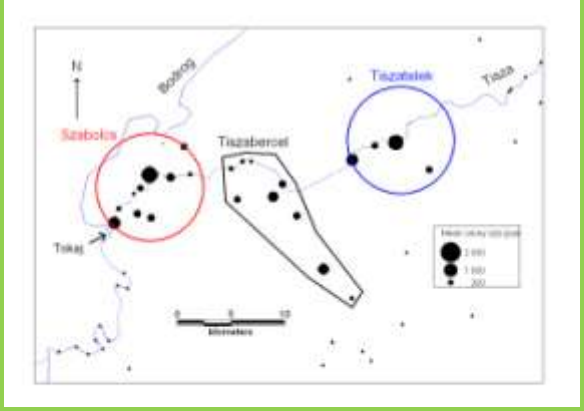




Movement of individuals with geolocators in the spring migration during 2018-2019 and sites of recaptured individuals between 1st April and 1st of June, belong to the studied population (left) and migration and wintering areas of two populations identified by our former study in 2014/2015 (Hahn et al. 2021) (right). (black dot: recaptured before 2018, red dot: recaptured during 2018-2021, green dot: stationary areas where breeding trial without pairing was detected in 2018 and 2019 during spring migration).

Regular survey of breeding since 1995

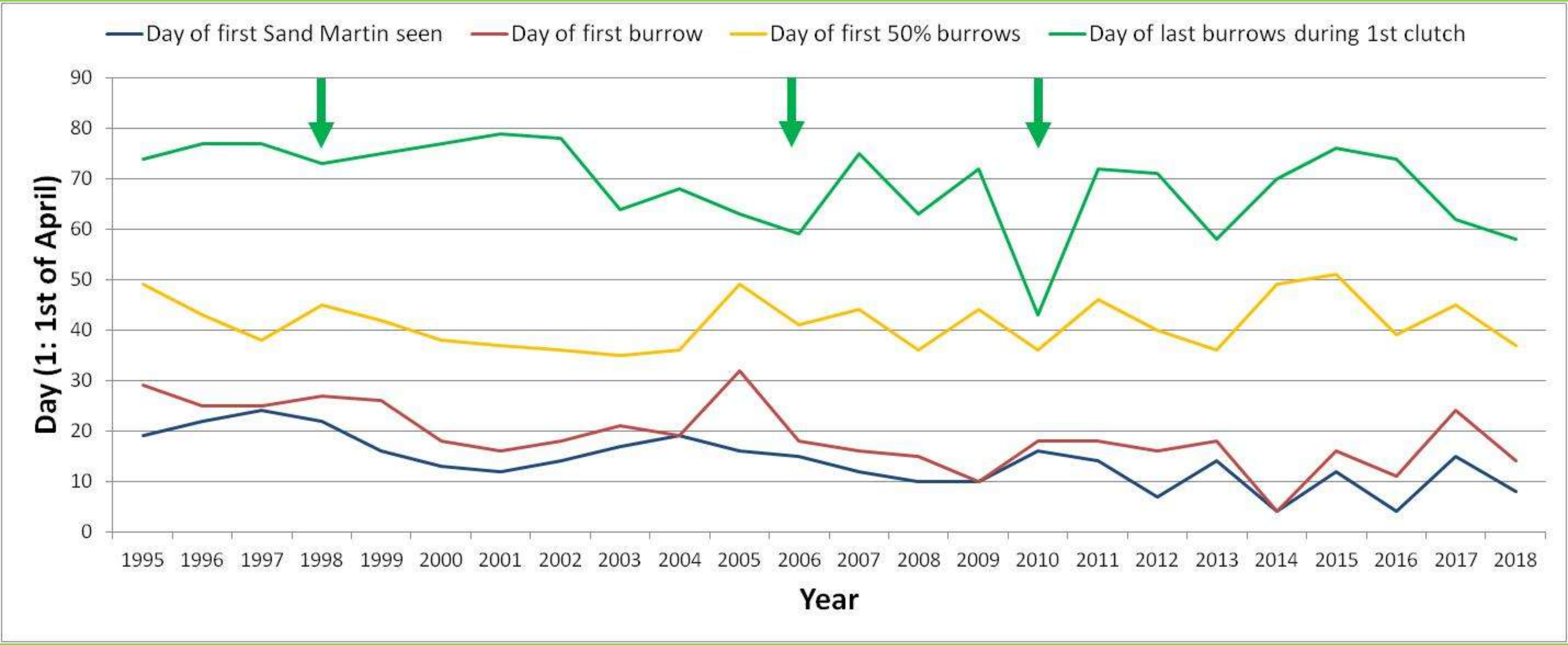
- Annually control 800-2000 burrows, at least once a week, since 1995 in the studied area with videoendoscope (~ 10% of all burrows)
- All burrows in randonly selected 2 meters wide section(s) of colonies
  - 478 sections
  - 29 753 burrows
  - 18 691 nests

