Invierno, animales y cambio climático

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IMIB – Instituto Mixto de Investigación en Biodiversidad

CSIC
Consejo Superior de Investigaciones Científicas

Universidad de Oviedo

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Technician

Heini Ali-Kovero

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Maria Delgado

Dmitry Schigel

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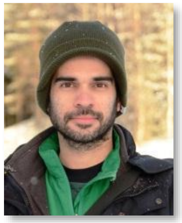
Jukka Sirén

PhD Students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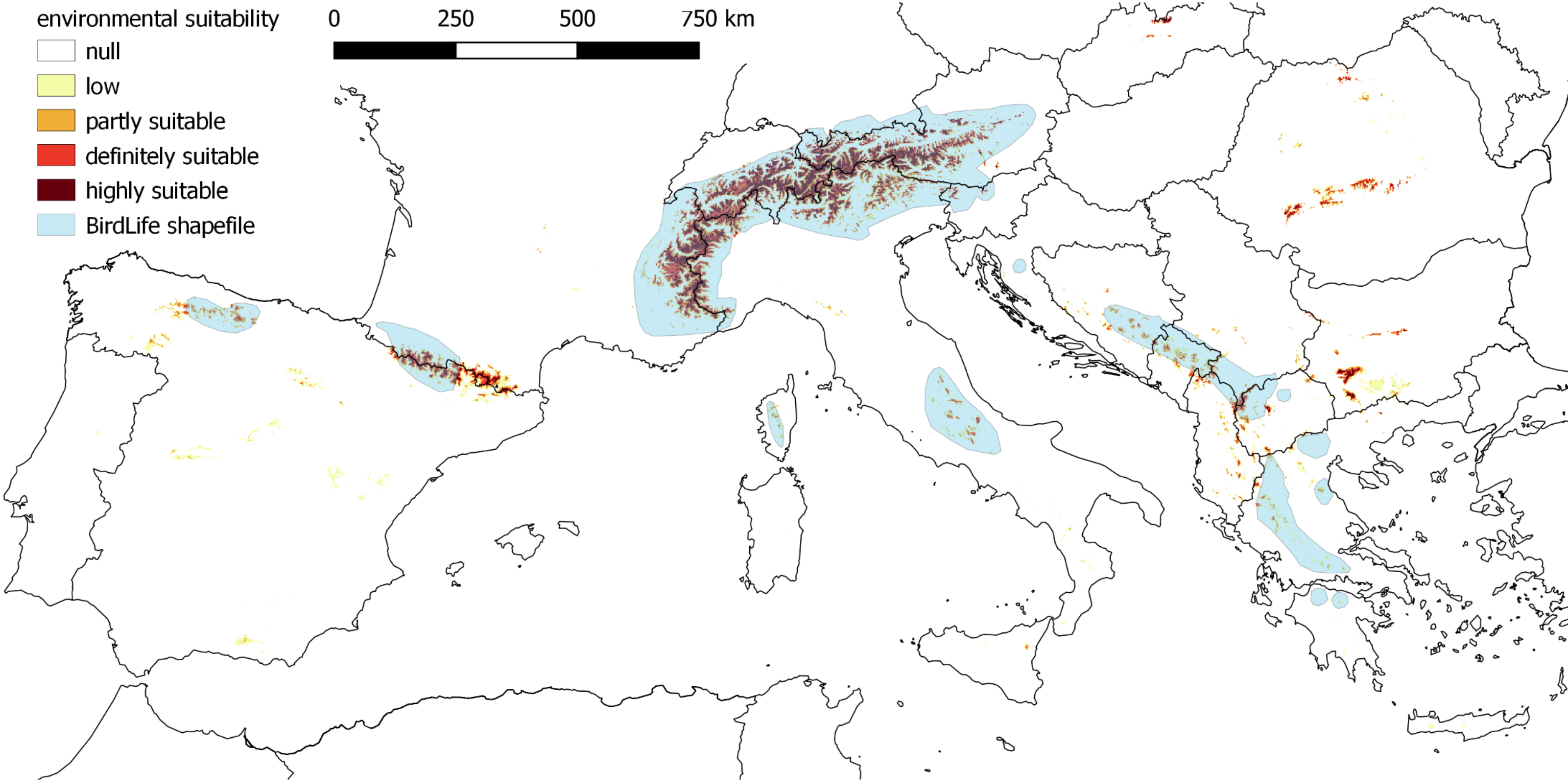
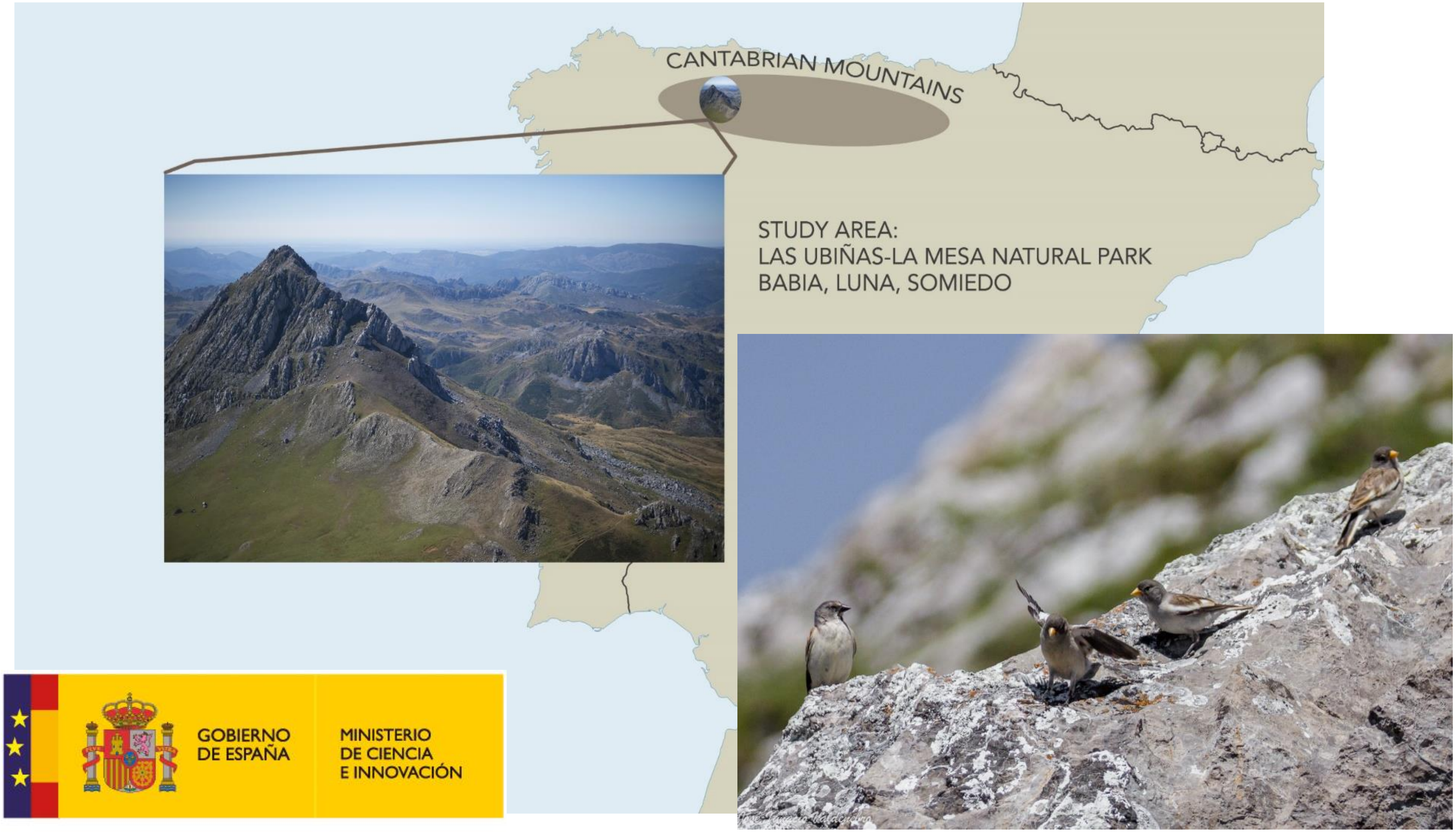

environmental suitability
null
low
partly suitable
definitely suitable
highly suitable
BirdLife shapefile
0
250
500
750 km

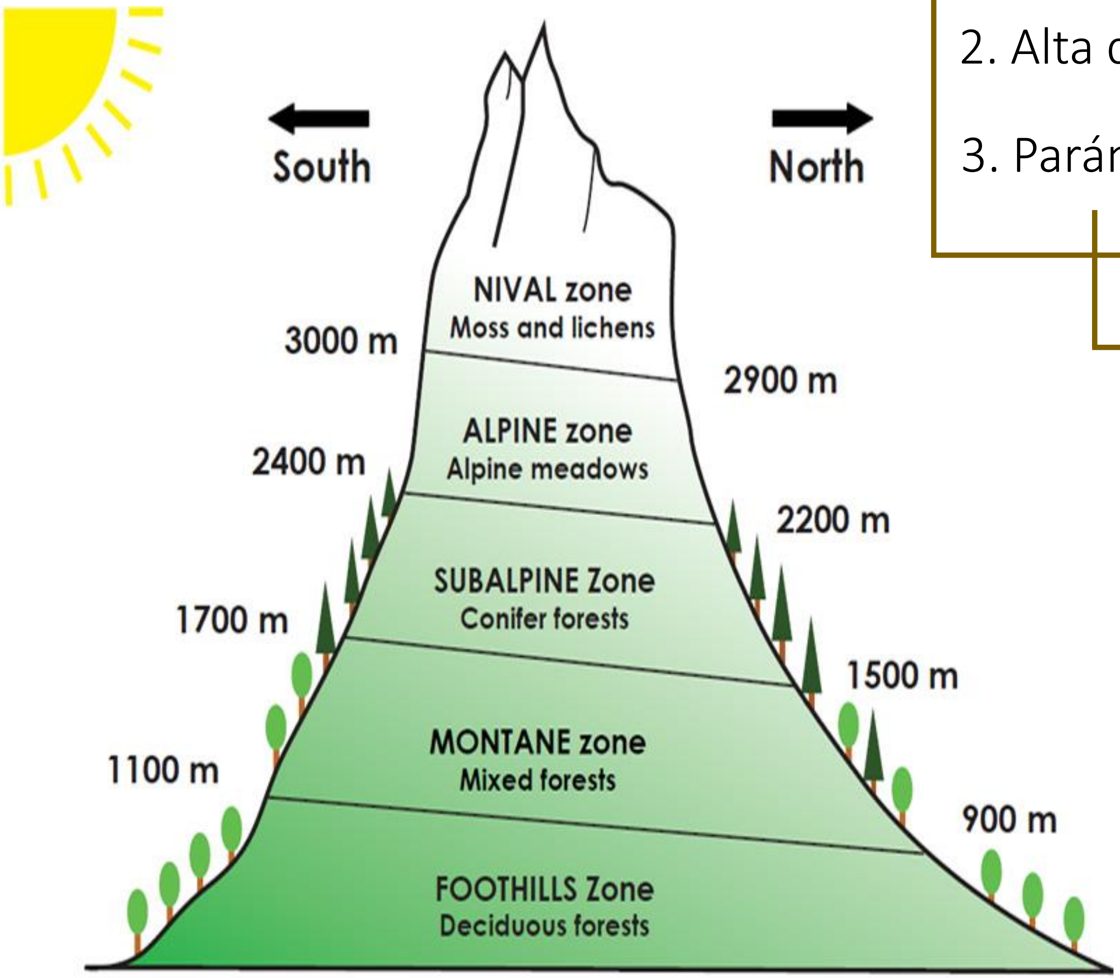

CANTABRIAN MOUNTAINS

STUDY AREA:
LAS UBIÑAS-LA MESA NATURAL PARK
BABIA, LUNA, SOMIEDO

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

FECYT
FUNDACIÓN ESPAÑOLA PARA LA CIENCIA Y LA TECNOLOGÍA

LAS MONTAÑAS SON ÚNICAS


South
North
NIVAL zone
Moss and lichens
3000 m
2900 m
ALPINE zone
Alpine meadows
2400 m
2200 m
SUBALPINE Zone
Conifer forests
1700 m
1500 m
MONTANE zone
Mixed forests
1100 m
900 m
FOOTHILLS Zone
Deciduous forests

1. Alta diversidad climática en el espacio
2. Alta diversidad climática en el tiempo
3. Parámetros físicos

- Alta tasa de especiación
- Coexistencia
- Persistencia de linajes de diferente trayectoria evolutiva

- Cunas

- Refugios

de...

BIODIVERSIDAD

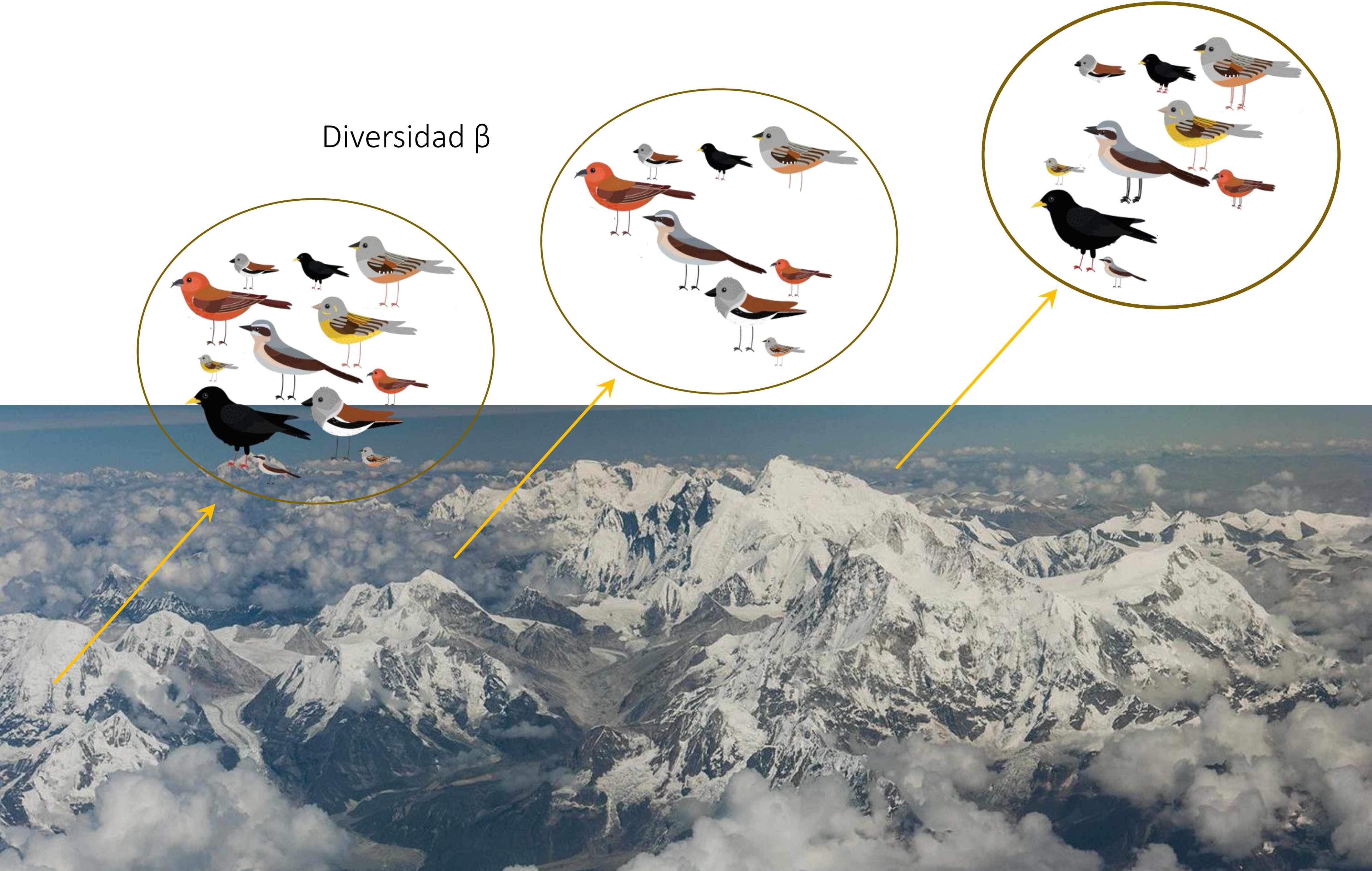
VIDA EN LA TIERRA

MIDIENDO LA BIODIVERSIDAD

McGill et al. (2015) Trends Ecol & Evol

MIDIENDO LA BIODIVERSIDAD

Riqueza de especies



Diversidad α

Diversidad β

MIDIENDO LA BIODIVERSIDAD

Convention on Biological Diversity

Información

(a) Comprensible
(b) Adecuada
(c) Científicamente rigurosa
(d) Estandarizada
(e) Relevante
(f) Global
(g) Representativa

Causas subyacentes de la pérdida de biodiversidad

Reducir las presiones directas sobre la biodiversidad y promover el uso sostenible

Mejorar el estado de la biodiversidad salvaguardando los ecosistemas, las especies y la diversidad genética

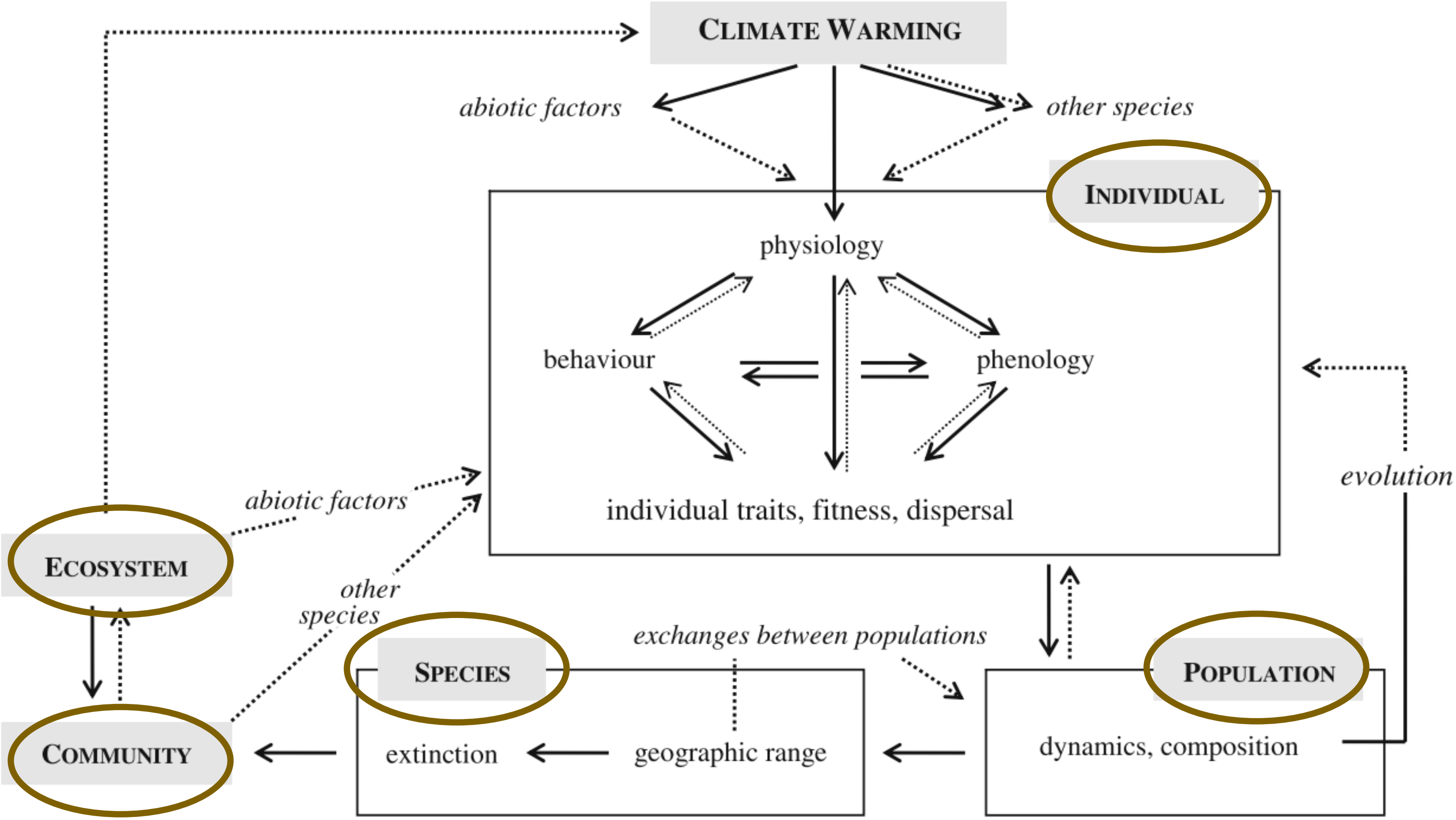
Mejorar los beneficios para todos de la biodiversidad y los servicios de los ecosistemas

Implementación

Pereira et al (2013) ***Essential Biodiversity Variables****. Science*

Schmeller et al (2018) A suite of ***essential biodiversity variables*** *for detecting critical biodiversity change. Biological Reviews*

MIDIENDO LA BIODIVERSIDAD


CLIMATE WARMING
abiotic factors
other species
INDIVIDUAL
physiology
behaviour
phenology
individual traits, fitness, dispersal
evolution
abiotic factors
ECOSYSTEM
other species
COMMUNITY
SPECIES
extinction
geographic range
exchanges between populations
POPULATION
dynamics, composition

Lepetz et al. (2009) Biodiv & Conserv

Causas subyacentes de la pérdida de biodiversidad

Reducir presiones directas sobre la biodiversidad y promover el uso sostenible

Mejorar estado de biodiversidad

Mejorar los beneficios

Implementación

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

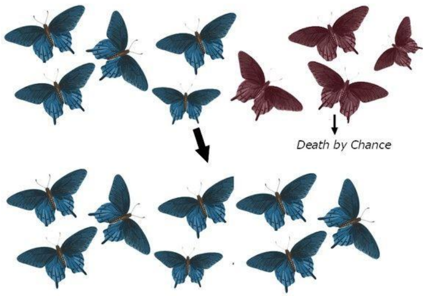
● Main contribution

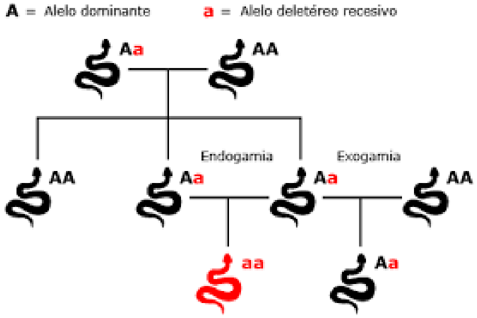
● Supplementary contribution

Genetic composition	Allelic diversity
	Co-ancestry
	Population genetic differentiation
	Breed and variety diversity

La **diversidad genética** es el componente básico de la biodiversidad y permite que las especies persistan al cambio ambiental a escalas cortas (ecológicas) y largas (evolutivas) de tiempo

<


Death by Chance


A = Alelo dominante
a = Alelo deletéreo recesivo
Aa
AA
AA
Aa
Endogamia
Aa
Exogamia
AA
aa
Aa

Deriva génica

Depresión endogámica

>

Favorece la riqueza de especies

Funcionamiento y la resiliencia

Resiliencia

evolutiva

Pereira et al (2013) Science

Schmeller et al (2019) A suite of ***essential biodiversity variables*** *for detecting critical biodiversity change. Biological Reviews*

Causas subyacentes de la pérdida de biodiversidad

Reducir las presiones directas sobre la biodiversidad y promover el uso sostenible

Mejorar el estado de la biodiversidad salvaguardando ecosistemas, especies y diversidad genética

Mejorar los beneficios para todos de la biodiversidad y los servicios de los ecosistemas