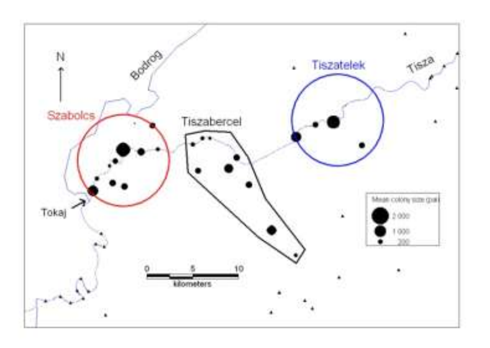


- First Sand Martin arrive ~ 10 days earlier since 1995

– **Arrival of the main part of the population has not changed**

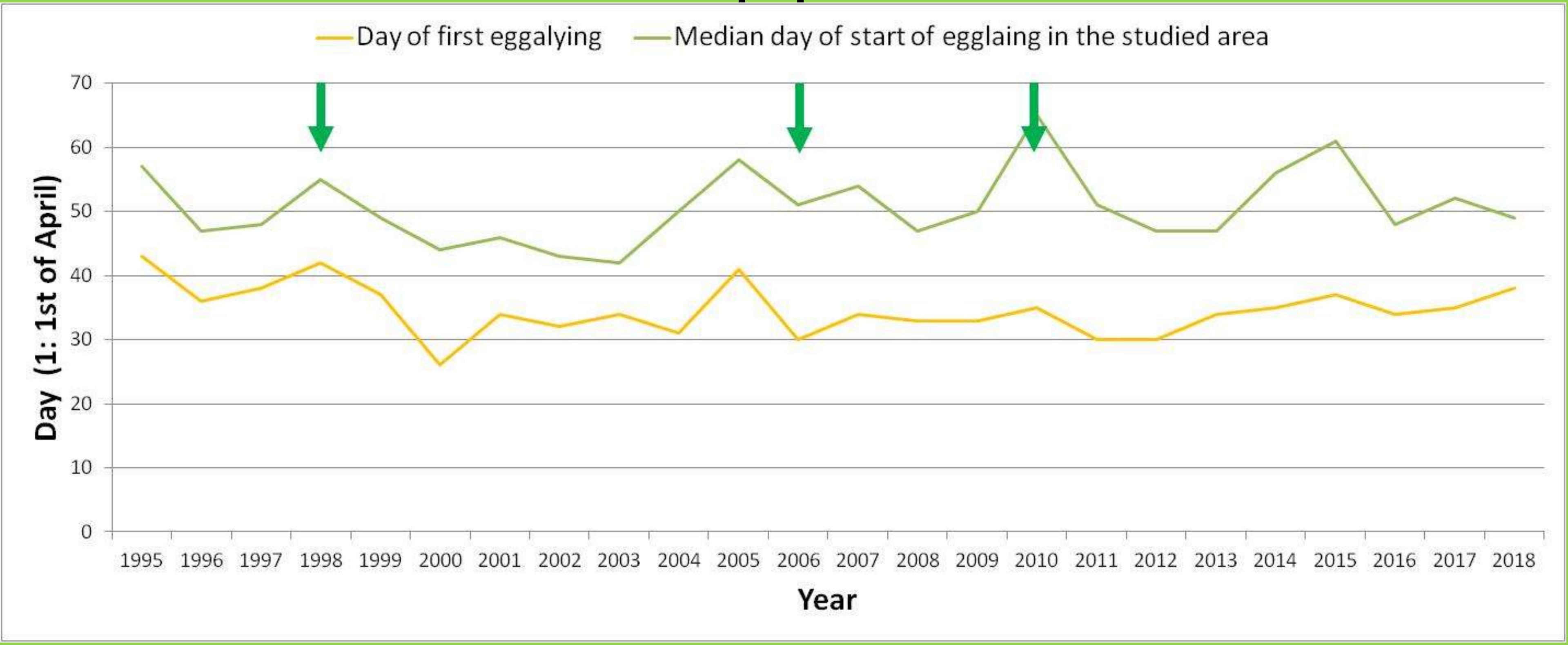
– The day of last arrival occur ~ 10 days earlier