Implementación

● Main contribution

● Supplementary contribution

1
2
3
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15
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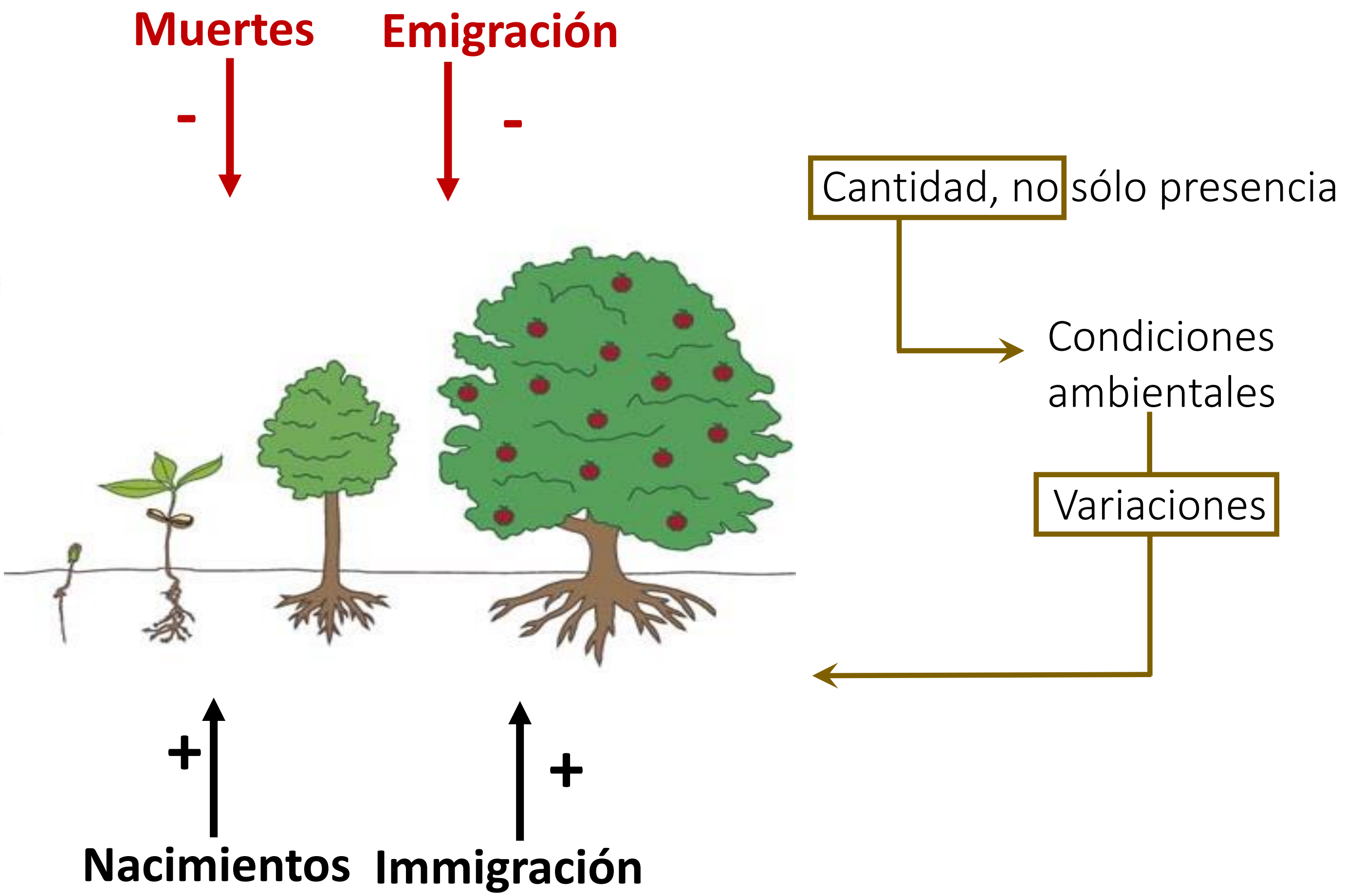
17
18

Species populations	**Species distribution/ range dynamics**
	Population abundance
	Survival rates
	Population structure by age/size class


Muertes -

Emigración -

Cantidad, no sólo presencia

Condiciones ambientales

Variaciones

+ **Nacimientos**

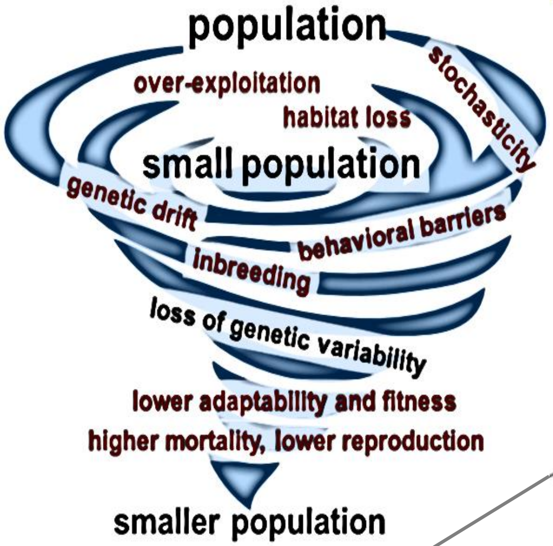
Immigración +

Pereira et al (2013) Science

Schmeller et al (2018) A suite of ***essential biodiversity variables*** *for detecting critical biodiversity change. Biological Reviews*

It's official, we're in the Anthropocene

Los problemas de las poblaciones pequeñas

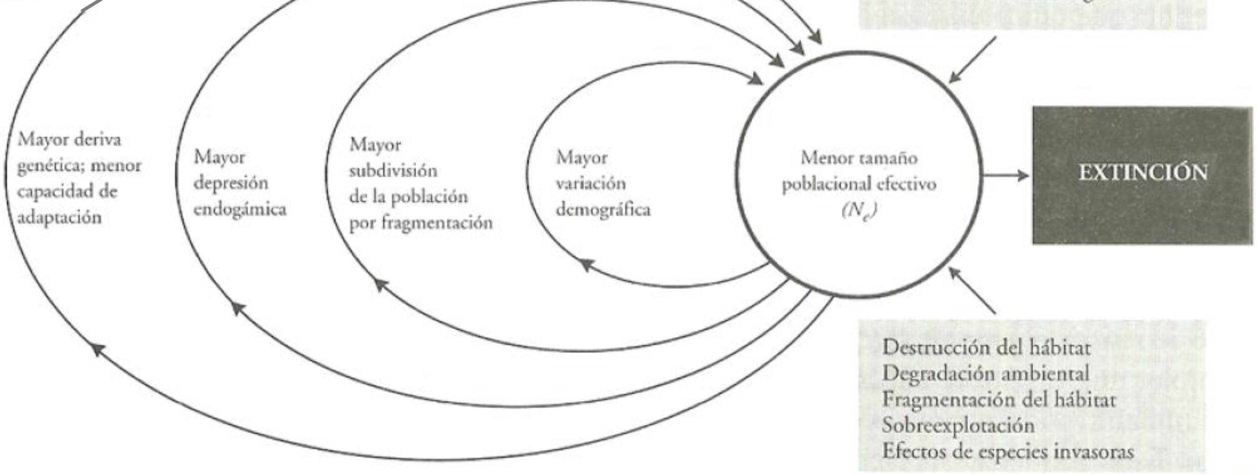

population
stochasticity
over-exploitation
habitat loss
small population
genetic drift
behavioral barriers
inbreeding
loss of genetic variability
lower adaptability and fitness
higher mortality, lower reproduction
smaller population

Las poblaciones pequeñas tienen una mayor tendencia a extinguirse debido a:

(1) PÉRDIDA DE VARIABILIDAD GENÉTICA

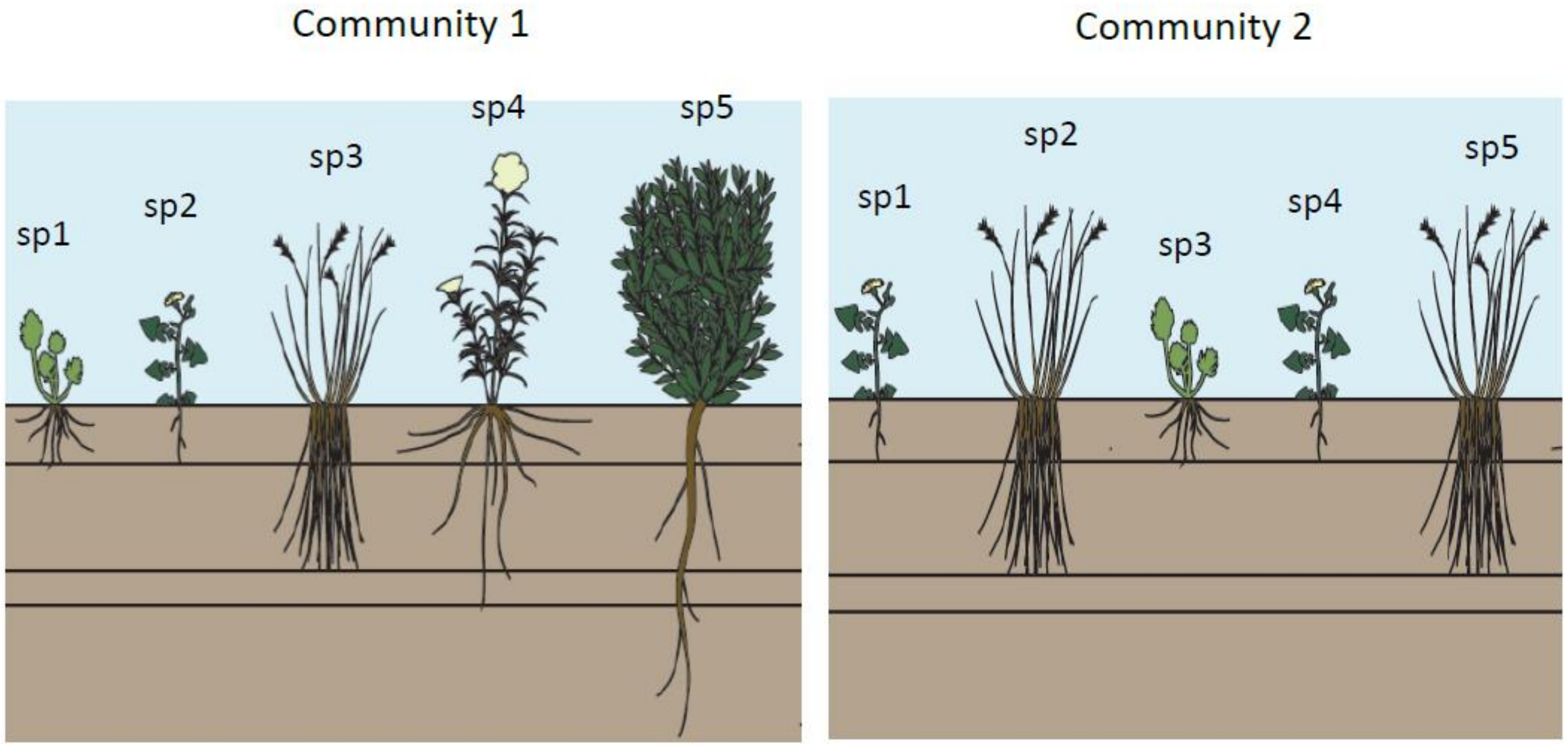
(2) **VARIACIÓN DEMOGRÁFICA**

(3) **VARIACIÓN AMBIENTAL**


Variación ambiental
Eventos catastróficos
Cambio climático global
Mayor deriva genética; menor capacidad de adaptación
Mayor depresión endogámica
Mayor subdivisión de la población por fragmentación
Mayor variación demográfica
Menor tamaño poblacional efectivo (N_e)
EXTINCIÓN
Destrucción del hábitat
Degradación ambiental
Fragmentación del hábitat
Sobreexplotación
Efectos de especies invasoras

Gilpin & Soulé (1986)

Un ecosistema sano y resistente depende de las diferentes características de las especies y lo que cada una de ellas aporta al ecosistema


Community 1
Community 2
sp1
sp2
sp3
sp4
sp5
sp1
sp2
sp3
sp4
sp5

Pereira et al (2013) Science

Schmeller et al (2019) A suite of ***essential biodiversity variables*** *for detecting critical biodiversity change. Biological Reviews*

CONSERVACIÓN VIDA EN LA TIERRA

La biodiversidad es siempre buena

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the N Co
The Influenc
Nor Jenn
"... should be read by everyone concerned with the fate of our own society and species." —Paul R. Ehrlich
A Wealth of Wild Species
Storehouse for Human Welfare
Norman Myers
Author of The Sinking Ark
Ballantine/Friends of the Earth
ORIGINAL
Dr. Paul R. Ehrlich
The P
THE MACHINERY OF NATURE
The Living World Around Us– And How It Works
"A brilliant insider's view: the complicated and swiftly moving science of ecology is here explained in lucid and entertaining style by one of its foremost practitioners. No one has contributed more broadly than Ehrlich to the many basic and applied issues, or explained the subject more skillfully to the general public."
Edward O. Wilson
Harvard University, Author of Sociobiology
PAUL R. EHRLICH
Author of The Population Bomb
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The bestselling 'celebration of the miracle of evolution' THE NEW YORK TIMES
The Diversity of Life
New Edition
Edward O. Wilson
Twice Winner of the Pulitzer Prize
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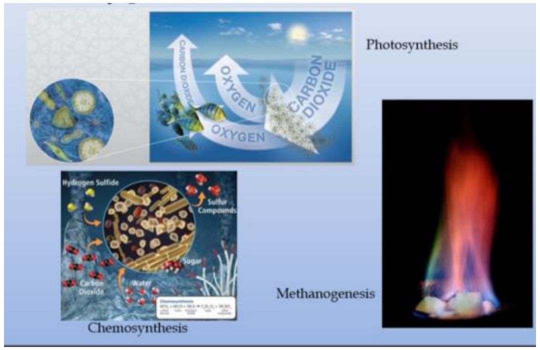
BIODIVERSITY
E. O. Wilson, Editor

VALOR UTILITARIO DE BIODIVERSIDAD

Funciones de los ecosistemas

1. Funciones del hábitat
2. Funciones regulatorias
3. Funciones productoras
4. Funciones culturales

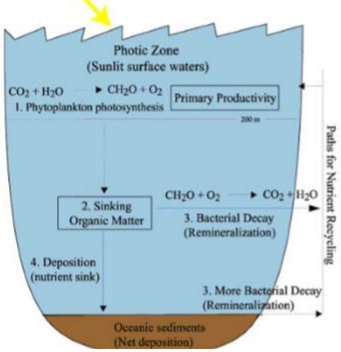
Producción primaria


Photosynthesis
CARBON DIOXIDE
OXYGEN
OXYGEN
CARBON DIOXIDE
Hydrogen Sulfide
Sulfur Compounds
Sugar
Carbon Dioxide
Water
Methanogenesis
Chemosynthesis

Turismo y ciencia

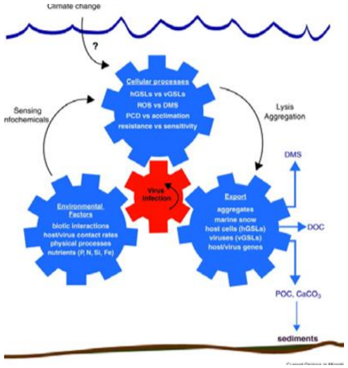
© Capt. Jim Robertson

Ciclo de nutrientes

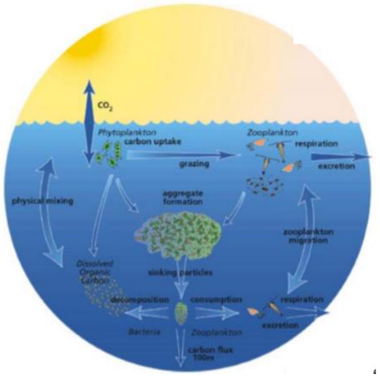

Photic Zone
(Sunlit surface waters)
CO2 + H2O → CH2O + O2
1. Phytoplankton photosynthesis
Primary Productivity
200 m
2. Sinking Organic Matter
CH2O + O2 → CO2 + H2O
3. Bacterial Decay (Remineralization)
4. Deposition (nutrient sink)
3. More Bacterial Decay (Remineralization)
Oceanic sediments (Net deposition)
Paths for Nutrient Recycling

Resiliencia

Control biológico

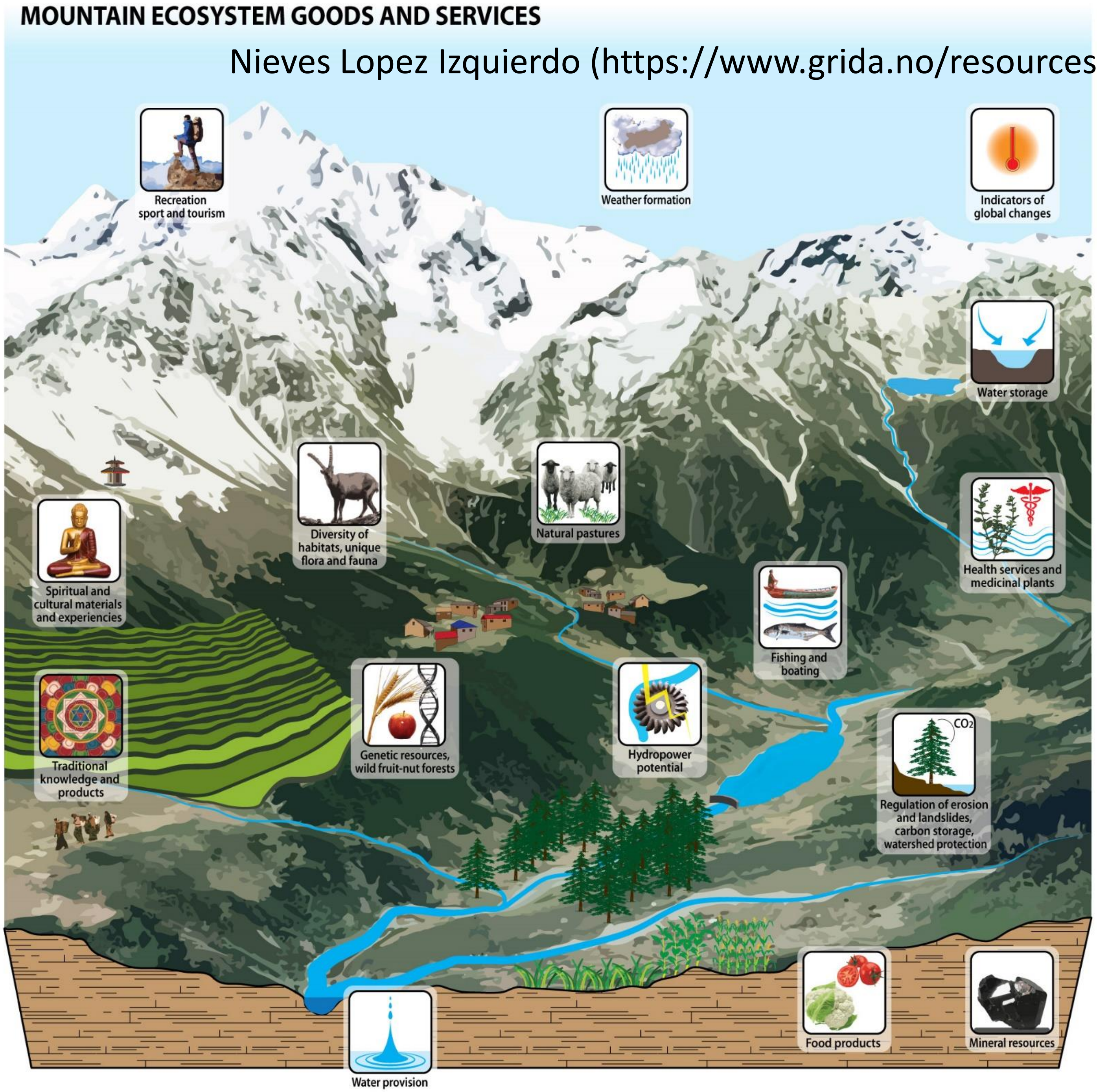

Climate change
?
Sensing infochemicals
Cellular processes
hGSLs vs vGSLs
ROS vs DMS
PCD vs acclimation
resistance vs sensitivity
Lysis
Aggregation
Virus infection
Environmental Factors
biotic interactions
host/virus contact rates
physical processes
nutrients (P, N, Si, Fe)
Export
aggregates
marine snow
host cells (hGSLs)
viruses (vGSLs)
host/virus genes
DMS
DOC
POC, CaCO3
sediments

Clima y gases atmósfericos


CO2
Phytoplankton
carbon uptake
grazing
Zooplankton
respiration
excretion
physical mixing
aggregate formation
zooplankton migration
Dissolved Organic Carbon
sinking particles
decomposition
consumption
respiration
excretion
Bacteria
Zooplankton
carbon flux 100m

Darwin (1859) On the Origin of species

Groot et al. (2002)


MOUNTAIN ECOSYSTEM GOODS AND SERVICES
Recreation sport and tourism
Weather formation
Indicators of global changes
Water storage
Spiritual and cultural materials and experiencies
Diversity of habitats, unique flora and fauna
Natural pastures
Health services and medicinal plants
Fishing and boating
Traditional knowledge and products
Genetic resources, wild fruit-nut forests
Hydropower potential
CO2
Regulation of erosion and landslides, carbon storage, watershed protection
Water provision
Food products
Mineral resources

Nieves Lopez Izquierdo (https://www.grida.no/resources/12619)

PÉRDIDA BIODIVERSIDAD

El mundo está cambiando, y la biodiversidad no es una excepción

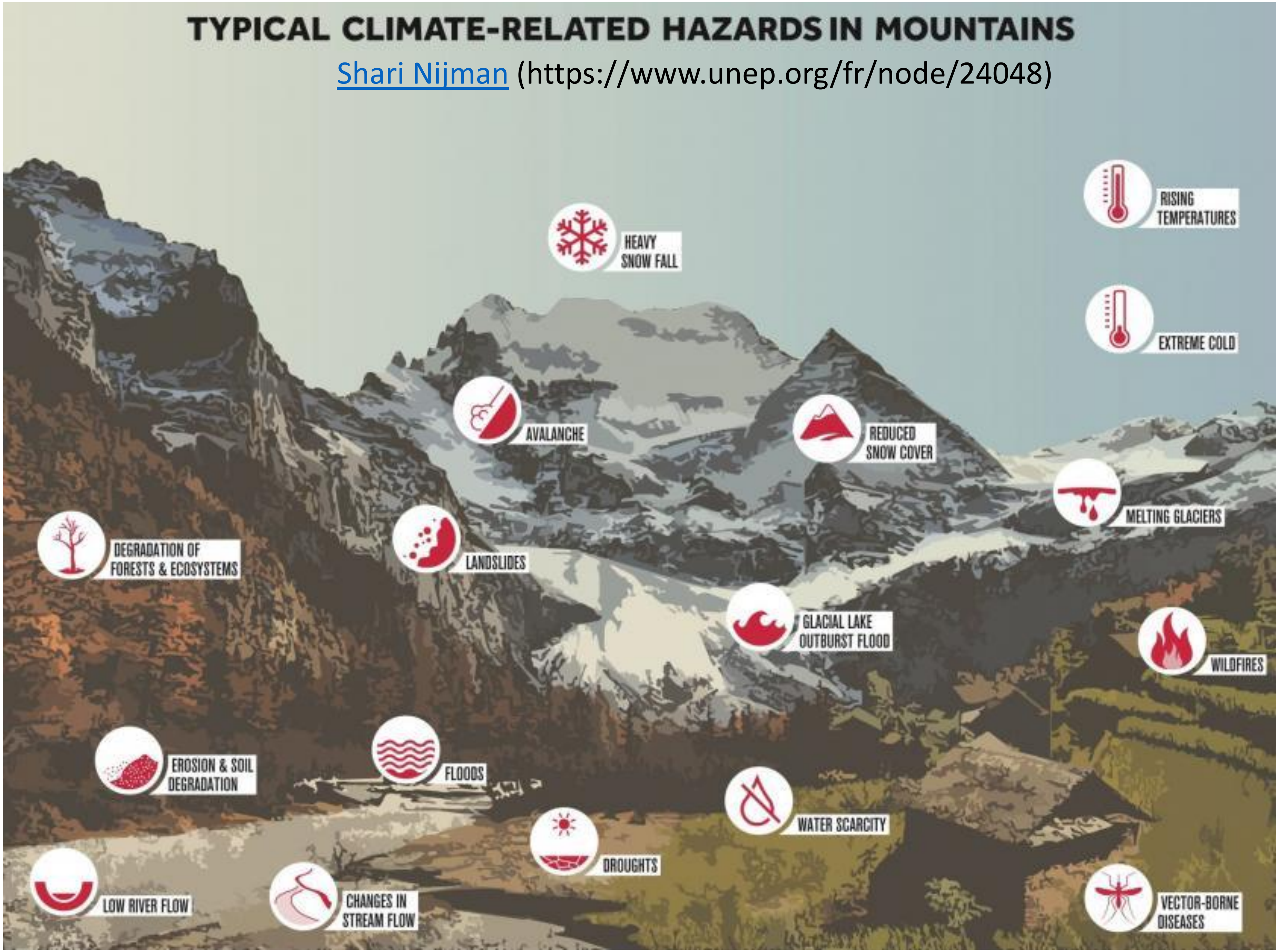
It's official, we're in the Anthropocene

Causas de pérdida de biodiversidad:

1. Pérdida de hábitat y fragmentación
2. Contaminación
3. Sobrexplotación
4. Cambio climático
5. Especies invasoras

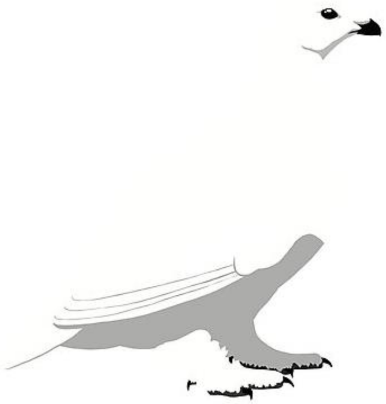
ESCENARIOS DE BIODIVERSIDAD

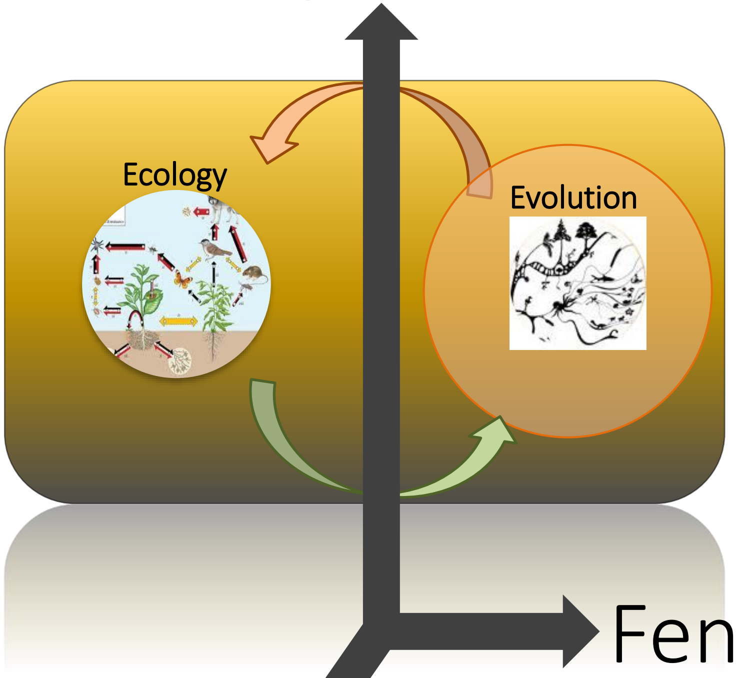
1. Extinción de especies
2. Cambios en la abundancia de especies y estructura de comunidades
3. Cambio distribución de especies