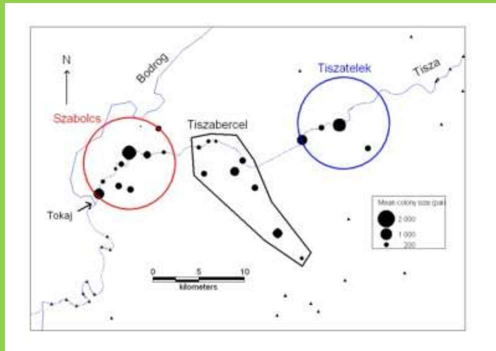




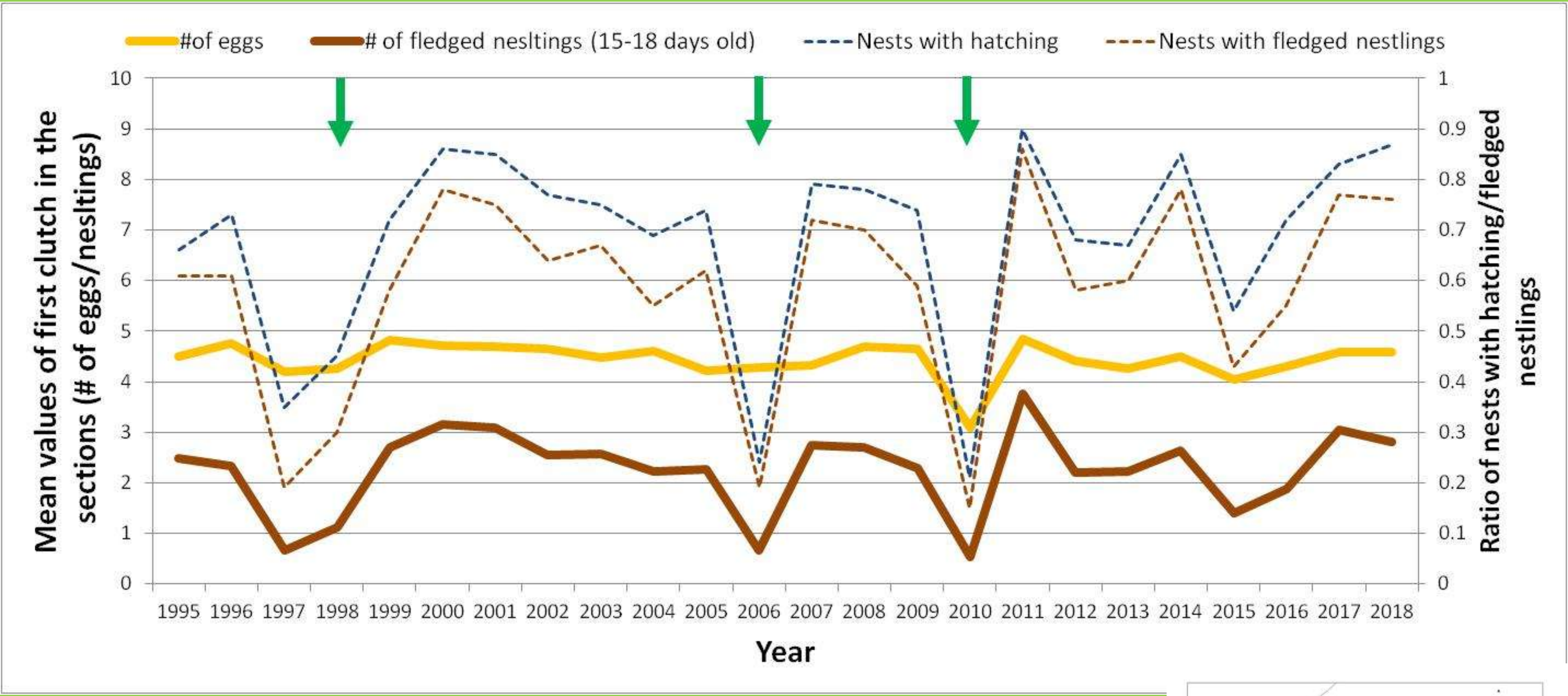
The day of egglaying started ~ 5 days earlier in the case of first breeder

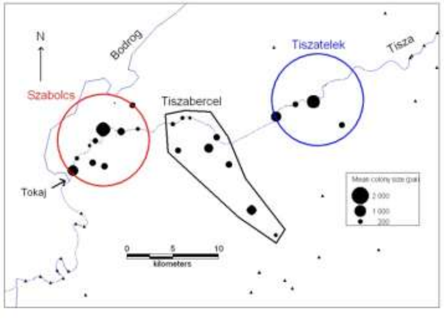
Day of start of egglaying has not changed in the main part of the population



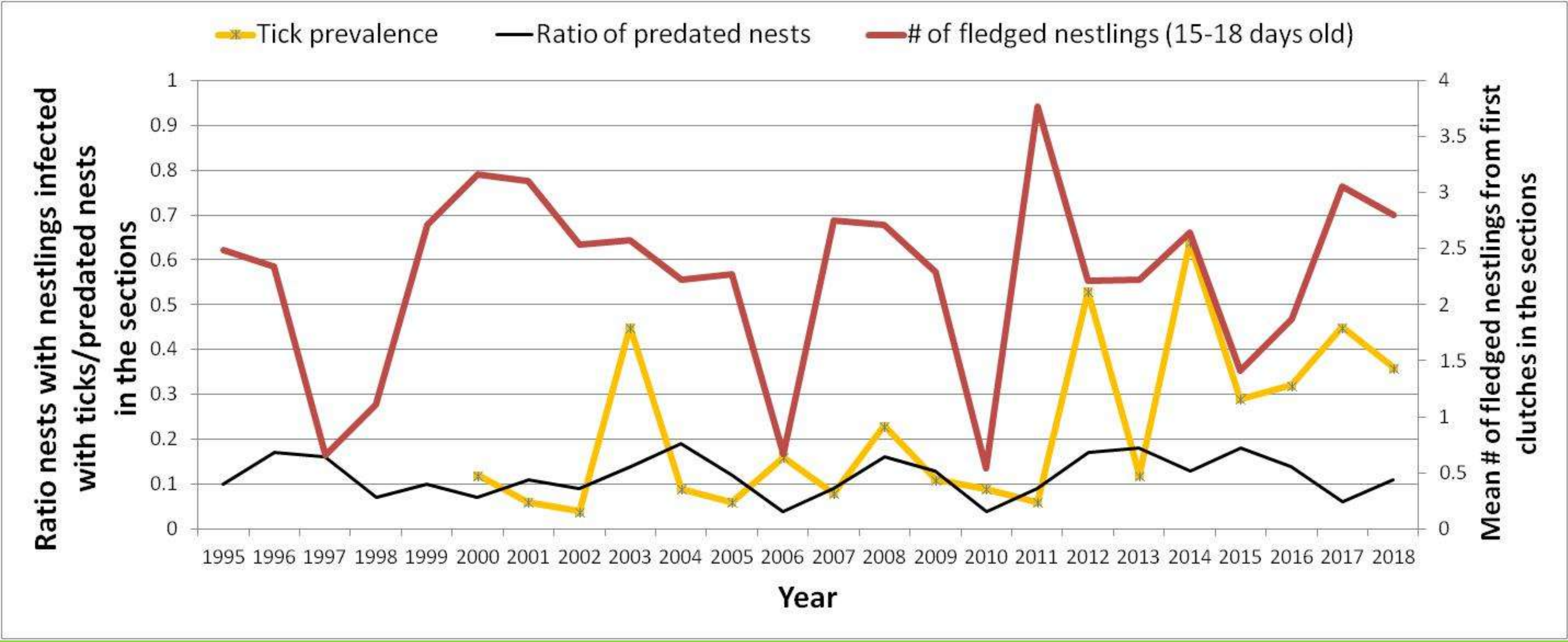


There is no declining trends in the annual breeding values



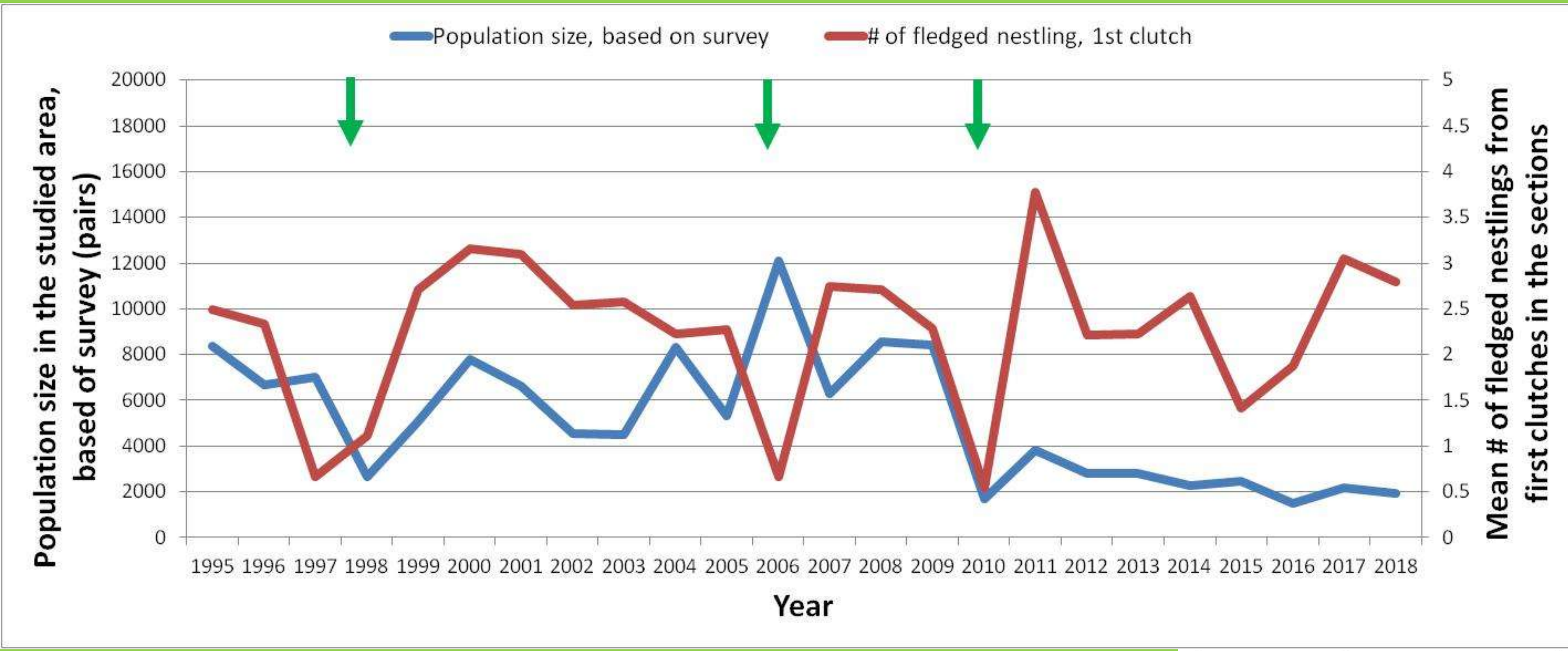


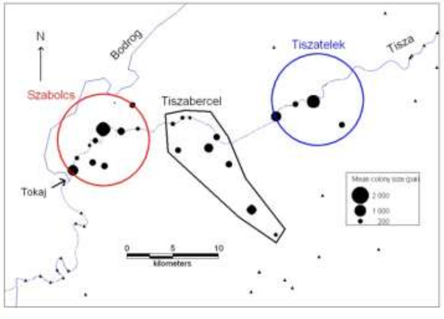