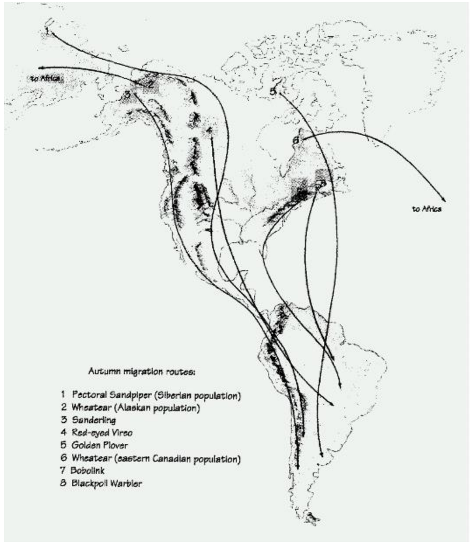

TYPICAL CLIMATE-RELATED HAZARDS IN MOUNTAINS
HEAVY SNOW FALL
RISING TEMPERATURES
EXTREME COLD
AVALANCHE
REDUCED SNOW COVER
MELTING GLACIERS
DEGRADATION OF FORESTS & ECOSYSTEMS
LANDSLIDES
GLACIAL LAKE OUTBURST FLOOD
WILDFIRES
EROSION & SOIL DEGRADATION
FLOODS
WATER SCARCITY
DROUGHTS
LOW RIVER FLOW
CHANGES IN STREAM FLOW
VECTOR-BORNE DISEASES

Shari Nijman (https://www.unep.org/fr/node/24048)

Migración

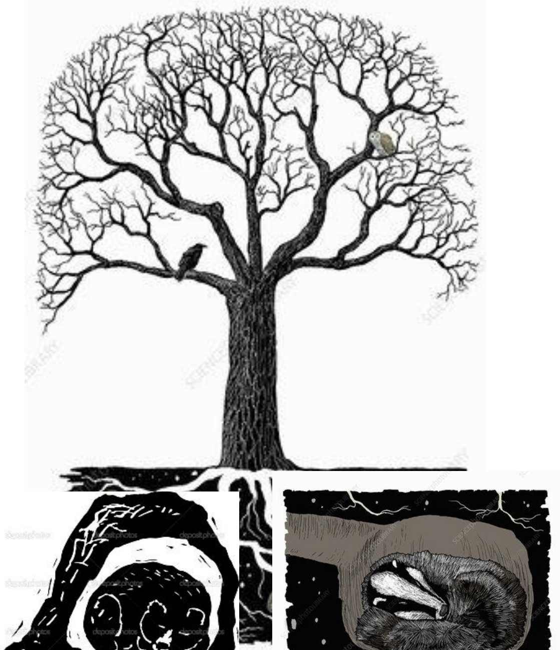



Ecology
Evolution


to Africa
to Africa
Autumn migration routes:
1 Pectoral Sandpiper (Siberian population)
2 Wheatear (Alaskan population)
3 Sanderling
4 Red-eyed Vireo
5 Golden Plover
6 Wheatear (eastern Canadian population)
7 Bobolink
8 Blackpoll Warbler

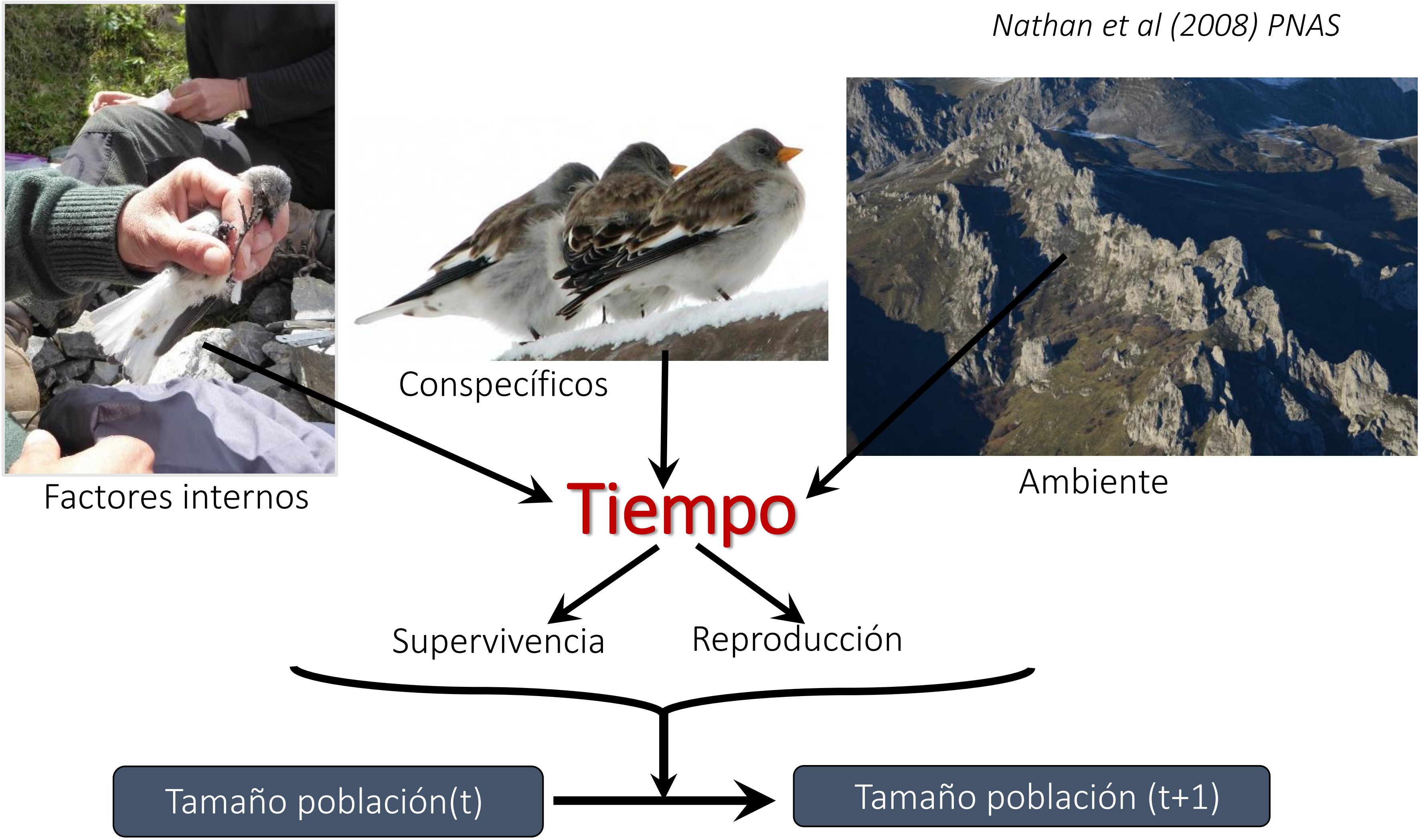
Fenología

Fisiología



Movimiento - Importante rasgo de vida

Nathan et al (2008) PNAS



Factores internos

Conspecíficos

Ambiente

Tiempo

Supervivencia

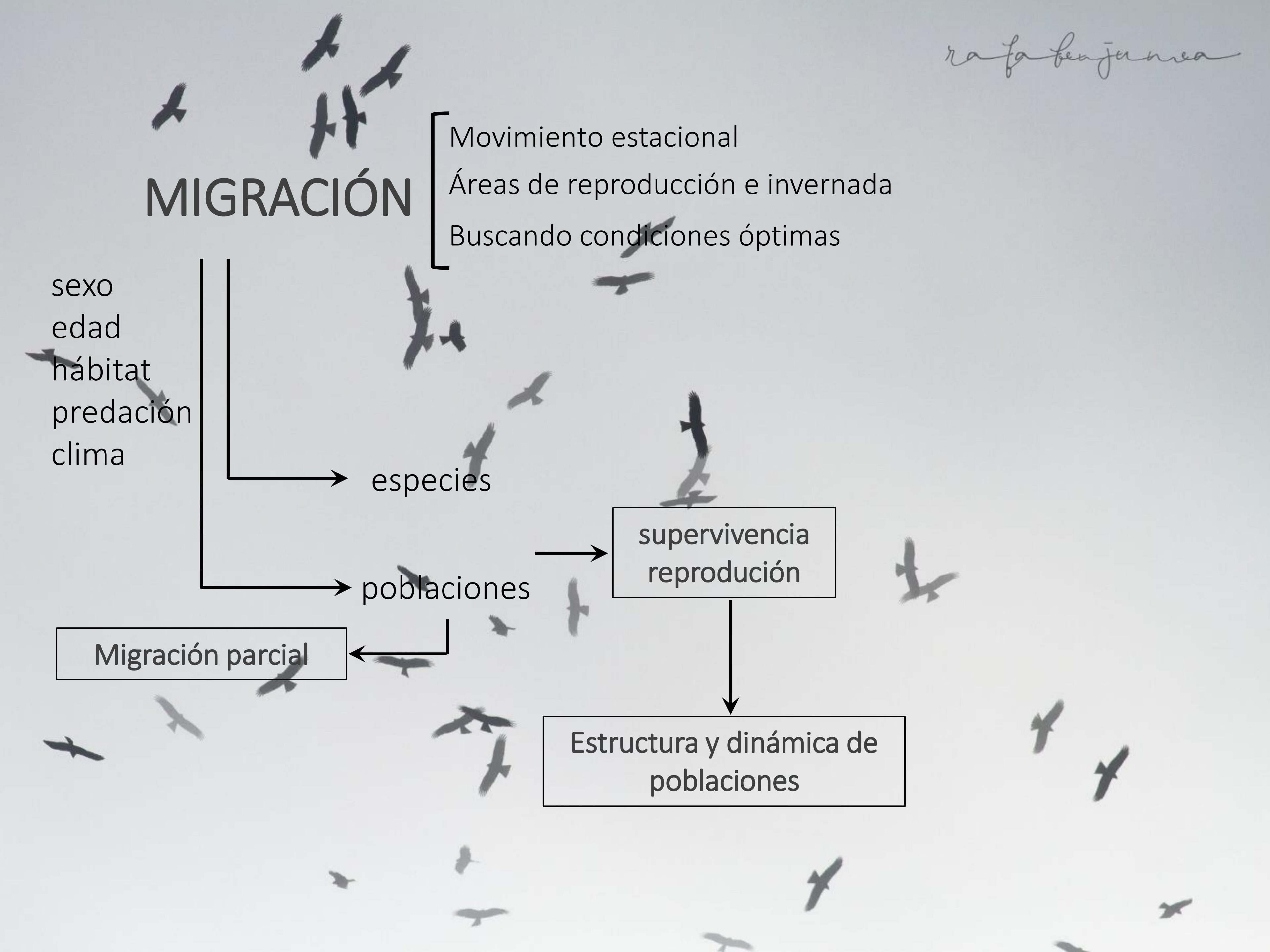
Reproducción

Tamaño población(t)

Tamaño población (t+1)

Morales et al (2010) Phil Trans R Soc B

rafa benjumea



MIGRACIÓN

Movimiento estacional

Áreas de reproducción e invernada

Buscando condiciones óptimas

sexo
edad
hábitat
predación
clima

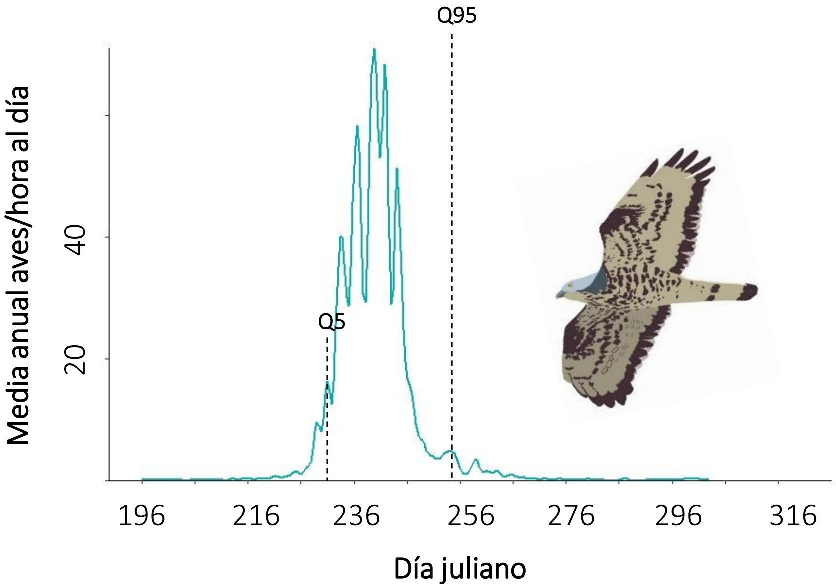
especies

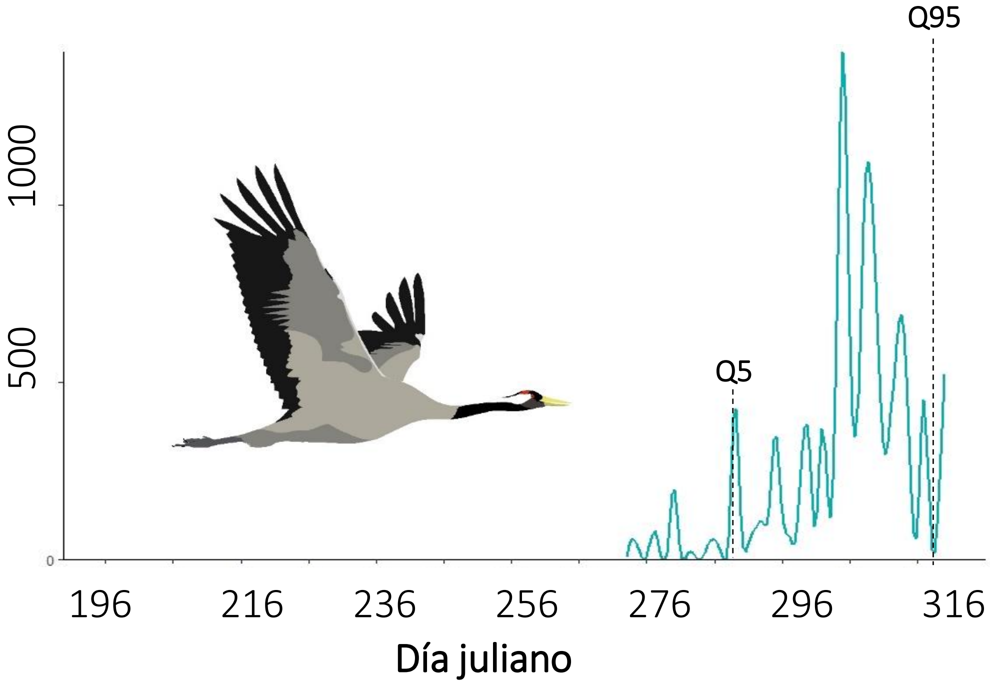
poblaciones

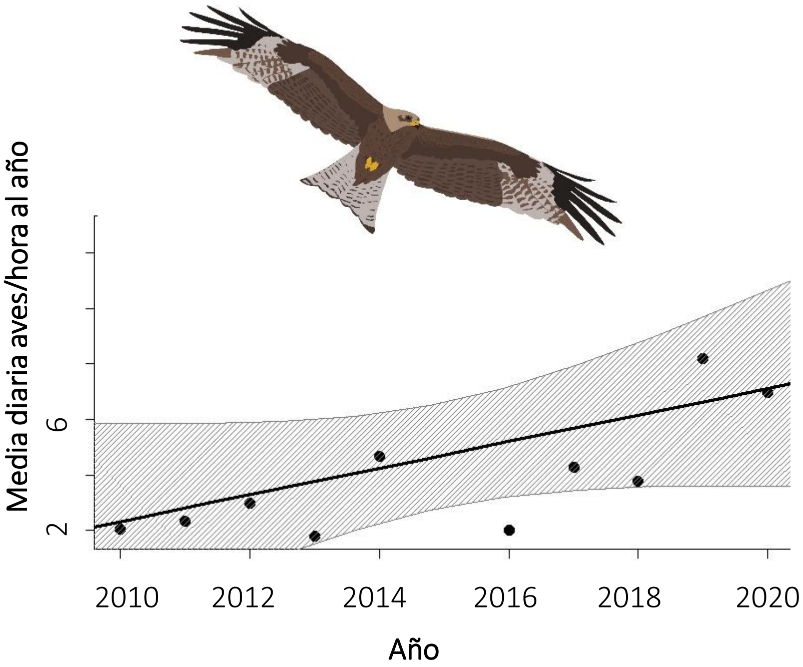
supervivencia
reprodución

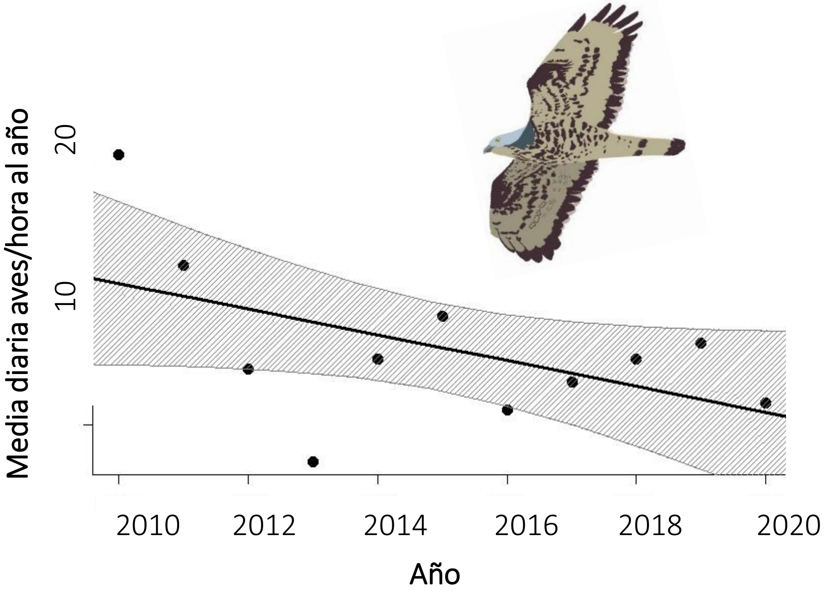
Migración parcial

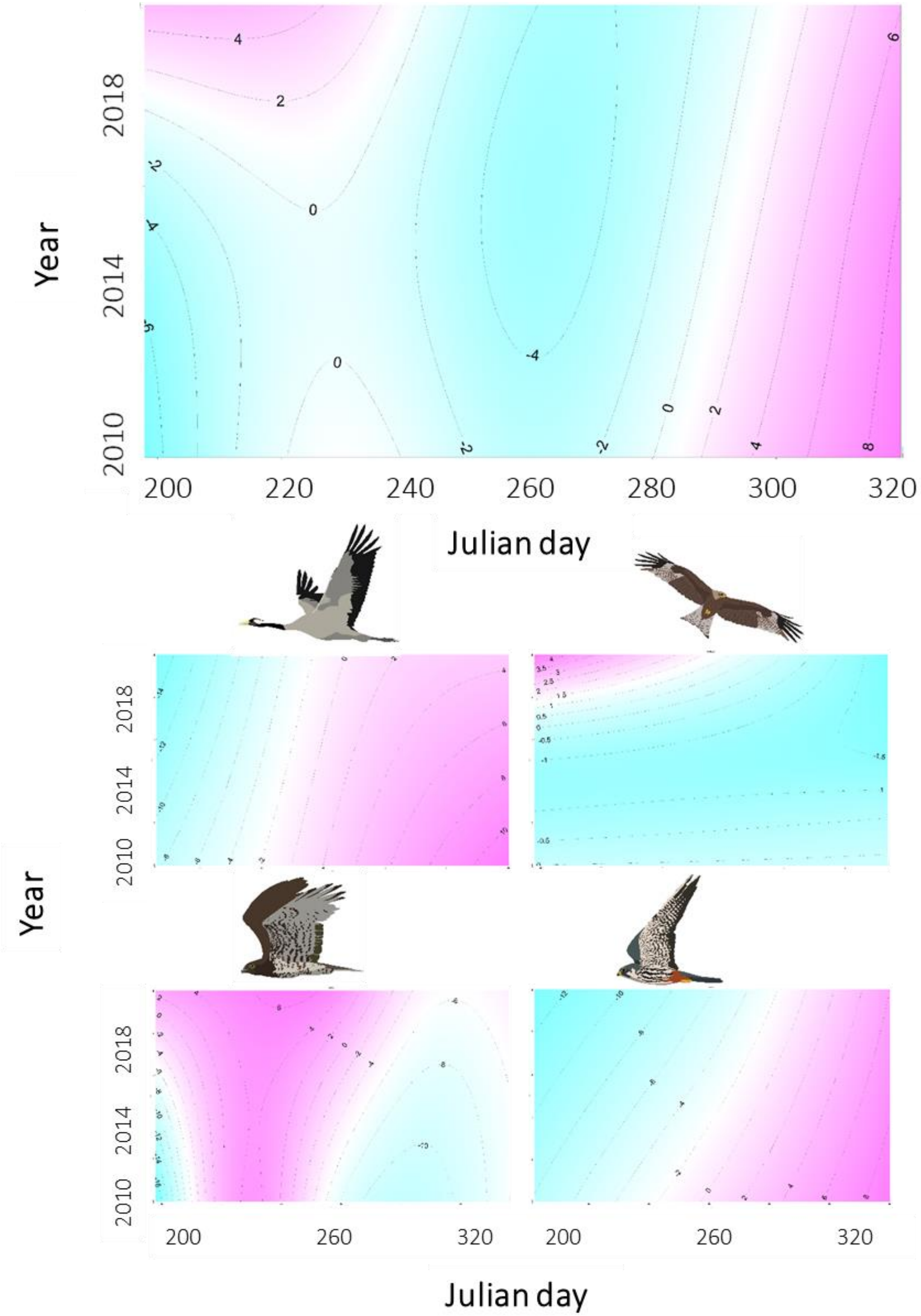
Estructura y dinámica de poblaciones

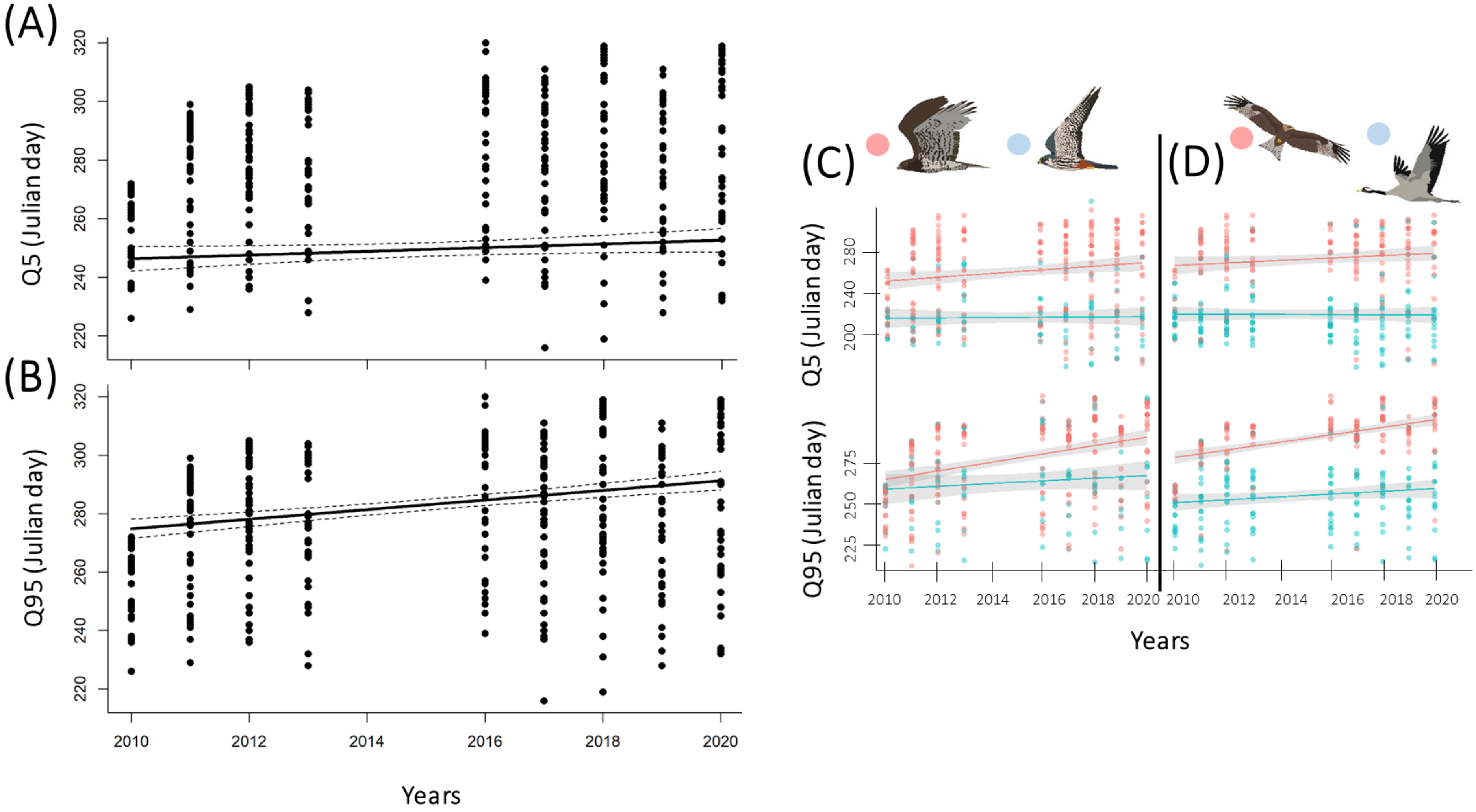

Q95
Q5
Media anual aves/hora al día
40
20
196
216
236
256
276
296
316
Día juliano