Only the tick prevalance showing increasing tendecy during the last decade



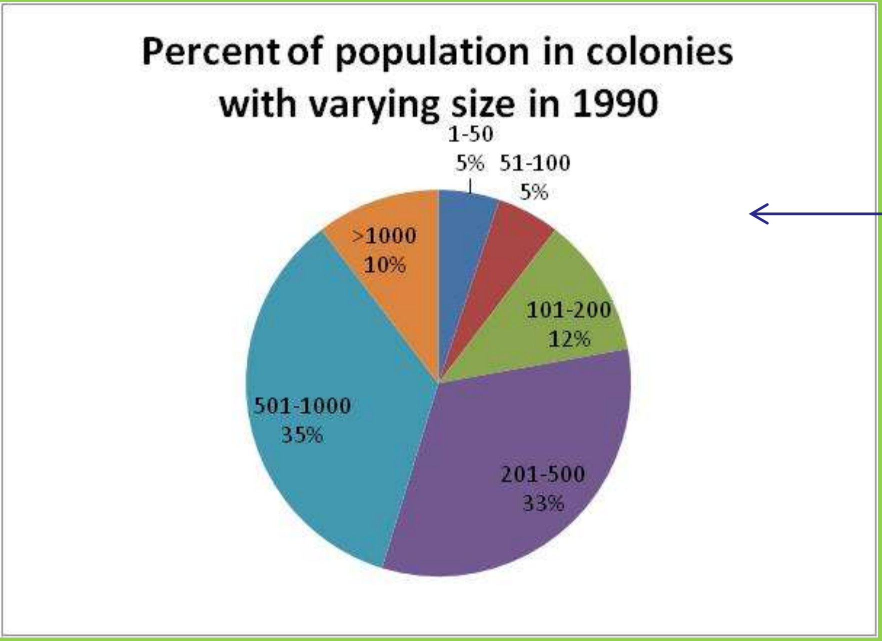
Host specific tick species, Ixodes lividus, – live and breed only in the Sand Martin nest and individuals and has significant effect on condition of nestlings Szép & Møller (1999, 2000 Oecologia)