Q95
1000
500
0
Q5
196
216
236
256
276
296
316
Día juliano


Media diaria aves/hora al año
2
6
2010
2012
2014
2016
2018
2020
Año


Media diaria aves/hora al año
20
10
2010
2012
2014
2016
2018
2020
Año

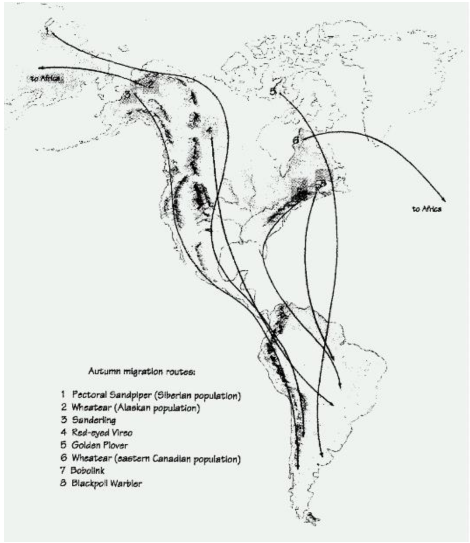

Year
2010
2014
2018
200
220
240
260
280
300
320
Julian day
4
2
0
-2
-4
-6
0
-4
0
2
4
6
8
-2
-2
Year
2010
2014
2018
2010
2014
2018
200
260
320
200
260
320
Julian day


(A)
Q5 (Julian day)
220
240
260
280
300
320
(B)
Q95 (Julian day)
220
240
260
280
300
320
2010
2012
2014
2016
2018
2020
Years
(C)
(D)
Q5 (Julian day)
200
240
280
Q95 (Julian day)
225
250
275
2010
2012
2014
2016
2018
2020
2010
2012
2014
2016
2018
2020
Years

Conclusiones

Cambios en los números
Cambios en la fenología

Ojo! Diferencias entre especies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to Africa
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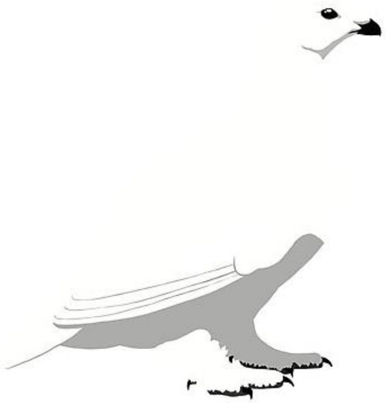
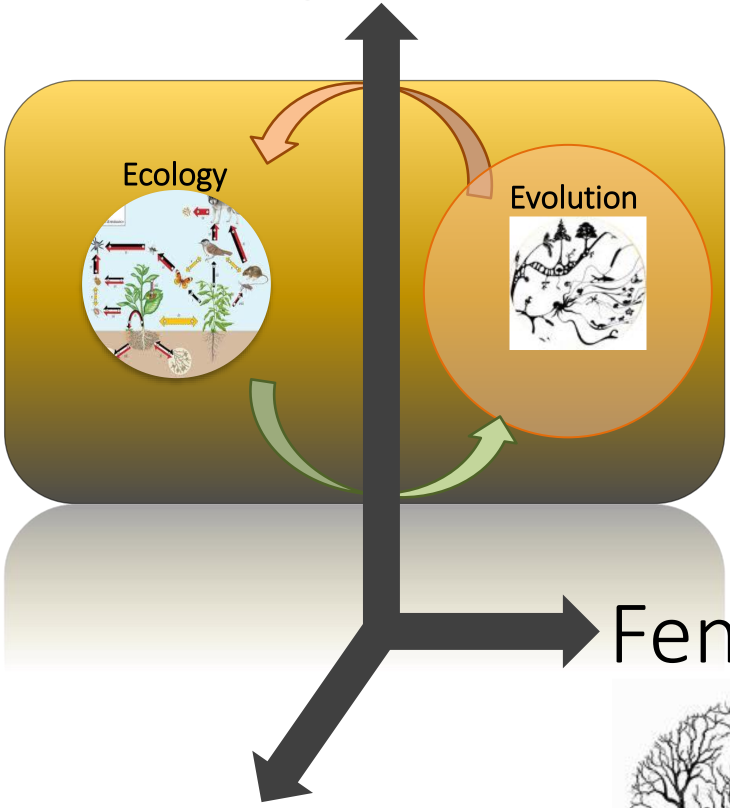
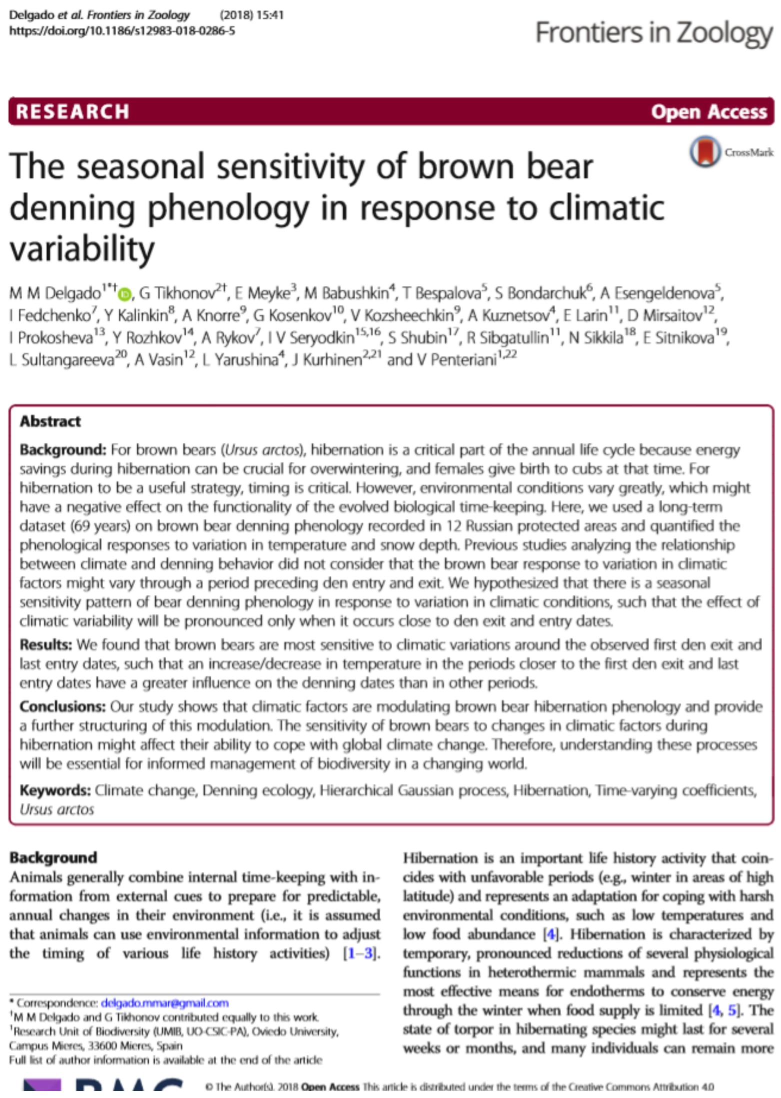



Ecology
Evolution

Migración

Fenología

Fisiología



Delgado *et al. Frontiers in Zoology* (2018) 15:41
https://doi.org/10.1186/s12983-018-0286-5

Frontiers in Zoology

RESEARCH **Open Access**

The seasonal sensitivity of brown bear denning phenology in response to climatic variability

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Abstract

Background: For brown bears (*Ursus arctos*), hibernation is a critical part of the annual life cycle because energy savings during hibernation can be crucial for overwintering, and females give birth to cubs at that time. For hibernation to be a useful strategy, timing is critical. However, environmental conditions vary greatly, which might have a negative effect on the functionality of the evolved biological time-keeping. Here, we used a long-term dataset (69 years) on brown bear denning phenology recorded in 12 Russian protected areas and quantified the phenological responses to variation in temperature and snow depth. Previous studies analyzing the relationship between climate and denning behavior did not consider that the brown bear response to variation in climatic factors might vary through a period preceding den entry and exit. We hypothesized that there is a seasonal sensitivity pattern of bear denning phenology in response to variation in climatic conditions, such that the effect of climatic variability will be pronounced only when it occurs close to den exit and entry dates.

Results: We found that brown bears are most sensitive to climatic variations around the observed first den exit and last entry dates, such that an increase/decrease in temperature in the periods closer to the first den exit and last entry dates have a greater influence on the denning dates than in other periods.

Conclusions: Our study shows that climatic factors are modulating brown bear hibernation phenology and provide a further structuring of this modulation. The sensitivity of brown bears to changes in climatic factors during hibernation might affect their ability to cope with global climate change. Therefore, understanding these processes will be essential for informed management of biodiversity in a changing world.

Keywords: Climate change, Denning ecology, Hierarchical Gaussian process, Hibernation, Time-varying coefficients, *Ursus arctos*

Background

Animals generally combine internal time-keeping with information from external cues to prepare for predictable, annual changes in their environment (i.e., it is assumed that animals can use environmental information to adjust the timing of various life history activities) [1–3]. Hibernation is an important life history activity that coincides with unfavorable periods (e.g., winter in areas of high latitude) and represents an adaptation for coping with harsh environmental conditions, such as low temperatures and low food abundance [4]. Hibernation is characterized by temporary, pronounced reductions of several physiological functions in heterothermic mammals and represents the most effective means for endotherms to conserve energy through the winter when food supply is limited [4, 5]. The state of torpor in hibernating species might last for several weeks or months, and many individuals can remain more

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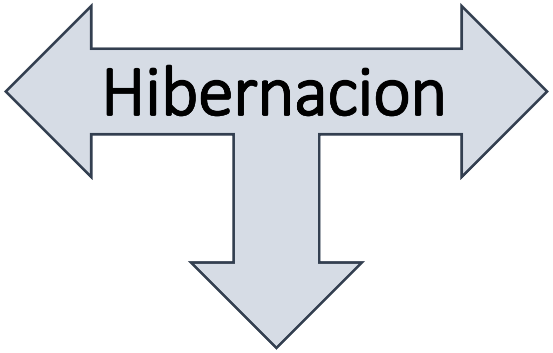
Sobrevivir al invierno



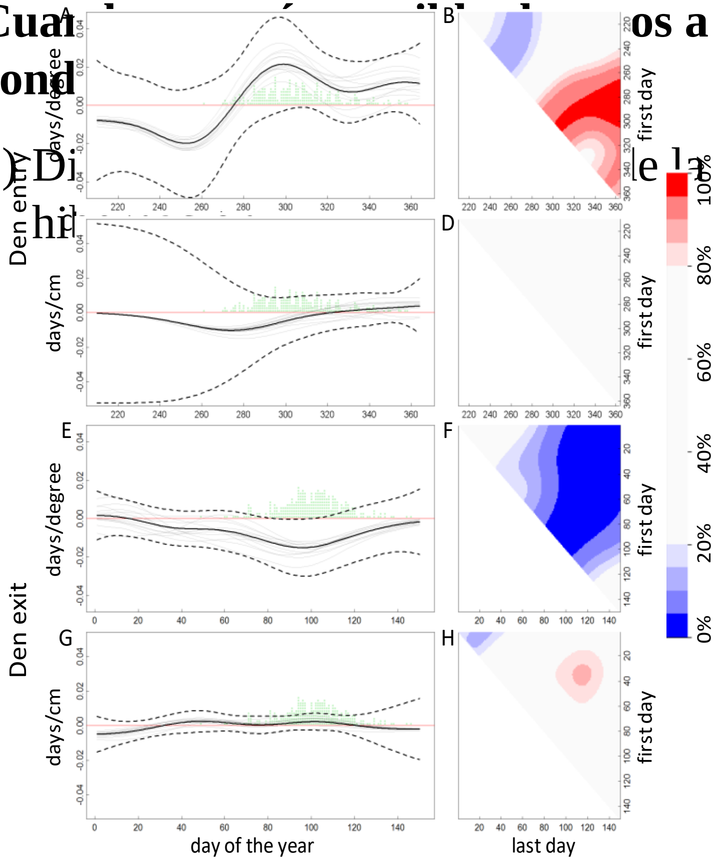
Hibernacion

Hembras tienen los oseznos

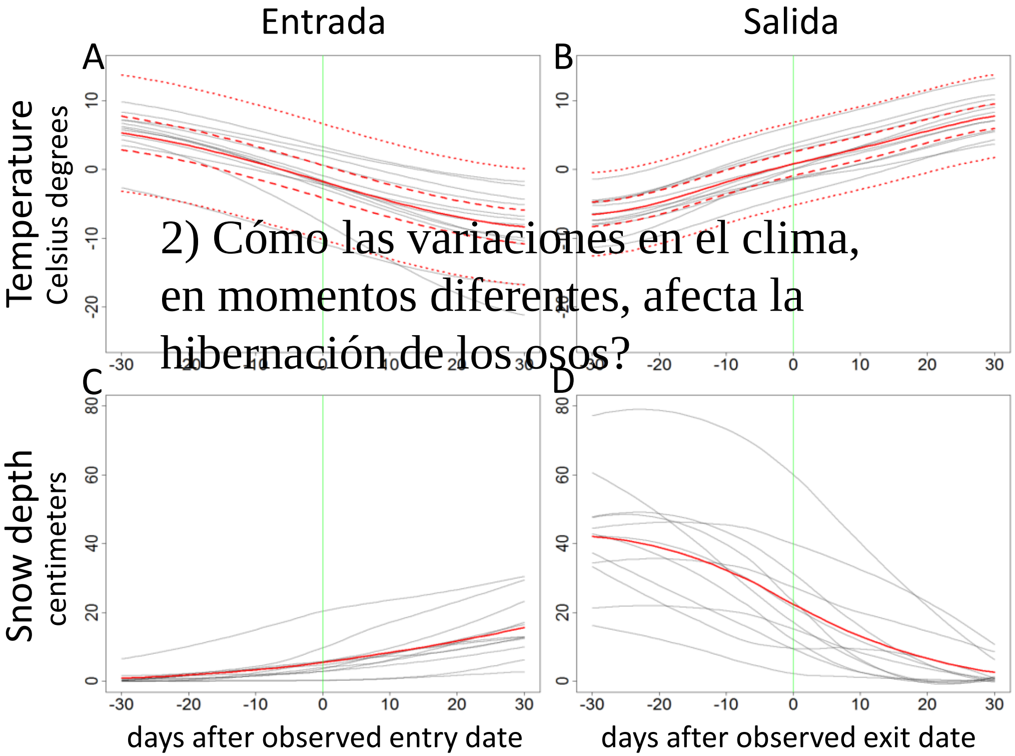
Cuando!

Cua os a las
cond

1) ¿Di le la
hi



2) Cómo las variaciones en el clima, en momentos diferentes, afecta la hibernación de los osos?



Primaveras cálidas = osos salen antes de las oseras

Otoños cálidos = osos entran más tarde en las oseras

El cambio climático afecta la hibernación de los osos

- Estrés energético
- Disminuye la supervivencia de los oseznos y el fitness
- Aumenta los conflictos con los humanos
- Aumenta las tasas metabólicas
- Desajustes tróficos

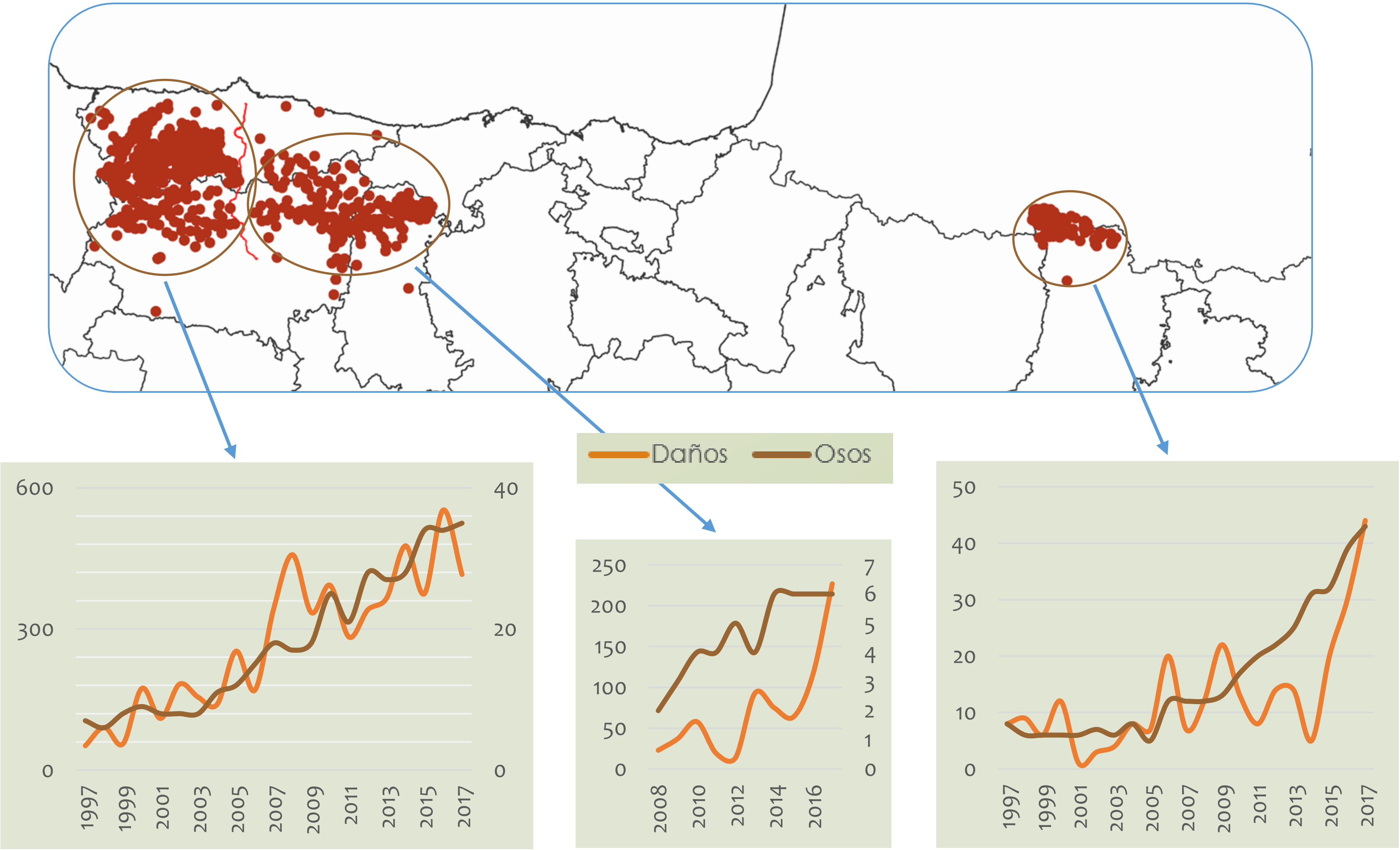
Factores que influyen en los daños producidos por el oso en la Cordillera Cantábrica y los Pirineos

https://doi.org/10.1111/jzo.12839

Alejandra Zarzo-Arias, María del Mar Delgado, Santiago Palazón Miñano, Iván Afonso Jordana, Giulia Bombieri, Enrique González-Bernardo, Andrés Ordiz & Vincenzo Penteriani.

CONFLICTOS
PREVENCIÓN

EVOLUCIÓN

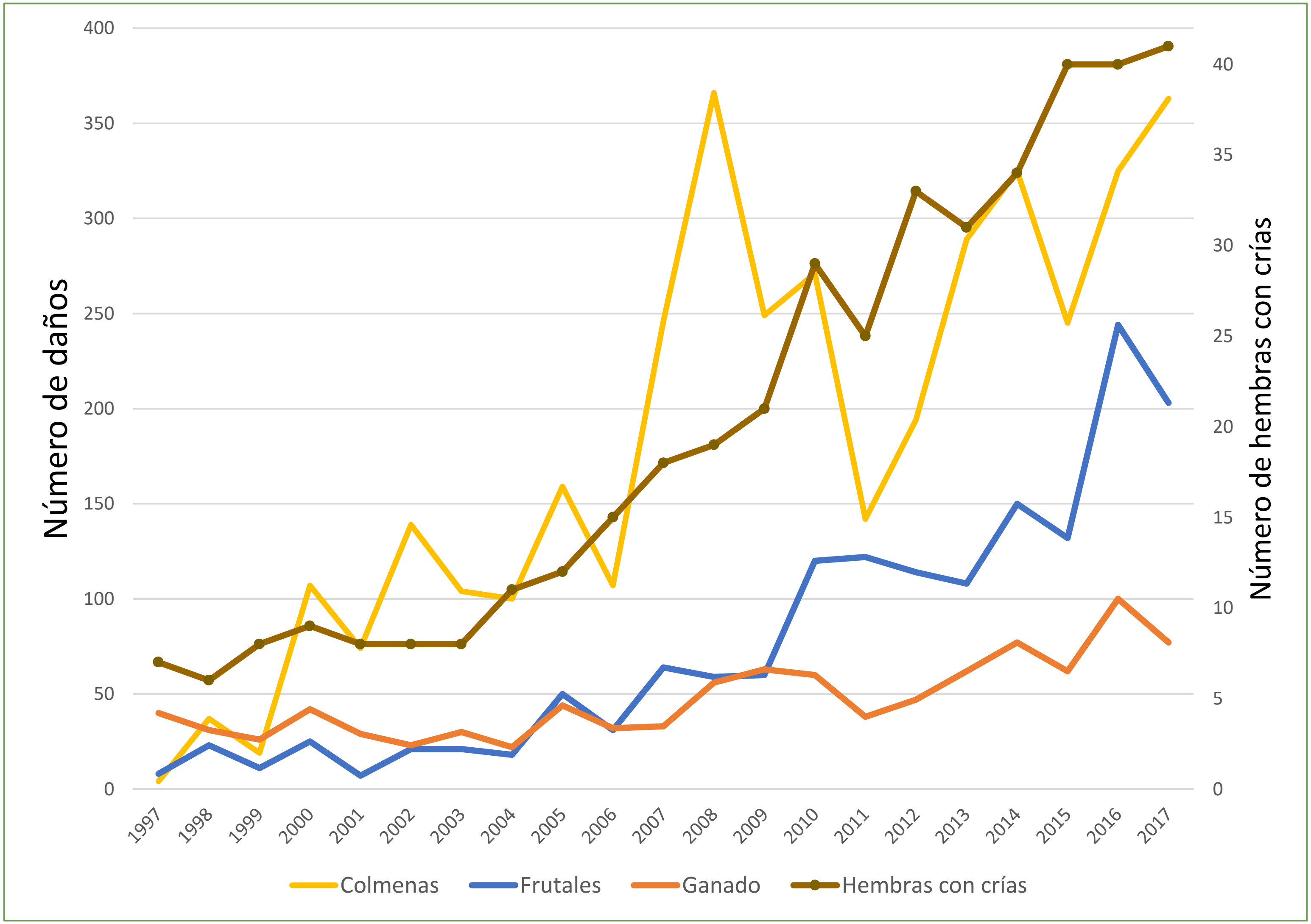


Subpoblación occidental

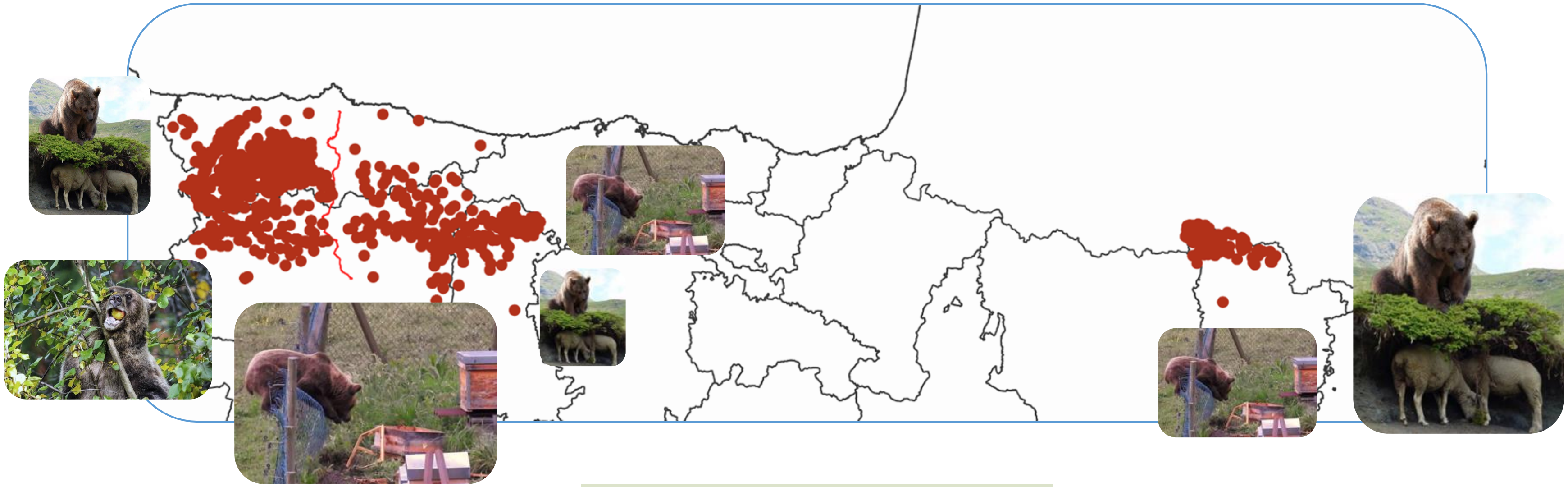
Subpoblación oriental

Pirineo español

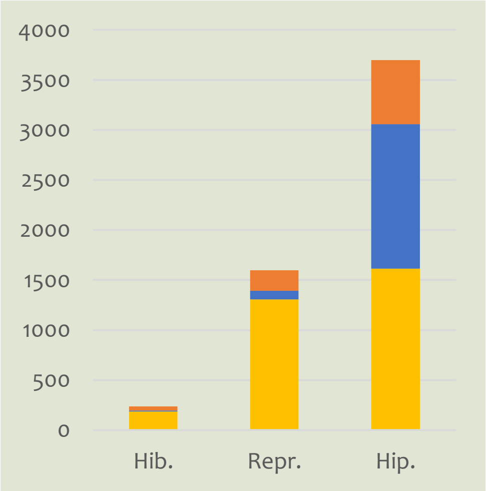
EVOLUCIÓN


400
350
300
250
200
150
100
50
0
Número de daños
40
35
30
25
20
15
10
5
0
Número de hembras con crías
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Colmenas
Frutales
Ganado
Hembras con crías

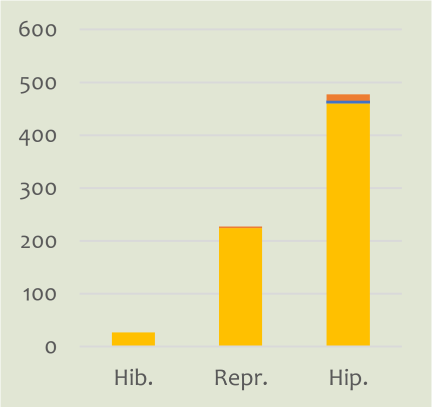
ESTACIONALIDAD



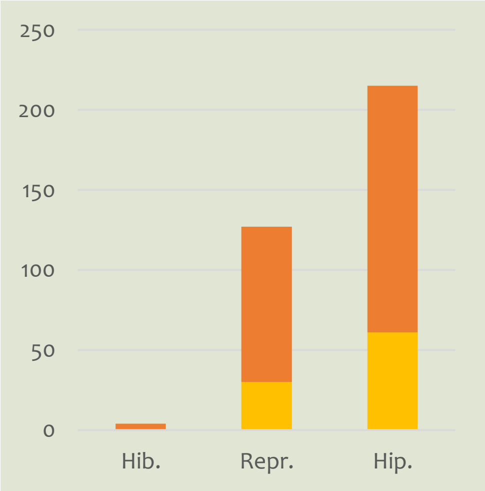
🟨 Colmenas 🟩 Cultivos 🟧 Ganado



Subpoblación occidental

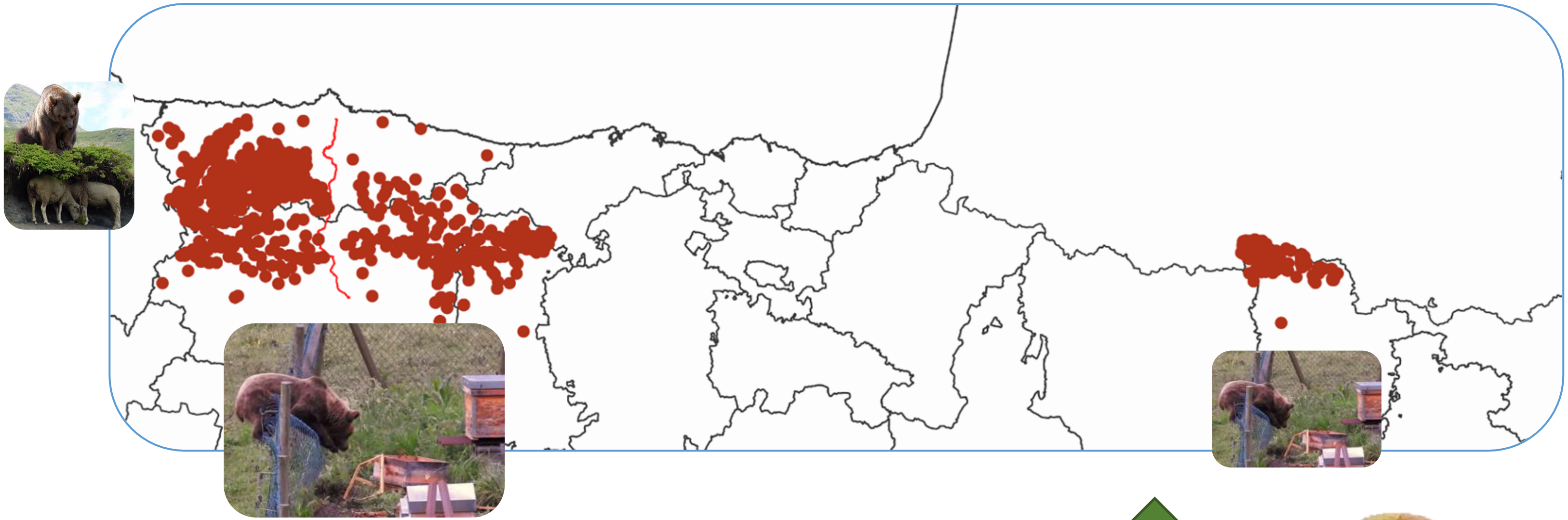


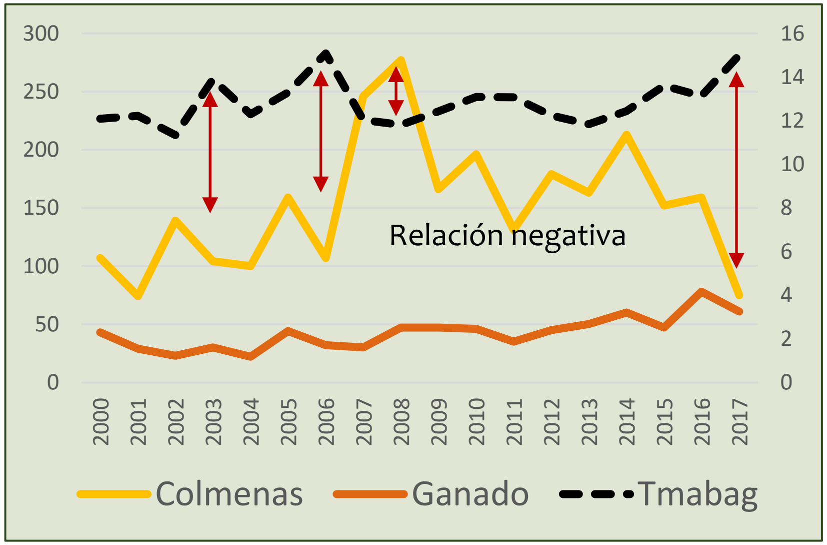
Subpoblación oriental



Pirineo español

PRODUCTIVIDAD





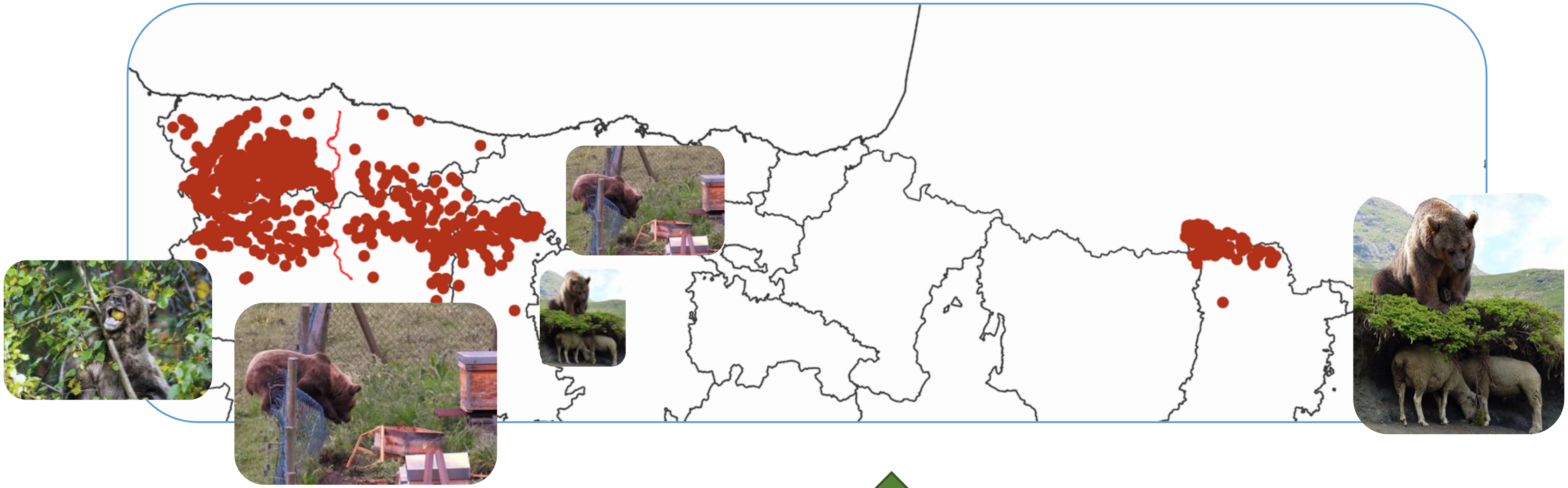
Mayor temperatura →

Mayor polinización →

Mayor productividad →

MENOS DAÑOS

PRODUCTIVIDAD



Diferentes actividades y métodos de prevención

Mayor temperatura →

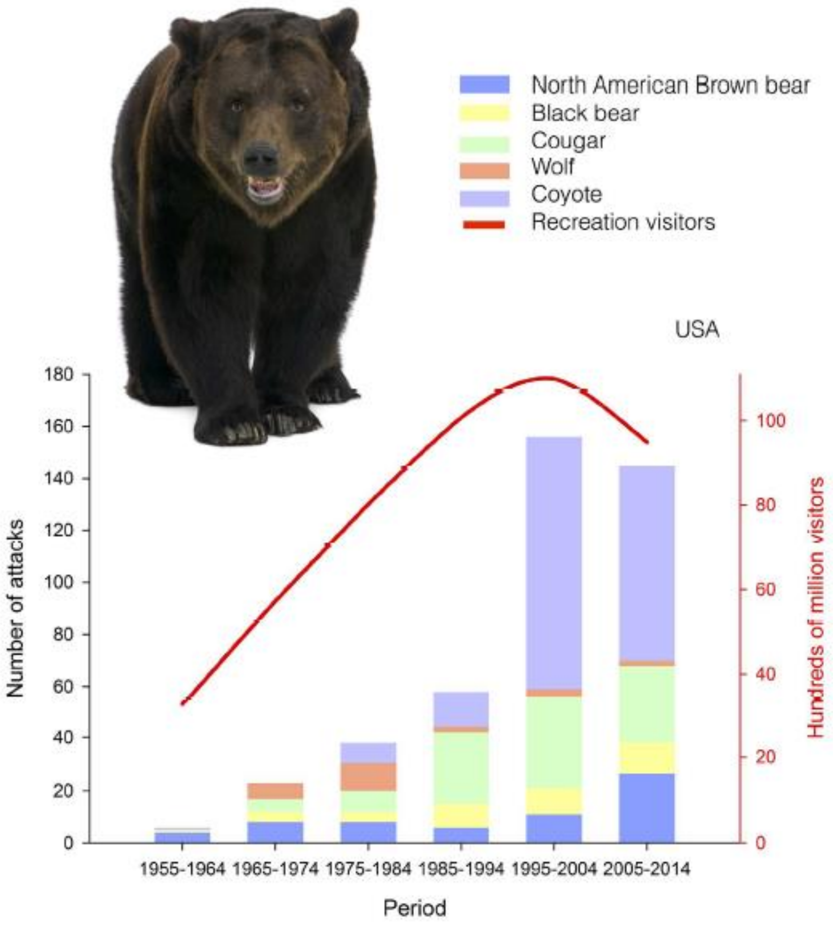
Mayor polinización →

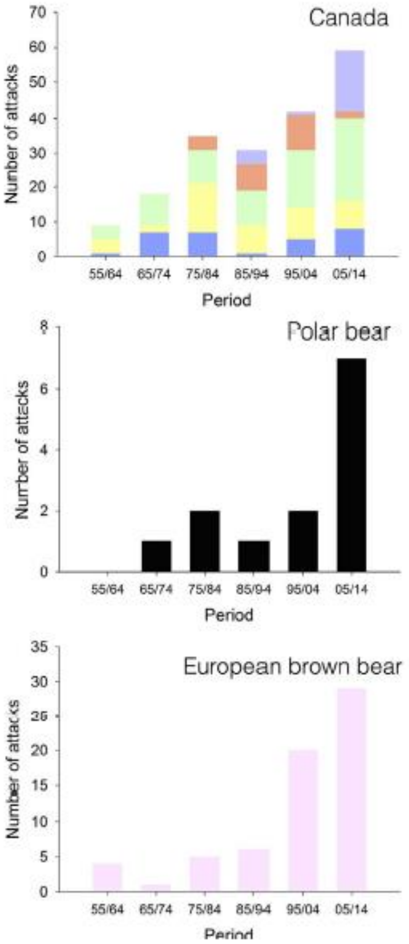
Mayor productividad →

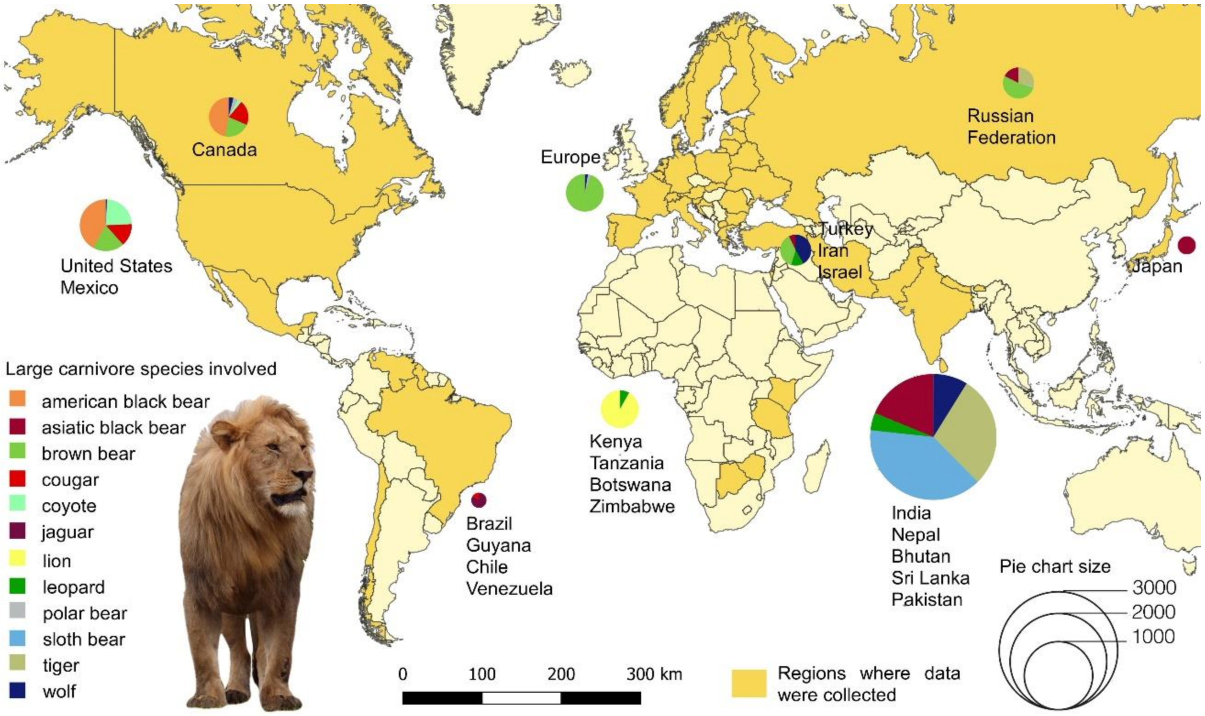
MÁS DAÑOS (mayor atracción)

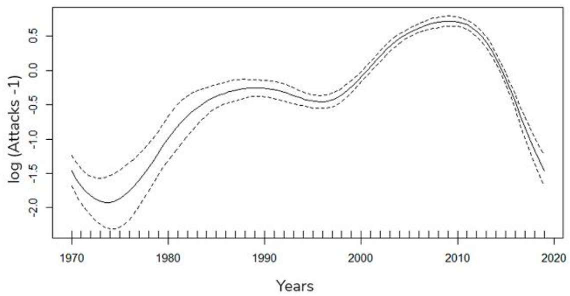
COEXISTENCIA
CONSERVACIÓN

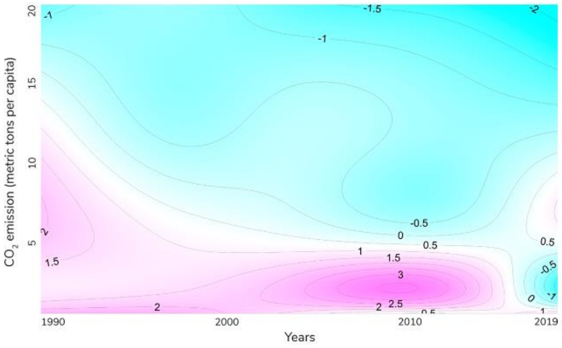
Vincenzo Penteriani (2016) Scientific Reports

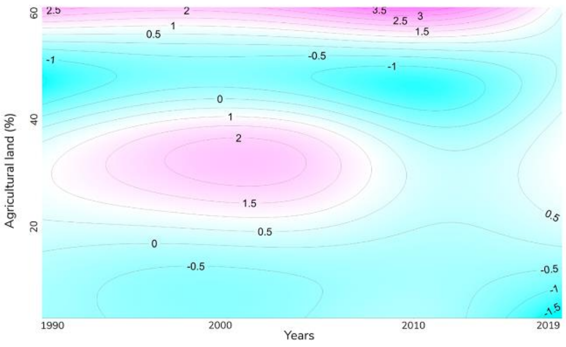


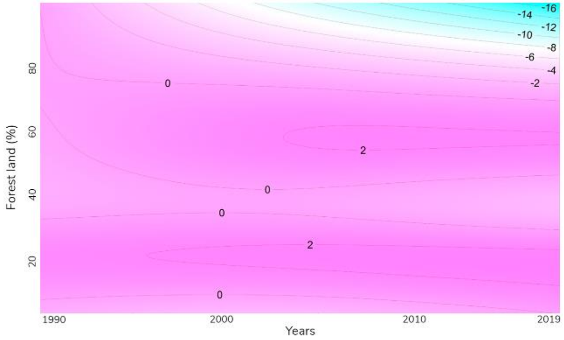


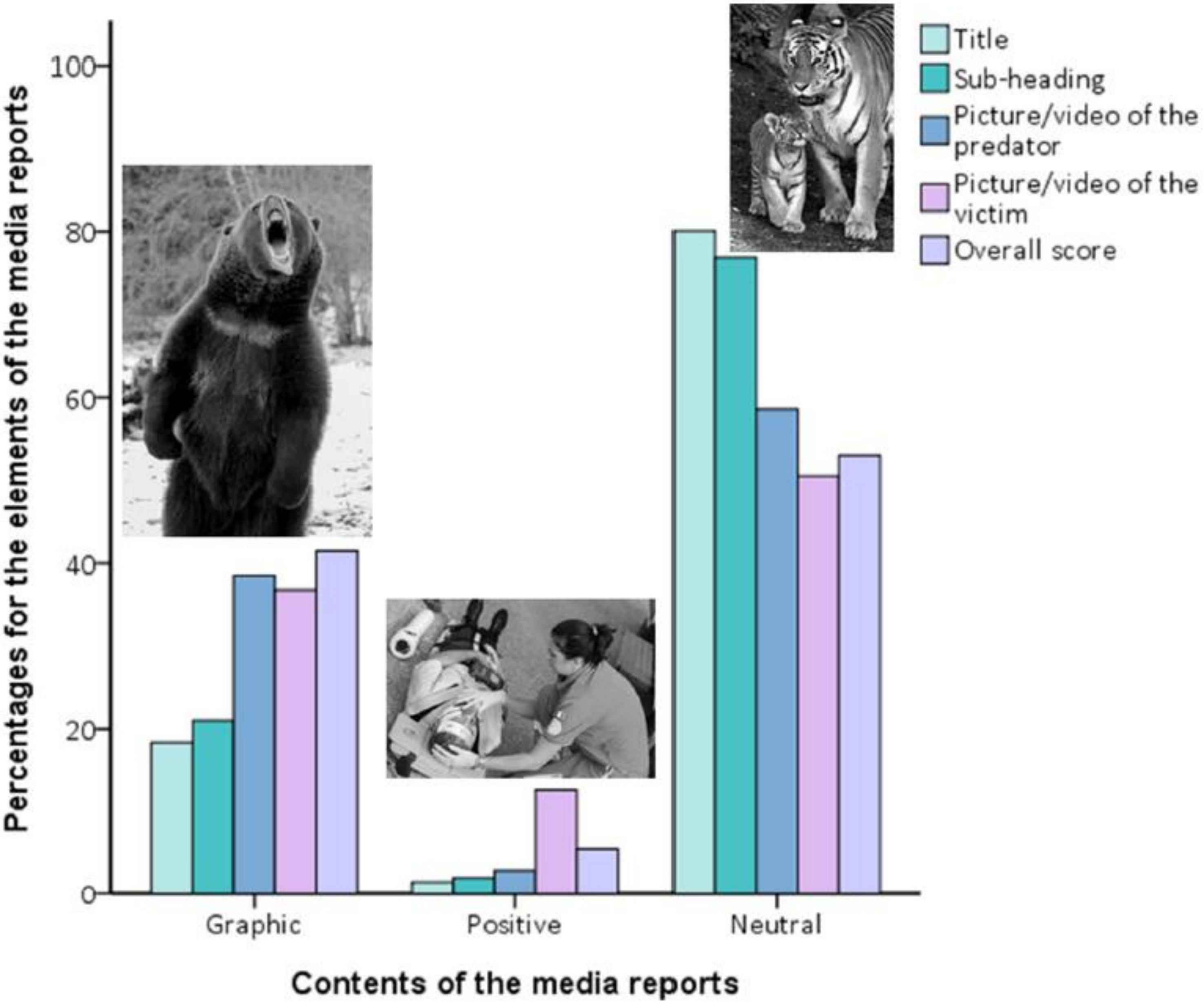

Canada
Russian Federation
Europe
United States
Mexico
Turkey
Iran
Israel
Japan
Kenya
Tanzania
Botswana
Zimbabwe
India
Nepal
Bhutan
Sri Lanka
Pakistan
Brazil
Guyana
Chile
Venezuela
Large carnivore species involved
american black bear
asiatic black bear
brown bear
cougar
coyote
jaguar
lion
leopard
polar bear
sloth bear
tiger
wolf
0
100
200
300 km
Regions where data were collected
Pie chart size
3000
2000
1000


log (Attacks -1)
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1970
1980
1990
2000
2010
2020
Years


CO$_2$ emission (metric tons per capita)
20
15
10
5
1990
2000
2010
2019
Years
-1
-1.5
-2
-0.5
0
0.5
1
1.5
2
2.5
3

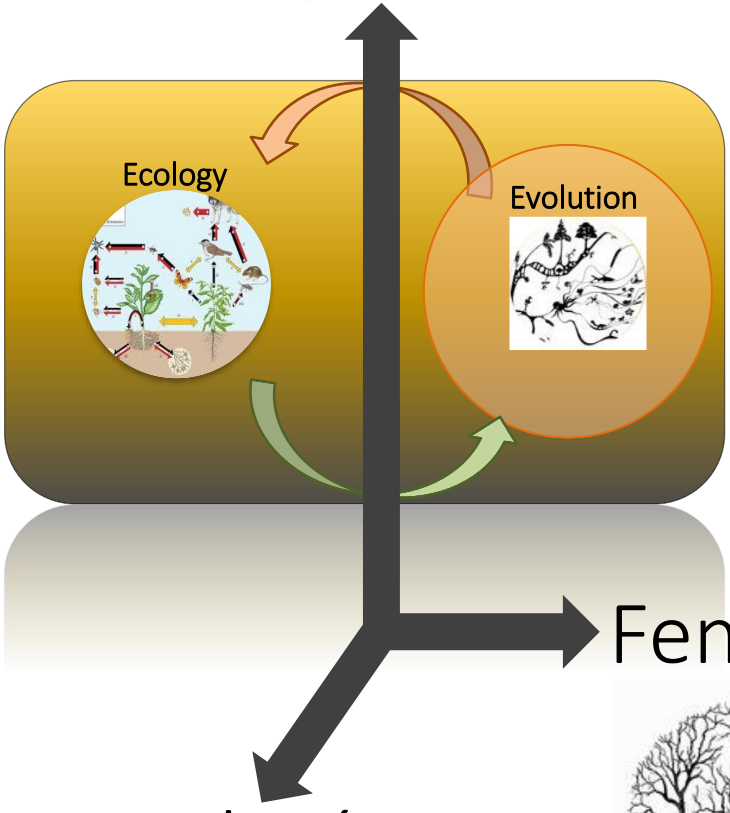

Agricultural land (%)
60
40
20
1990
2000
2010
2019
Years
2.5
2
3.5
3
0.5
1
1.5
-1
-0.5
0
-1.5


Forest land (%)
80
60
40
20
1990
2000
2010
2019
Years
-16
-14
-12
-10
-8
-6
-4
-2
0
2