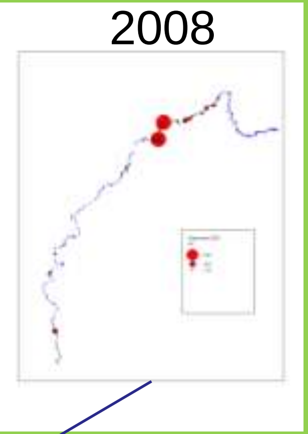
The mean number of nestlings before fledging did not explain the population decline – importance of postfledging condition/survival, emigration/immigration !?

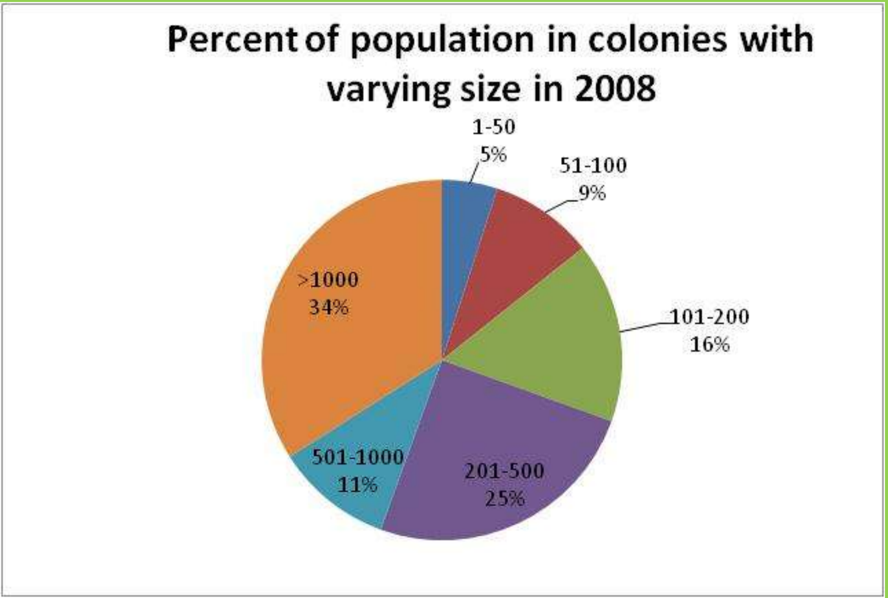


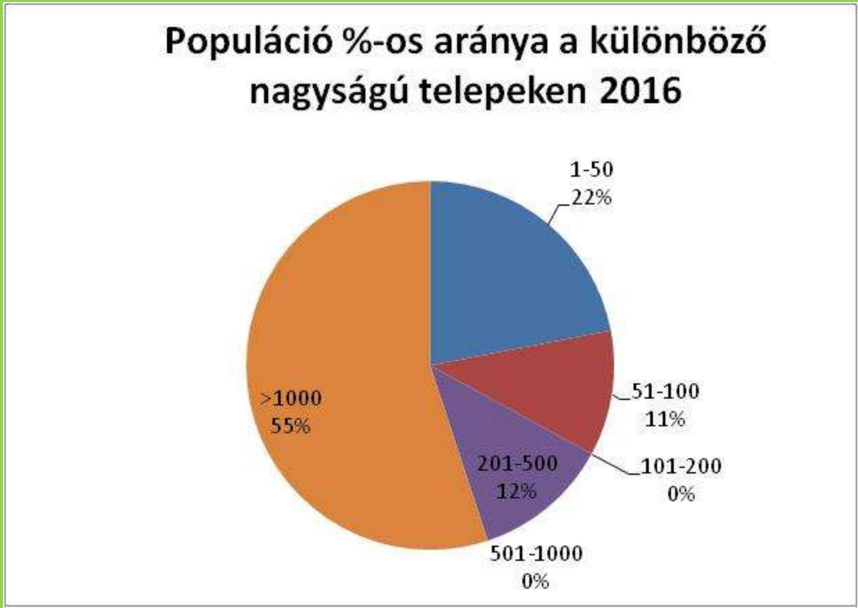


Importance of large and dense colonies increased









Colonial breeding

High level of parasitism cause high cost of this breeding

More than 38 ectoparasite insect species in Sand Martin nest (Masan és Kristofik 1993)

Highly specalised tick species (Ixodes lividus) – Occurs dominantly in Sand Martin, cause heavy impact on development of nestlings

(Szép and Møller 1999, 2000)

What benefits could compensate/exceed the costs of the colonial breeding in the case of Sand Martin?