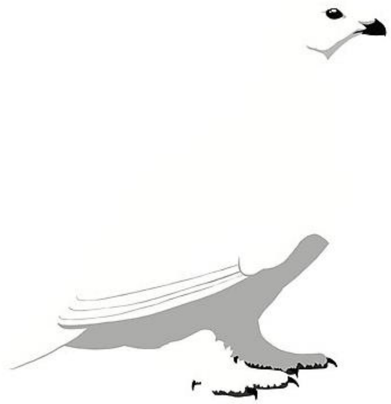
Bombieri (2018) Biosciences

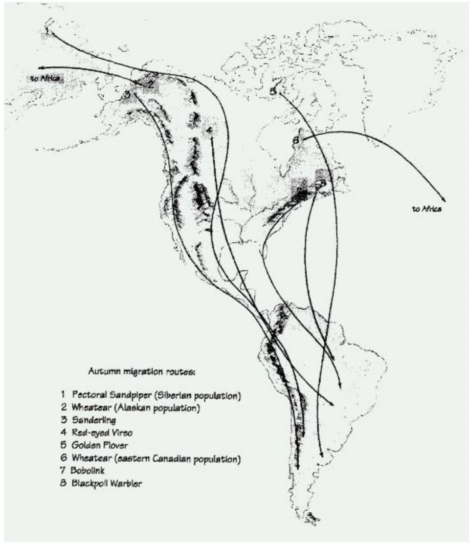
Migración

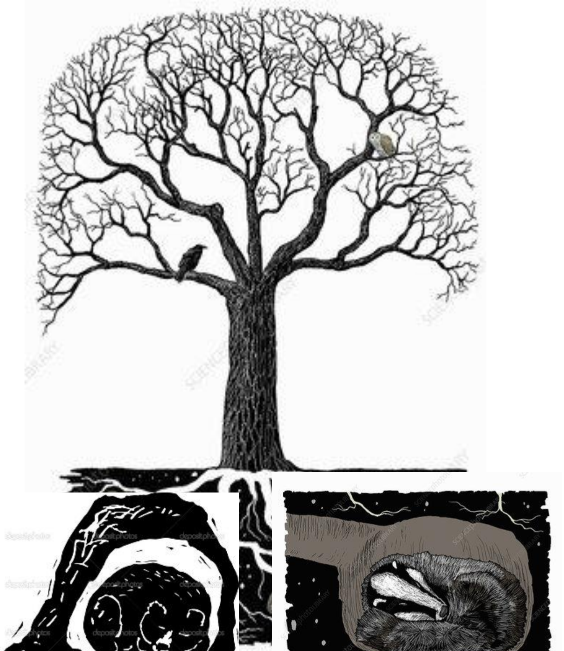

Ecology
Evolution

Fenología

Fisiología



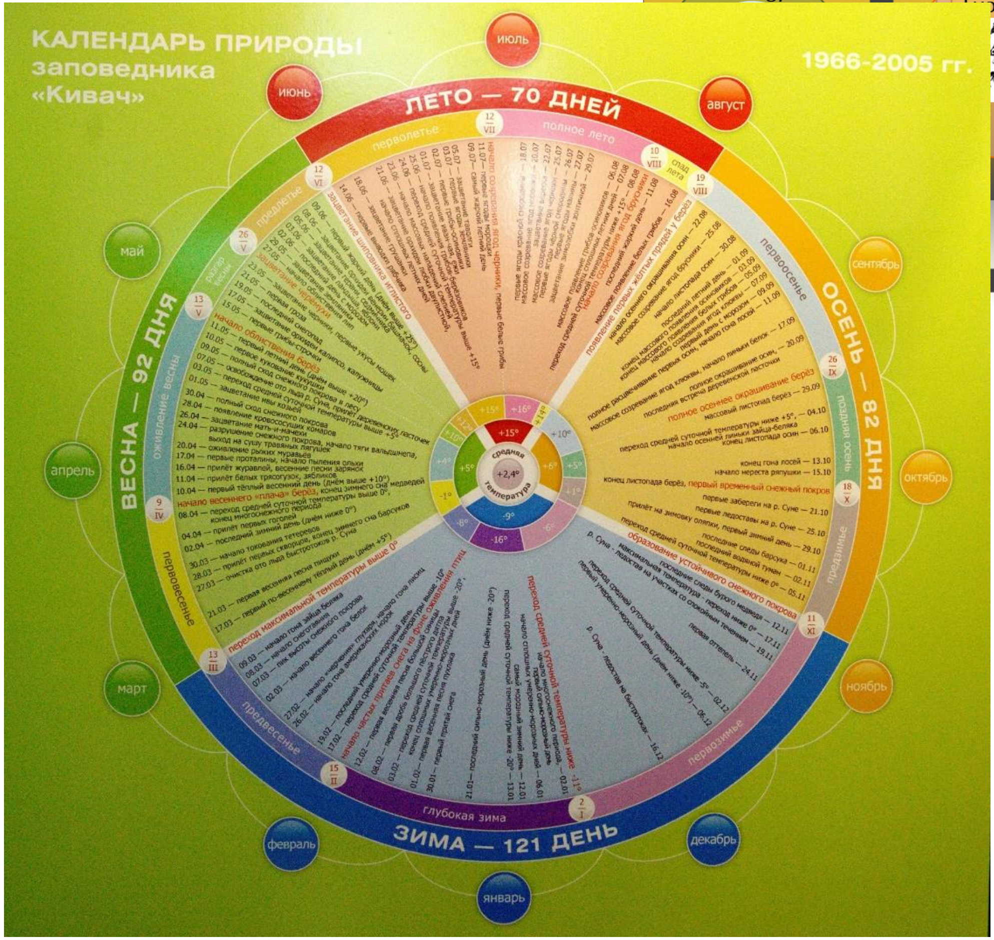

to Africa
to Africa
Autumn migration routes:
1 Pectoral Sandpiper (Siberian population)
2 Wheatear (Alaskan population)
3 Sanderling
4 Red-eyed Vireo
5 Golden Plover
6 Wheatear (eastern Canadian population)
7 Bobolink
8 Blackpoll Warbler

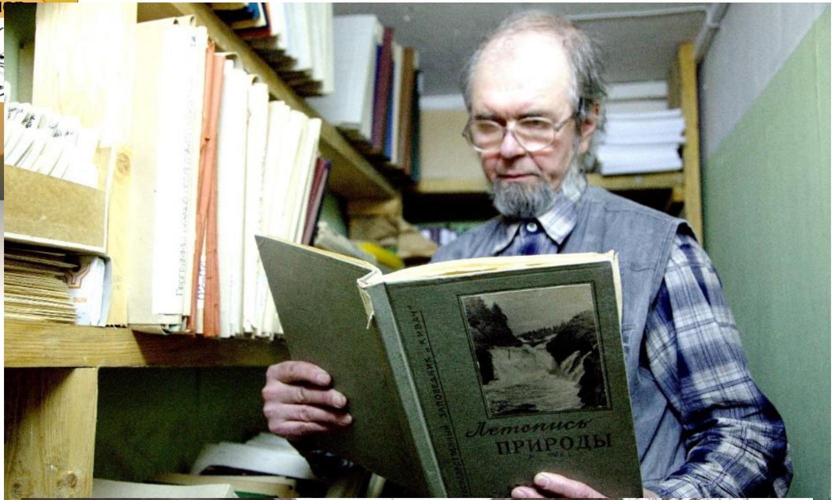


Migration

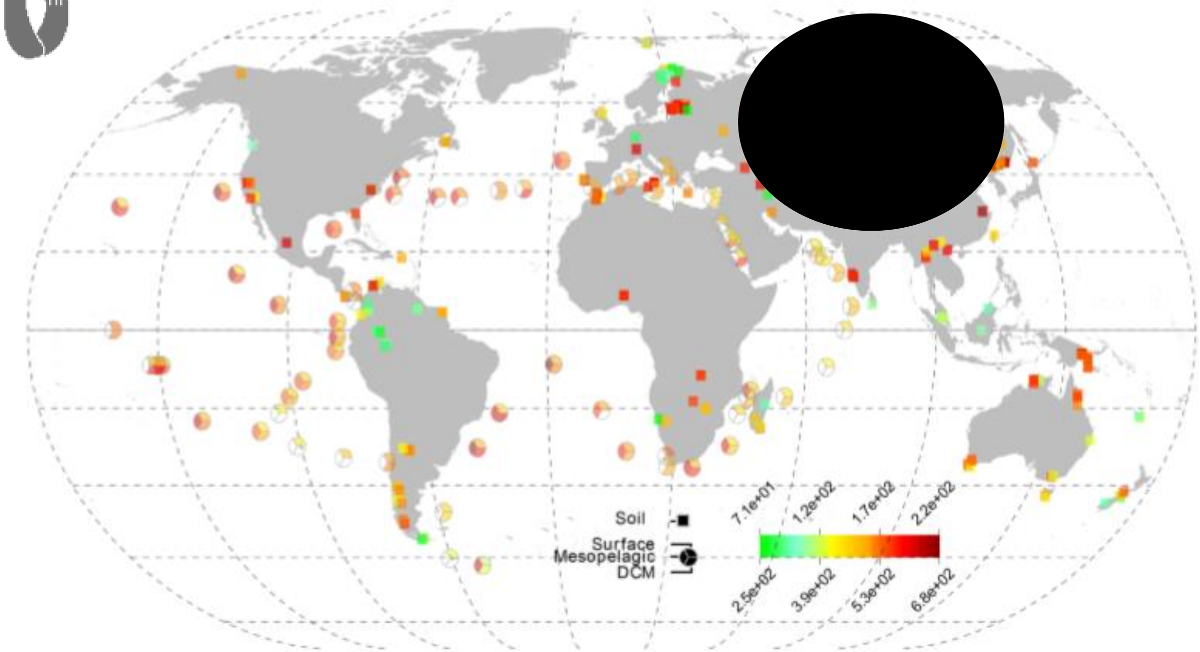
Resano-Mayor (2020) Global Ecology and Conservation

Ecology
Evolution

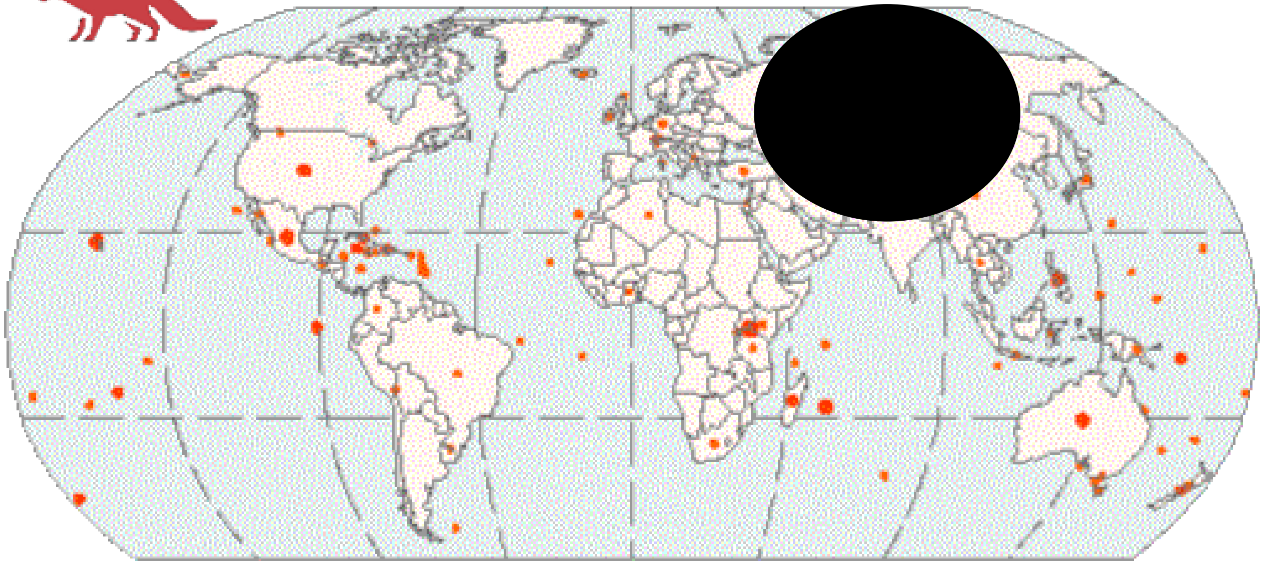

КАЛЕНДАРЬ ПРИРОДЫ
заповедника
«Кивач»
1966-2005 гг.
ЛЕТО — 70 ДНЕЙ
ОСЕНЬ — 82 ДНЯ
ЗИМА — 121 ДЕНЬ
ВЕСНА — 92 ДНЯ
июнь
июль
август
сентябрь
октябрь
ноябрь
декабрь
январь
февраль
март
апрель
май
первoлетье
полное лето
спад лета
предлетье
первоосенье
поздняя осень
предзимье
первозимье
глубокая зима
предвесенье
первовесенье
оживление весны
разгар весны
средняя температура
+2,4°


Летопись природы
Заповедник Кивач

Что уже выполнено на данный момент?

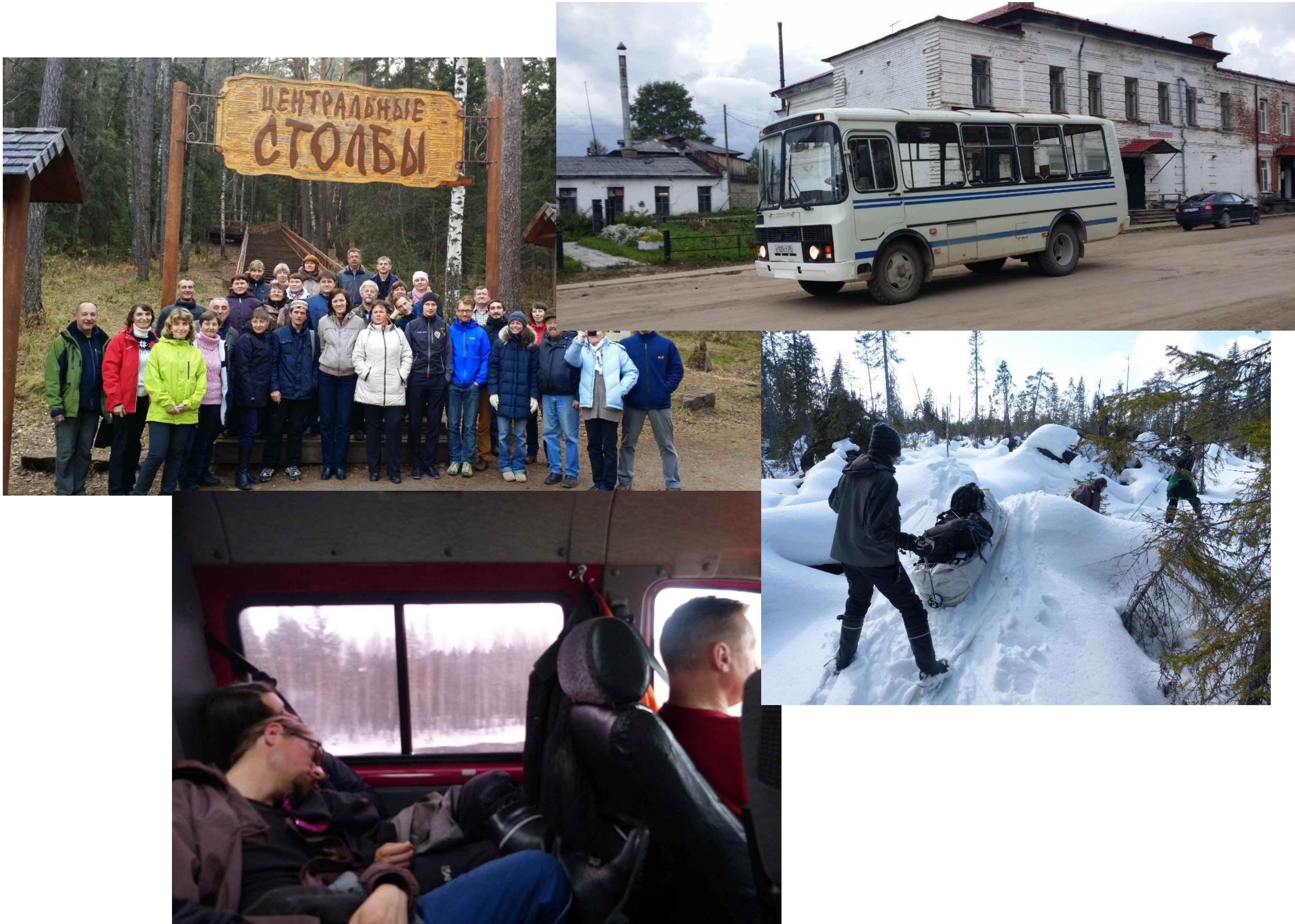

Soil
Surface
Mesopelagic
DCM
7.1e+01
1.2e+02
1.7e+02
2.2e+02
2.5e+02
3.9e+02
5.3e+02
6.8e+02

[redacted]

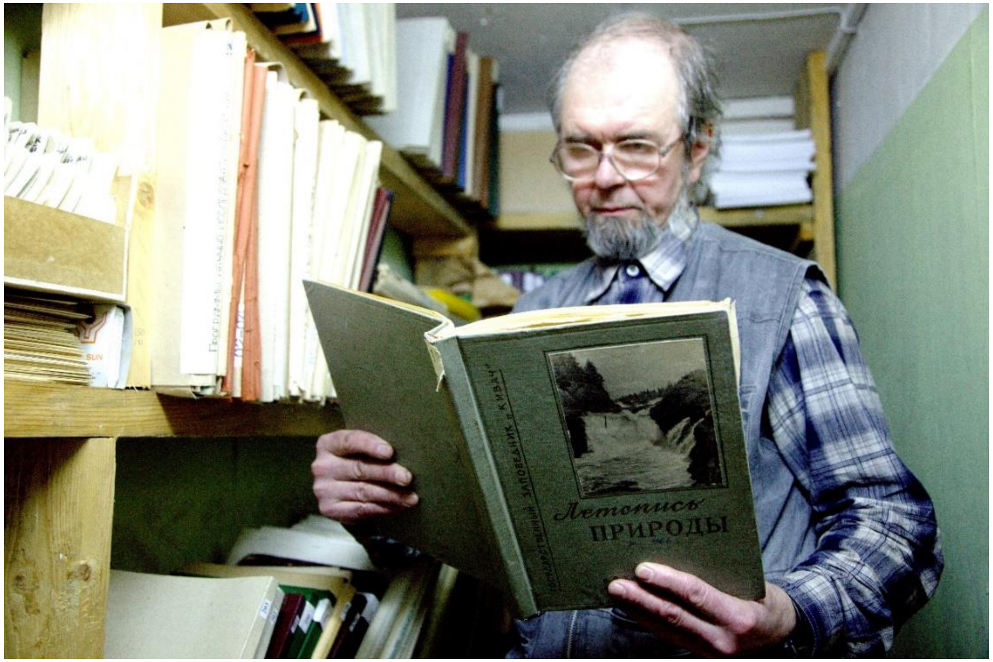


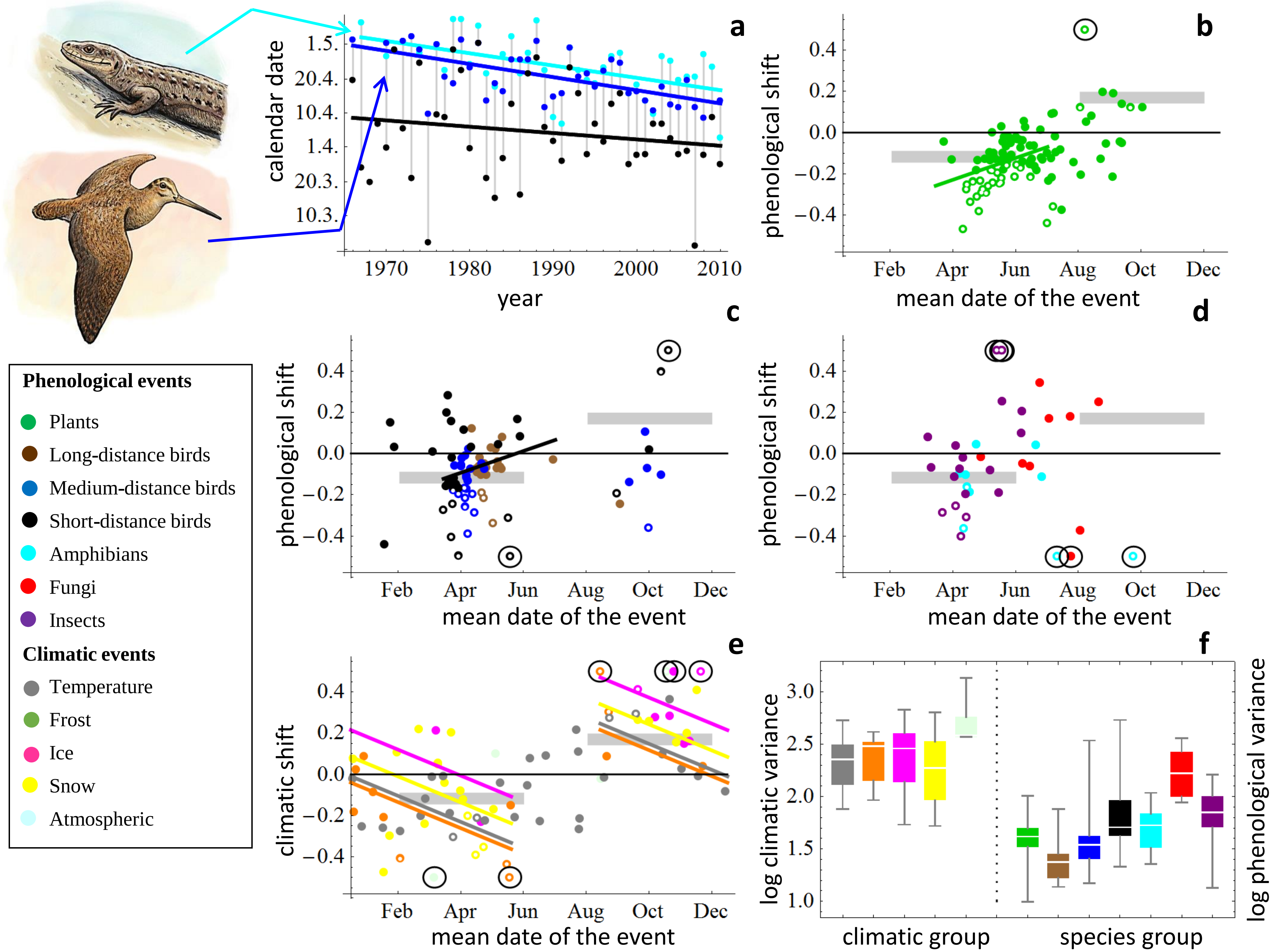
[redacted]

Bahram et al (2018) Nature
Tedersoo et al. (2014) Science

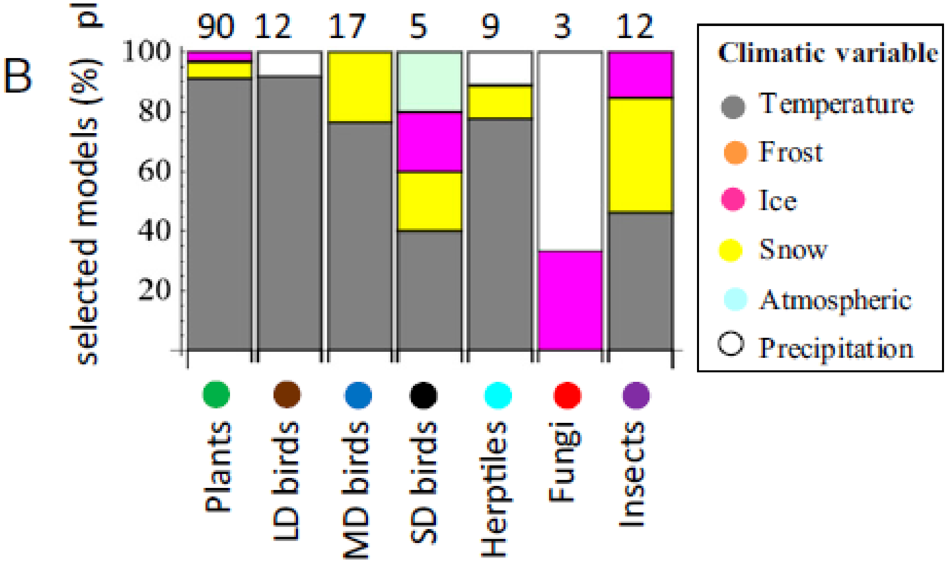

ЦЕНТРАЛЬНЫЕ
СТОЛБЫ

2010-3
2009-3
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986 II
1986 I
1985 ч II
1985 ч I
1984 ч III
1984 ч II
1984 ч I
1983 ч I р.
1983 ч II
1982 ч I
1981
1980
1979
1978
1977
1976

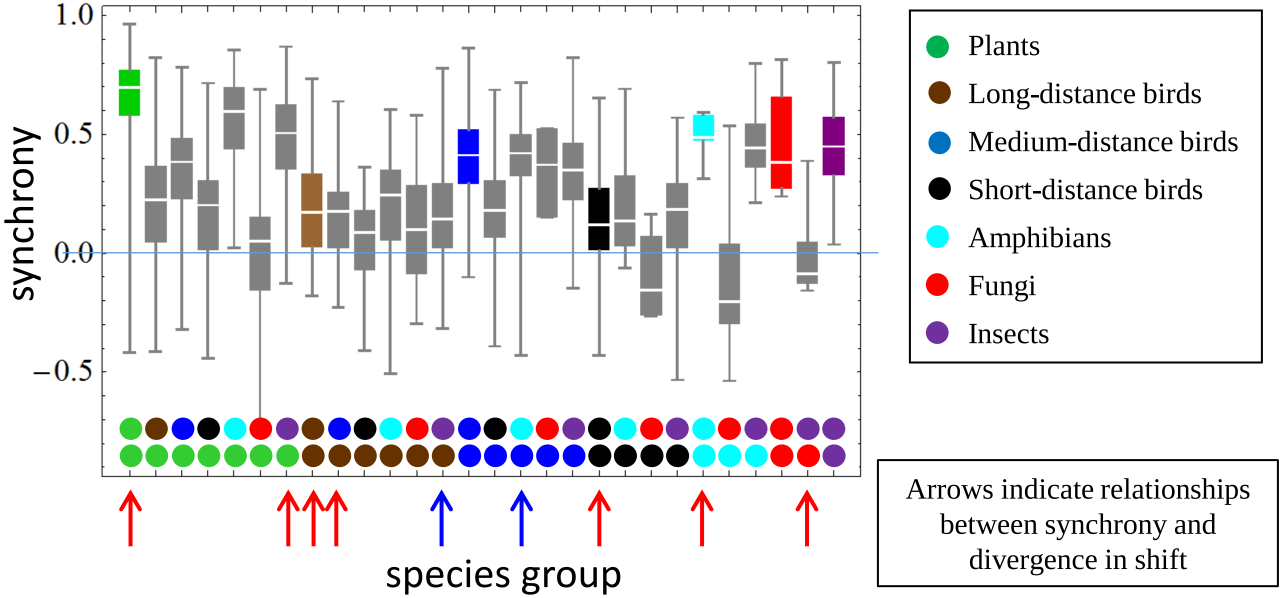

Государственный заповедник «Кивач»
Летопись
ПРИРОДЫ


a
calendar date
1.5.
20.4.
10.4.
1.4.
20.3.
10.3.
1970
1980
1990
2000
2010
year
b
phenological shift
0.4
0.2
0.0
−0.2
−0.4
Feb
Apr
Jun
Aug
Oct
Dec
mean date of the event
c
phenological shift
mean date of the event
d
phenological shift
mean date of the event
e
climatic shift
mean date of the event
f
log climatic variance
3.0
2.5
2.0
1.5
1.0
log phenological variance
climatic group
species group
Phenological events
Plants
Long-distance birds
Medium-distance birds
Short-distance birds
Amphibians
Fungi
Insects
Climatic events
Temperature
Frost
Ice
Snow
Atmospheric

¿Qué variables climáticas están cambiando la fenología?



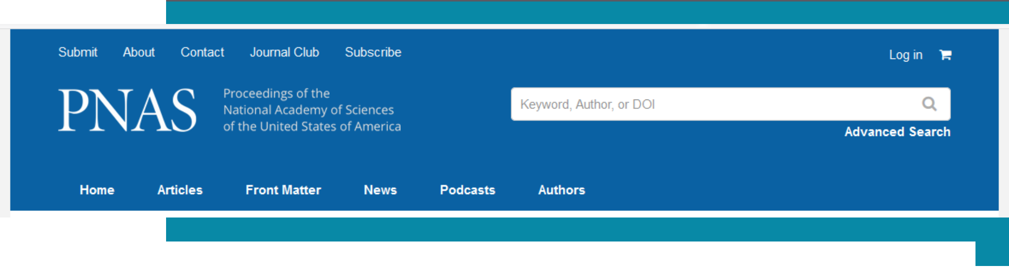
Sincronía



Arrows indicate relationships between synchrony and divergence in shift

BIOLOGICAL SCIENCES: Ecology

Differences in spatial versus temporal reaction norms for spring and autumn phenological events



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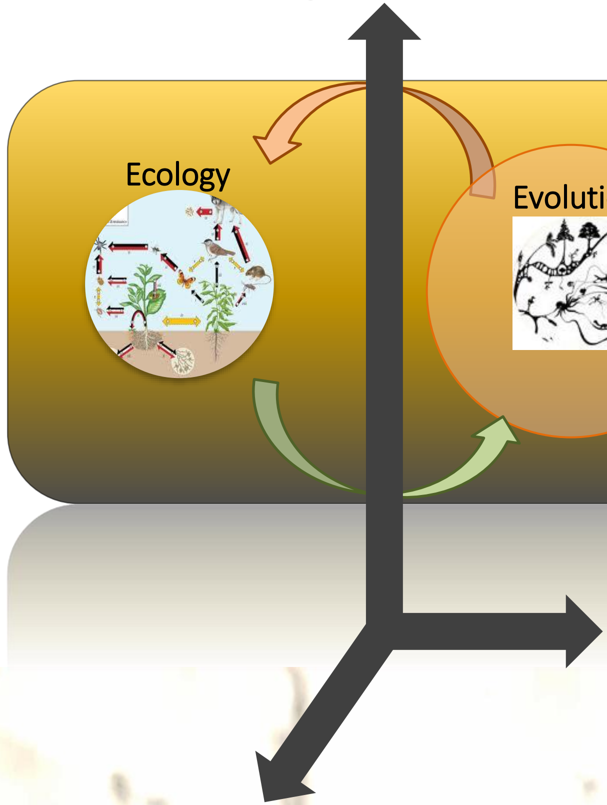
Hay vida!

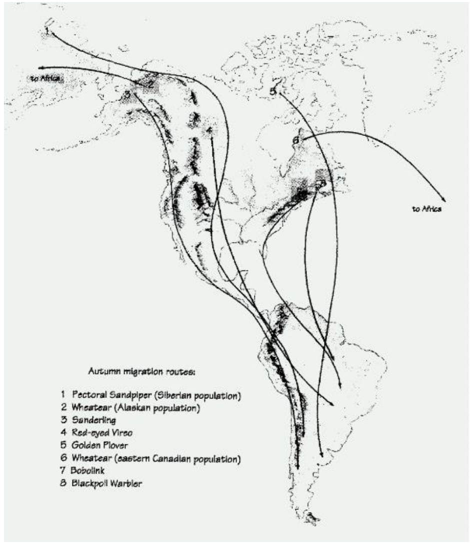
Frío
No mucha comida
Días cortos, noches largas

Migración



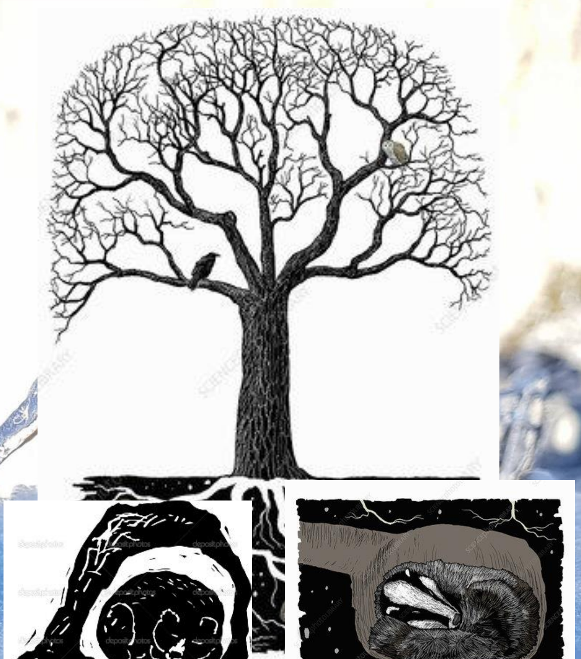
Ecology

Evolution


to Africa
to Africa
Autumn migration routes:
1 Pectoral Sandpiper (Siberian population)
2 Wheatear (Alaskan population)
3 Sanderling
4 Red-eyed Vireo
5 Golden Plover
6 Wheatear (eastern Canadian population)
7 Bobolink
8 Blackpoll Warbler

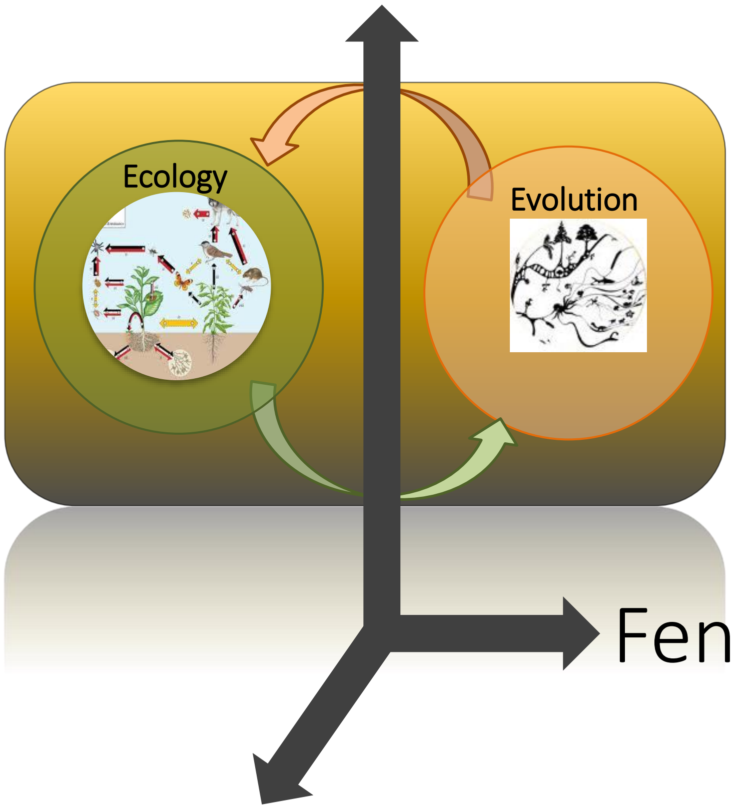
Hibernación

Resistencia



Cambio climático

Movimientos

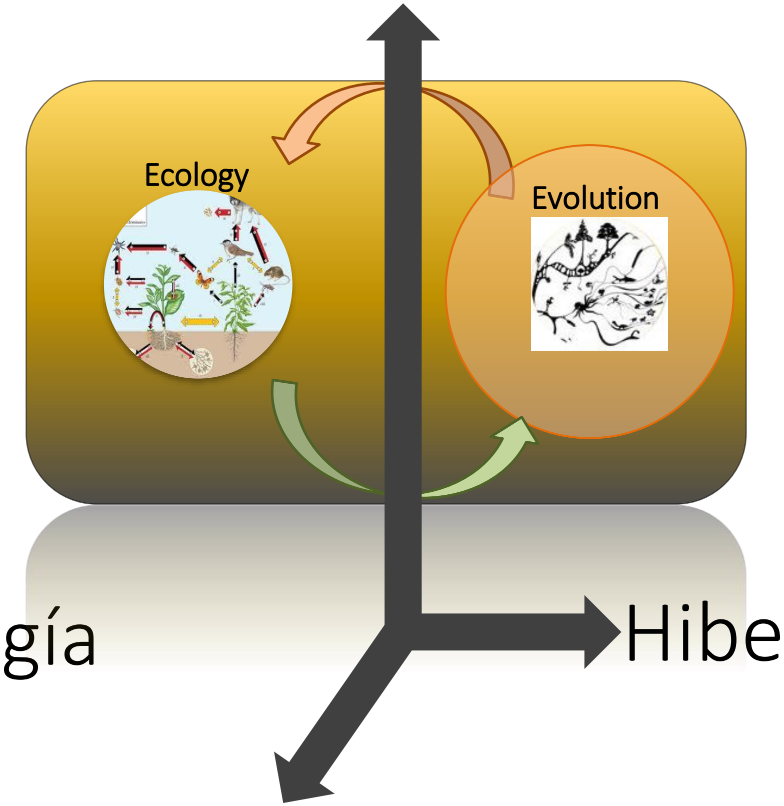

Ecology
Evolution

Fenología

Fisiología

Invierno

Migración


Ecology
Evolution

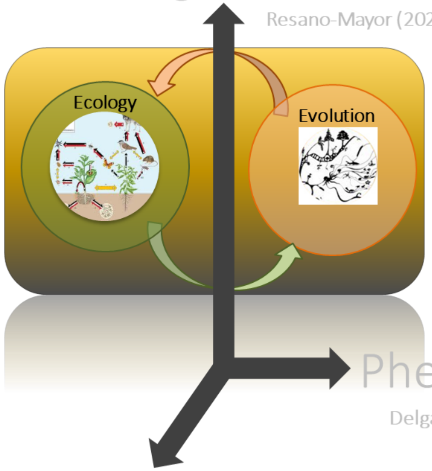
Hibernación

Resistencia

Cleland et al (2009) Ecology Letters

Migration

Resano-Mayor (2020) Global Ecology and Conservation



Phenology

Delgado et al. (2021) Proc. R. Soc. B

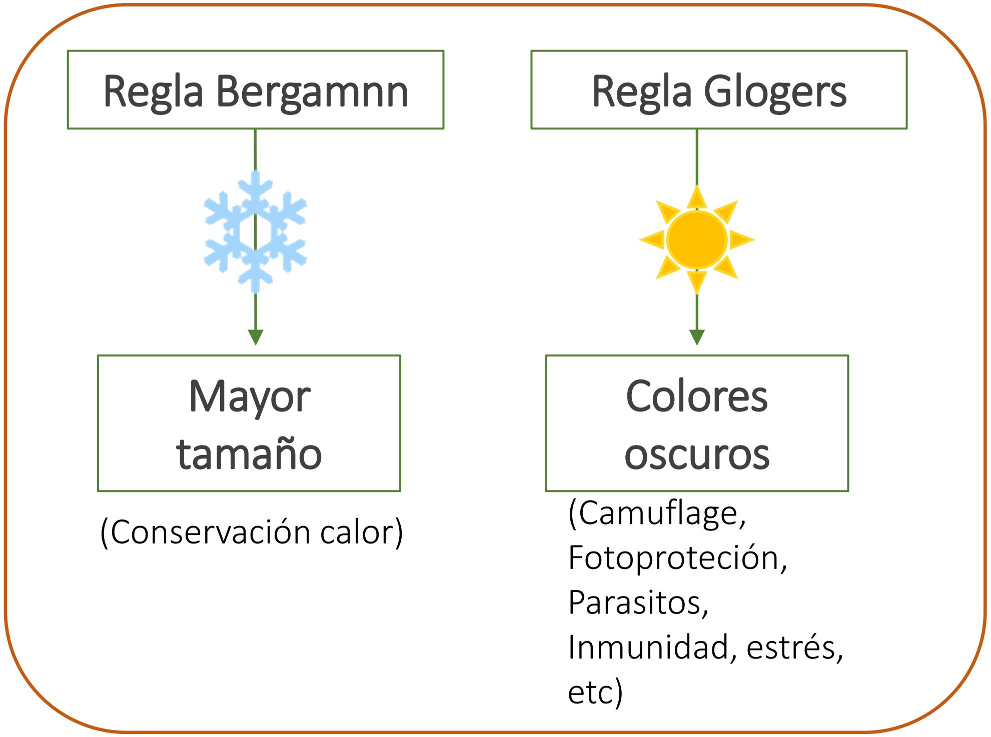
Physiology

Delgado et al. (2019) Scientisfic Reports

Ecotypic responses of alpine birds to climate change

Delgado et al. (2019) Scientisfic Reports

British Ecological Society



Regla Bergamnn

Mayor tamaño

(Conservación calor)

Regla Glogers

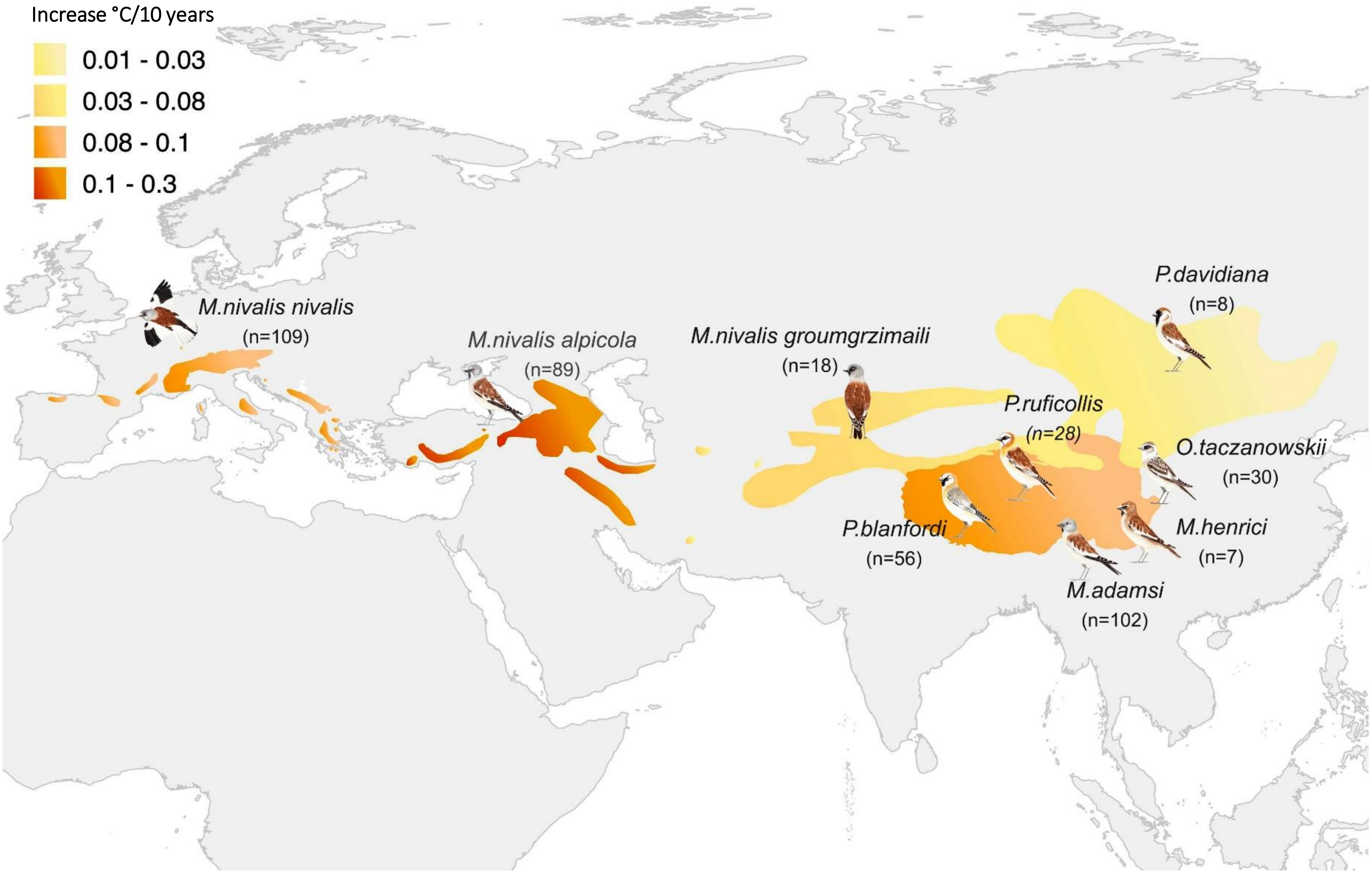
Colores oscuros

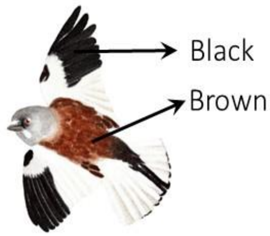
(Camuflage,
Fotoproteción,
Parasitos,
Inmunidad, estrés,
etc)

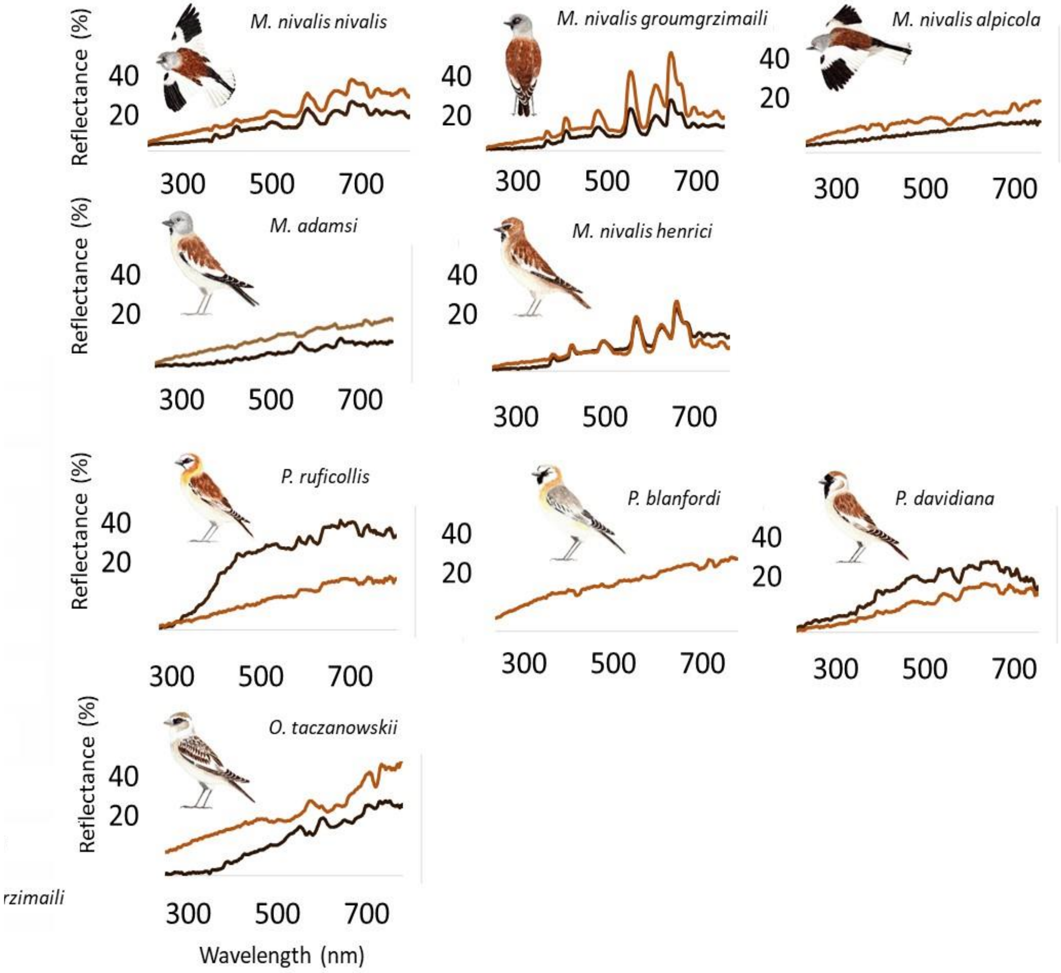
REGLAS ECOTÍPICAS

Cambio climático

Serie de datos de 100 años (desde 1850 a 1950)


Increase °C/10 years
0.01 - 0.03
0.03 - 0.08
0.08 - 0.1
0.1 - 0.3
M.nivalis nivalis
(n=109)
M.nivalis alpicola
(n=89)
M.nivalis groumgrzimaili
(n=18)
P.davidiana
(n=8)
P.ruficollis
(n=28)
O.taczanowskii
(n=30)
P.blanfordi
(n=56)
M.henrici
(n=7)
M.adamsi
(n=102)


Black
Brown


M. nivalis nivalis
M. nivalis groumgrzimaili
M. nivalis alpicola
M. adamsi
M. nivalis henrici
P. ruficollis
P. blanfordi
P. davidiana
O. taczanowskii
rzimaili
Reflectance (%)
40
20
300
500
700
Wavelength (nm)

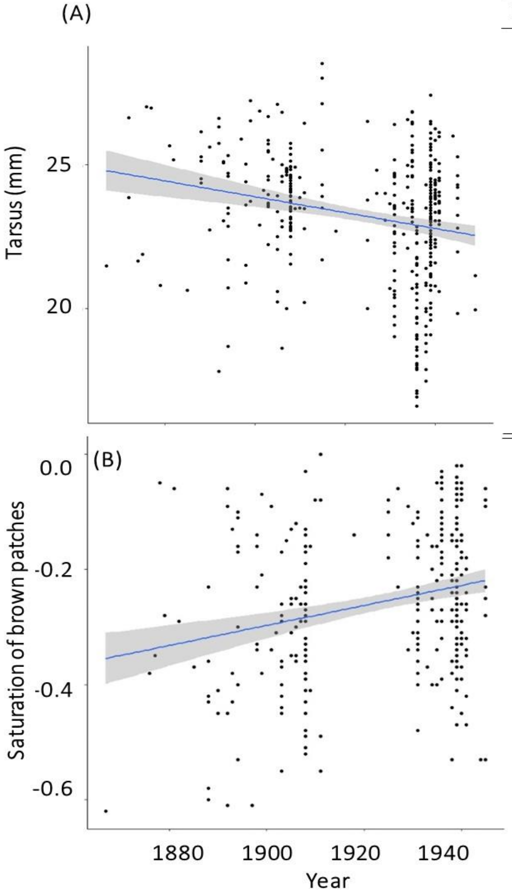
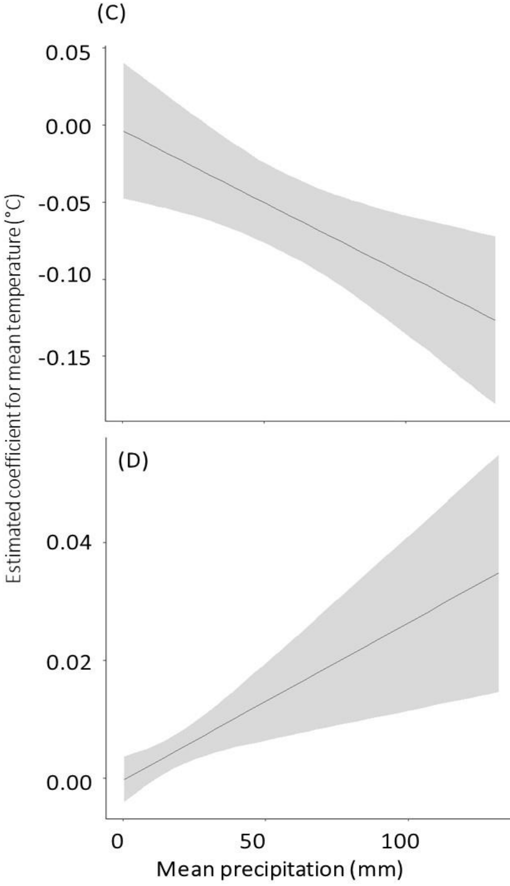
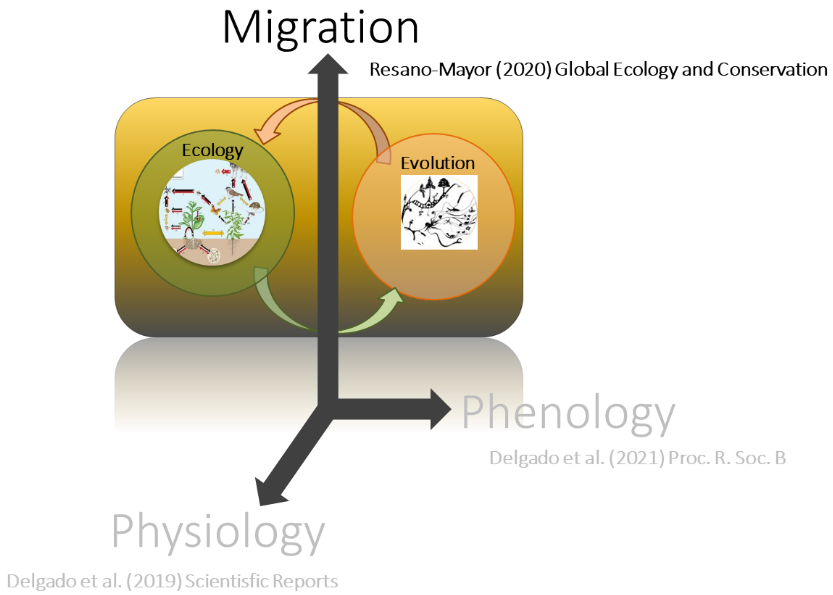