- **Better protection against predators ?**
  - **Aerial predators**
    - **Earlier detection - dilution**
    - **Low level of individual threat by Hobby (Szép and Barta 1992)**
  - **Nest predators**
    - **Large threat at large and „stable” colonies by fox (Szép et al. 2016)**

Nest predation

- Extrem large level by fox (in 2016 ~30% of 2400 burrows were dug by fox at the largest colony, Szabolcs-Zalkod) https://www.youtube.com/watch?v=g-OUsIeQlcY

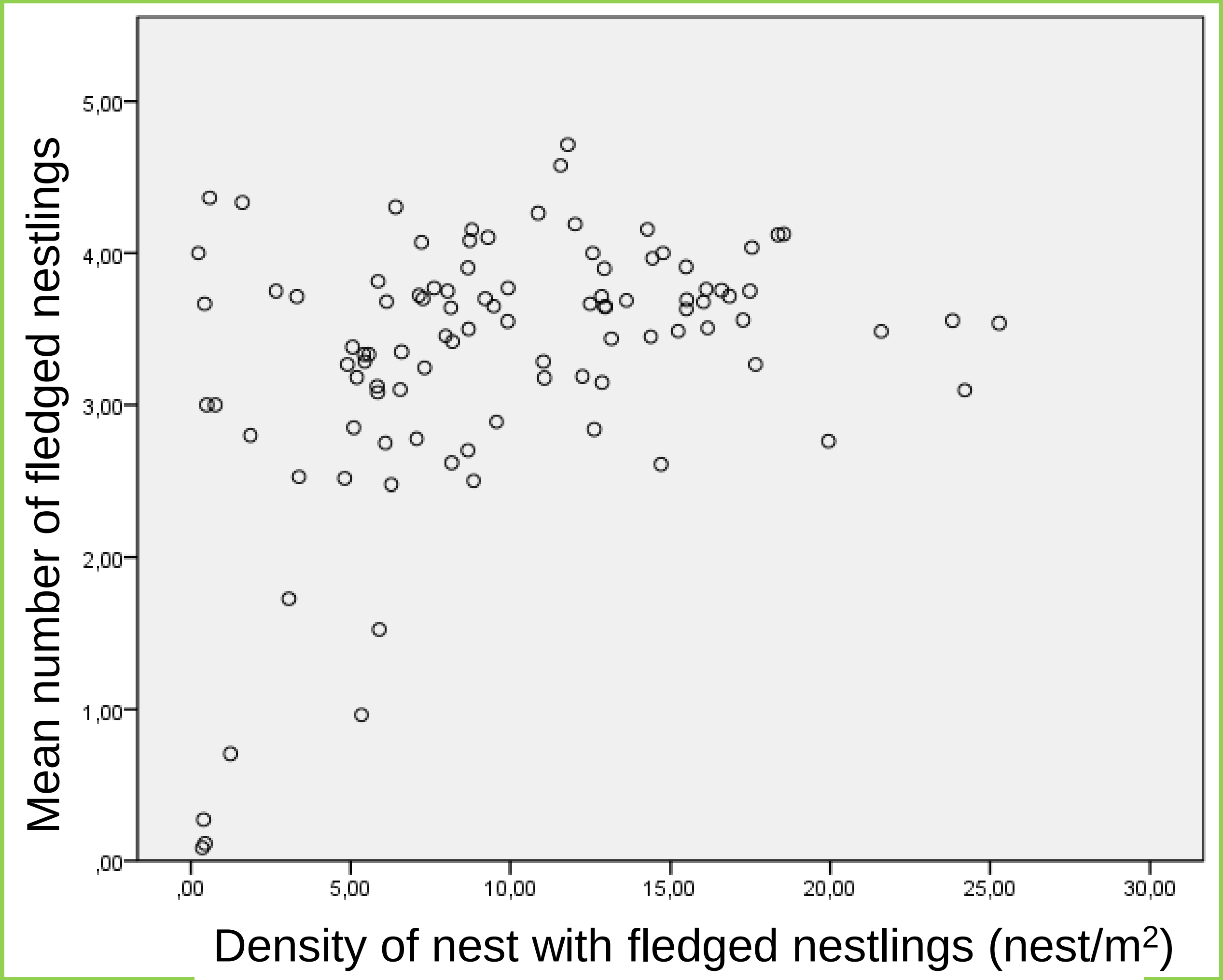
Colonial breeding

Better foraging efficiency -> better condition and number of nestlings

Information Centre – When the food occurs in large but hard to find patches

Passive/active information exchange about food patches – larger/denser colonies with opportunity for more efficient foraging/feeding

More fledged nestlings in more dense subcolonies, when only subcolonies without sign of any nest predation are considered



(r=0.382, P<0.001, N=99, Pearson)

Colonial breeding

Better foraging efficiency -> better condition and number of nestlings

Information Centre – When the food occurs in large but hard to find patches

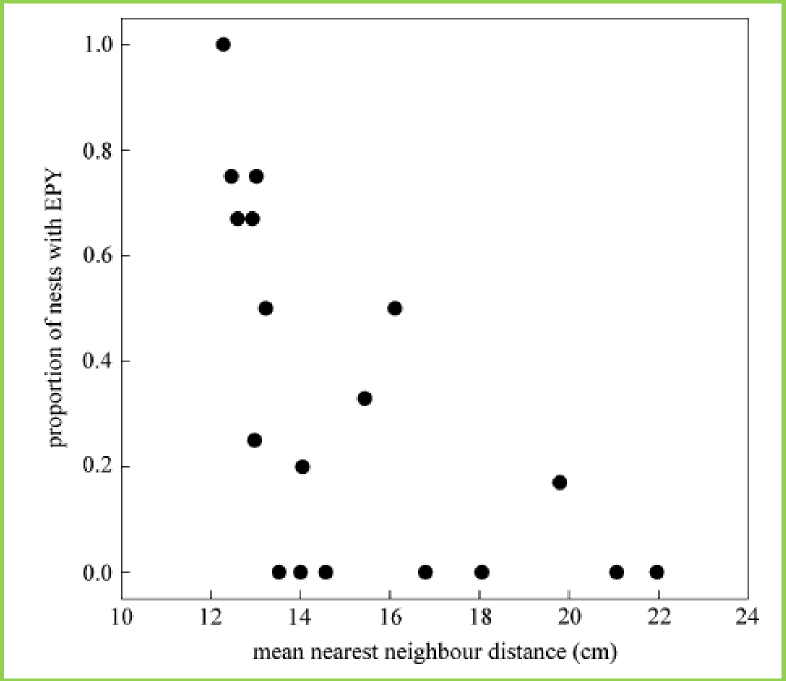
Problem:

This function of the colony able to provide more benefit than solitary breeding when individuals searching for food patches has more direct/indirect benefits than individuals waiting for the information -> needs of „enough" food finders

Colonial breeding

Increasing interaction within individuals

- **Social monogamy, but**
  - **Large number of nest (38%) with extra-pair nestlings (EPY)**
  - **The level of EPY is higher in the case of higher density of nests**
  - **Large individually varying benefits and disadvantages during pair-formation/pairing**



(Augustin et al. 2007)

(r = – 0.76, N = 18, P < 0.001, Spearman)

Which factors potentially responsible behind the decline ?

- Changing intensity of flood intensity – changing quantity and quality breeding habitats?
- Increasing parasite pressure?
- Changing quantity and quality postbreeding/premigratory/wintering habitats by seasonal/transseasonal (carry-over) effects?
- Phenological mismatch?

- Importance to identify used nonbreeding areas, spatial/temporal characteristics
- Investigation of postfledging condition/survival
- Investigation of natal/breeding dispersals, direction/level of emigration/immigration – other populations
- Investigation on levels of individual/population, IPM

- Opportunity to use new methods for difficult to measure parameters, geolocators, MOTUS network with traditional radiotransmitters, LifeTags, Blümorpho
- Opportunity to use remote sensing data, chemical/physical characteristics of feathers

Recent directions

- More behavioural investigations of parents during arrival, pairing, mate-guarding and nestling feeding periods with genetic studies (paternity/maternity, sexing, telomer)

- Specific radiotelemetry investigation with LifeTag

Who, where, what, how

Opportunity to investigate dispersal