Table 1. Model-averaged coefficients, AICc, ΔAICc, weighted AICc and RIV values for morphometric and colour features against climatic variables

Dependent variable	Competing models		AICc	ΔAICc	Weighted AICc
	Temp + Sex		1197.30	6.37	0.03
	Temp + **Precip**		1197.04	6.12	0.03
	Temp		1195.24	4.32	0.07
	Sex + Temp*Precip		1193.00	2.08	0.22
	Temp*Precip		**1190.92**	**0.00**	**0.64**
	Explanatory variables	Model-averaged coefficients and relative importance values			
		β	SE	p	RIV
	Intercept	23.1481	0.4912	<2 e-16	
	Precip	0.0604	0.1500	0.6884	0.90
	Temp	-0.4223	0.1076	<0.001	1.00
	Precip*Temp	-0.2437	0.0846	<0.001	0.86
	Sex	-0.0168	0.1697	0.9212	0.26
	Null		-301.78	13.14	0.00
	Precip		-302.29	12.63	0.00
	Temp		-307.54	7.38	0.02
	Precip + Temp		-307.80	7.12	0.03
	Temp*Precip		**-314.92**	**0.00**	**0.95**
	Explanatory variables	Model-averaged coefficients and relative importance values			
		β	SE	p	RIV
	Intercept	-0.2604	0.0239	<2 e-16	
	Precip	0.0408	0.0158	0.0103	0.98
	Temp	0.0532	0.0149	0.0004	1.00
	Precip:Temp	0.0433	0.0177	0.0151	0.95





Migration

Resano-Mayor (2020) Global Ecology and Conservation

Ecology

Evolution

Phenology

Delgado et al. (2021) Proc. R. Soc. B

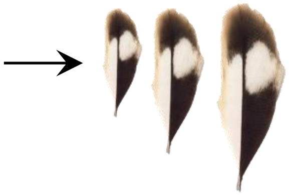
Physiology

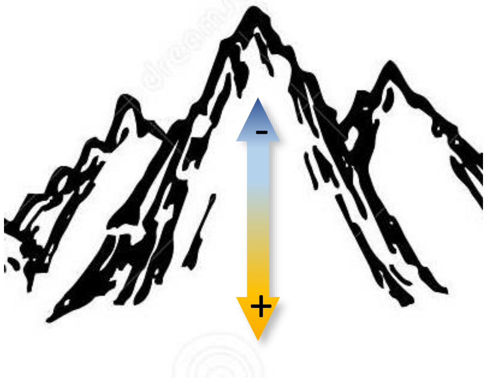
Delgado et al. (2019) Scientisfic Reports

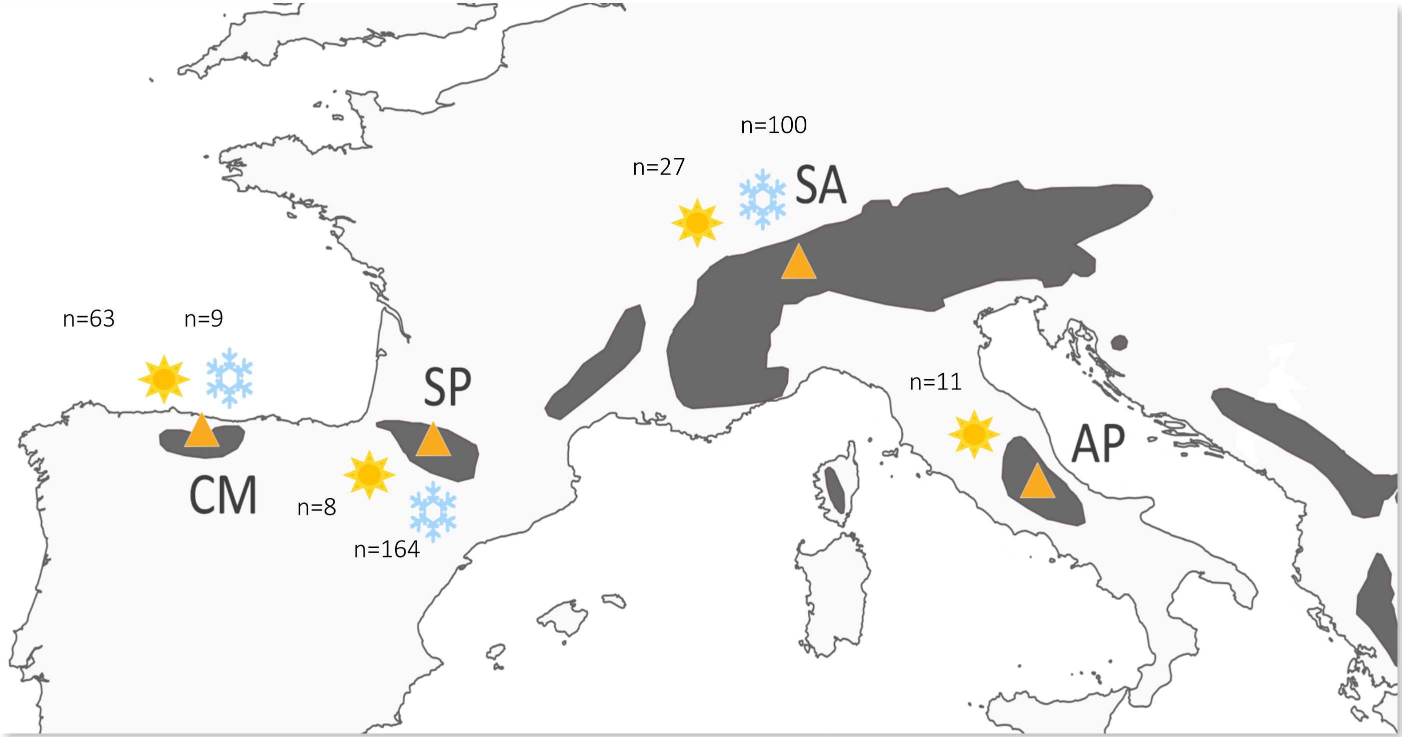
Partial migration of the White-winged Snowfinch is correlated with winter weather conditions

Resano-Mayor et al. (2020) Global Ecology and Conservation

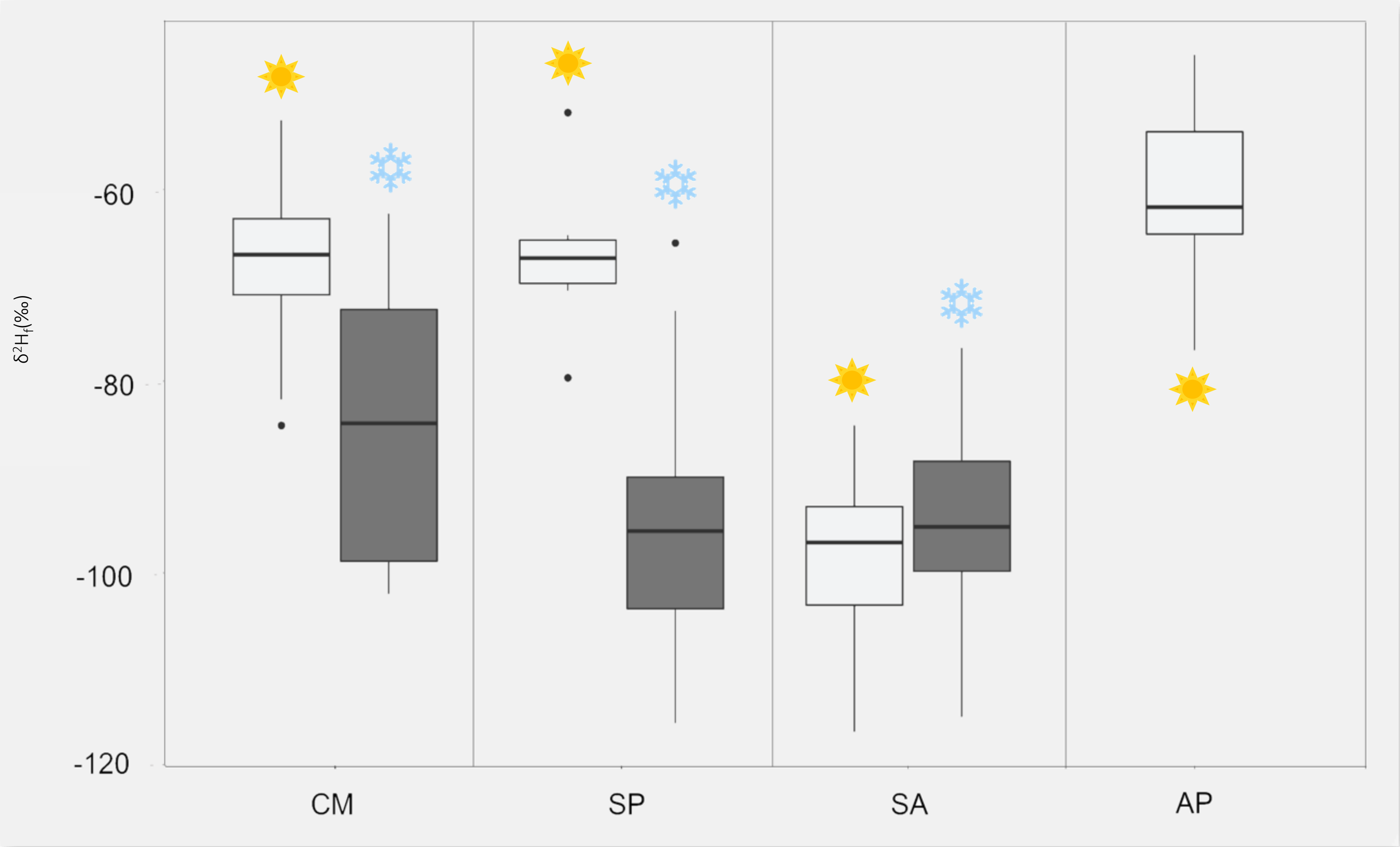
δ^{2}H
precipitación
Superficies de agua



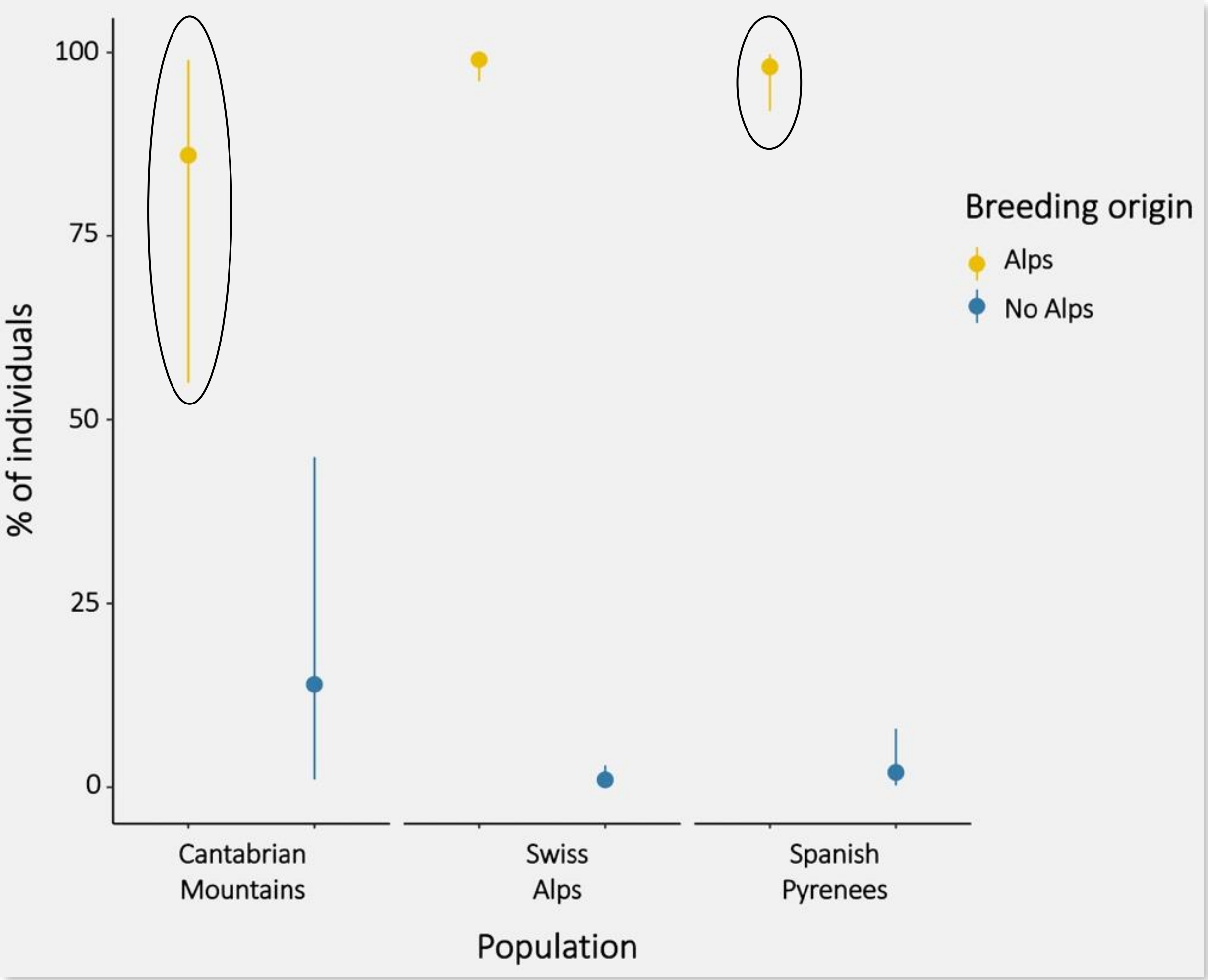



n=100
n=27
SA
n=63
n=9
SP
CM
n=8
n=164
n=11
AP

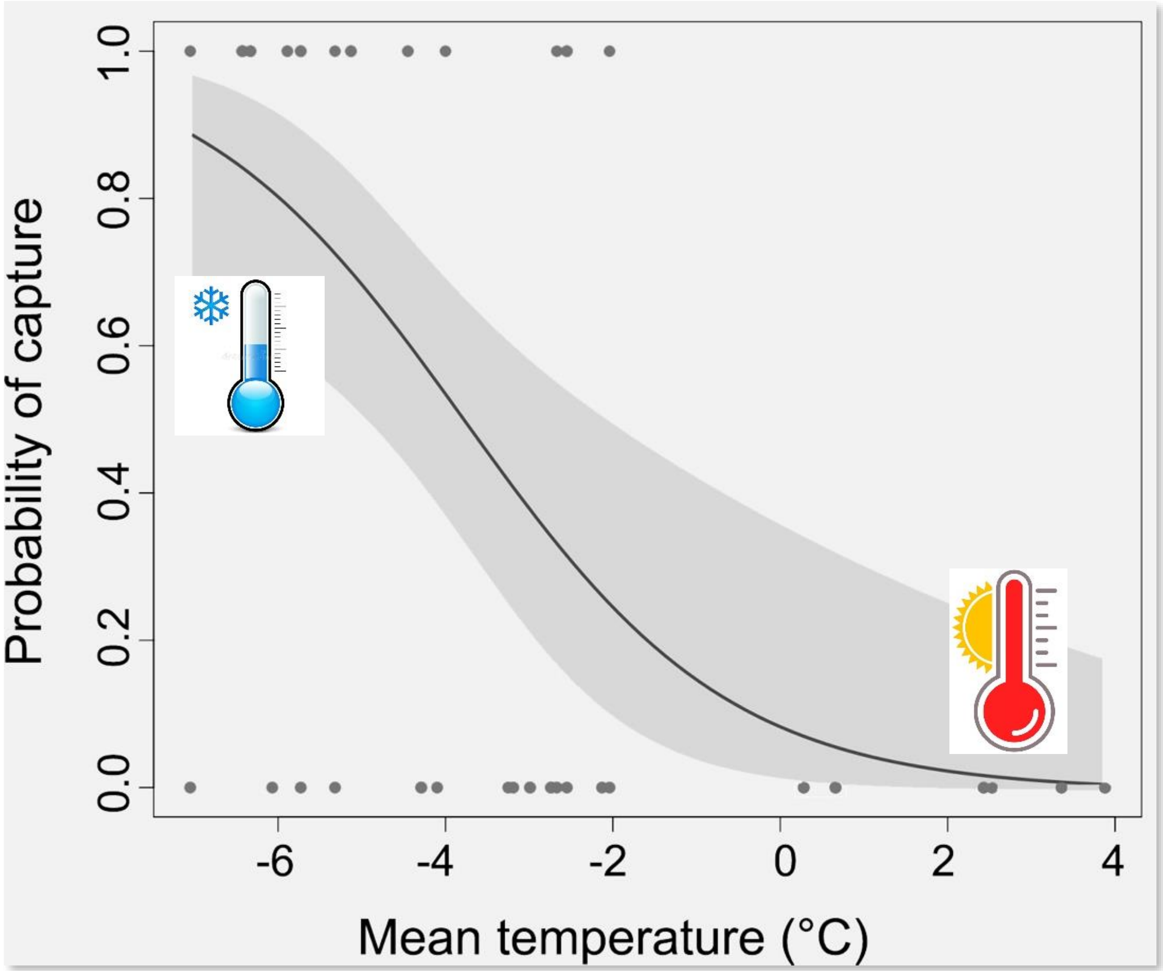
Hay diferencias en δ^2H_f entre las poblaciones?



Probabilidad de orígen



Afecta las condiciones climáticas durante el invierno la probabilidad de migrar?



rafabenjumea

Flujo genético → Estructura genética & rescate de poblaciones aisladas

↑ ✗

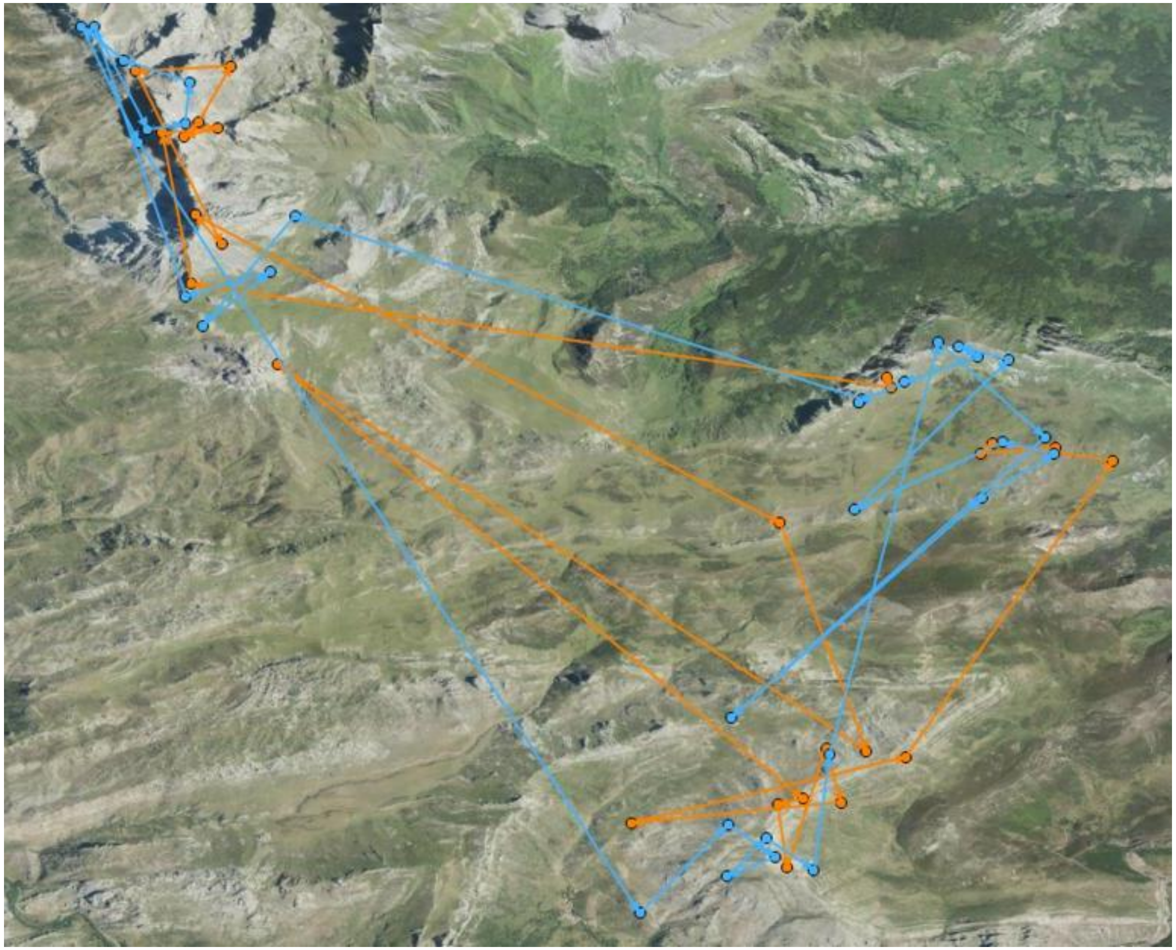
Cambio climático

=

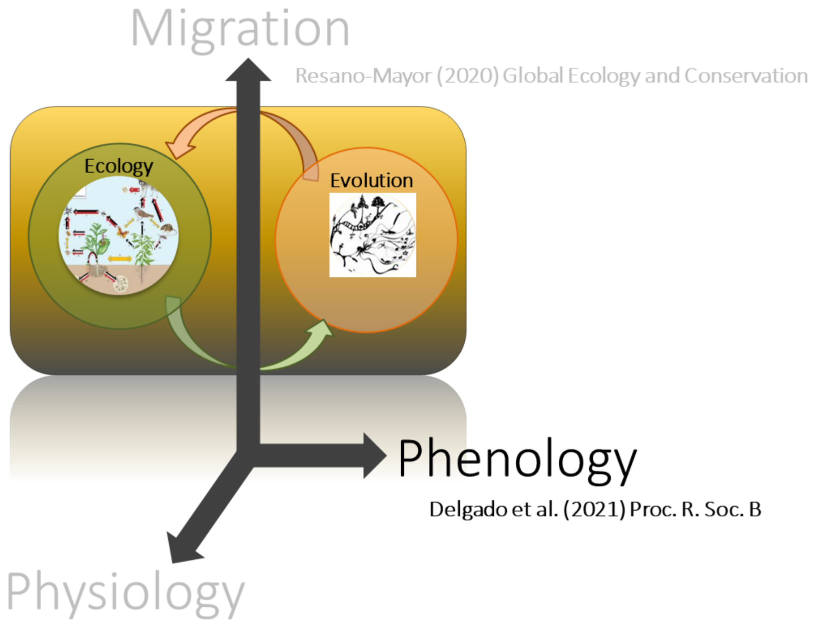
Inviernos templados

< **Propensidad migración?**

A) Nivel del individuo



B) Nivel de grupo



Migration

Resano-Mayor (2020) Global Ecology and Conservation

Ecology

Evolution

Phenology

Delgado et al. (2021) Proc. R. Soc. B

Physiology

Spatio-temporal variation in the wintering associations of an alpine bird

Delgado et al. (2021) Proc. R. Soc. B 288: 20210690

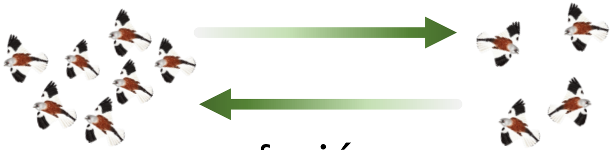
✓

Evitar predación
Encontrar recursos

✗

Enfermedades
Competición

balance



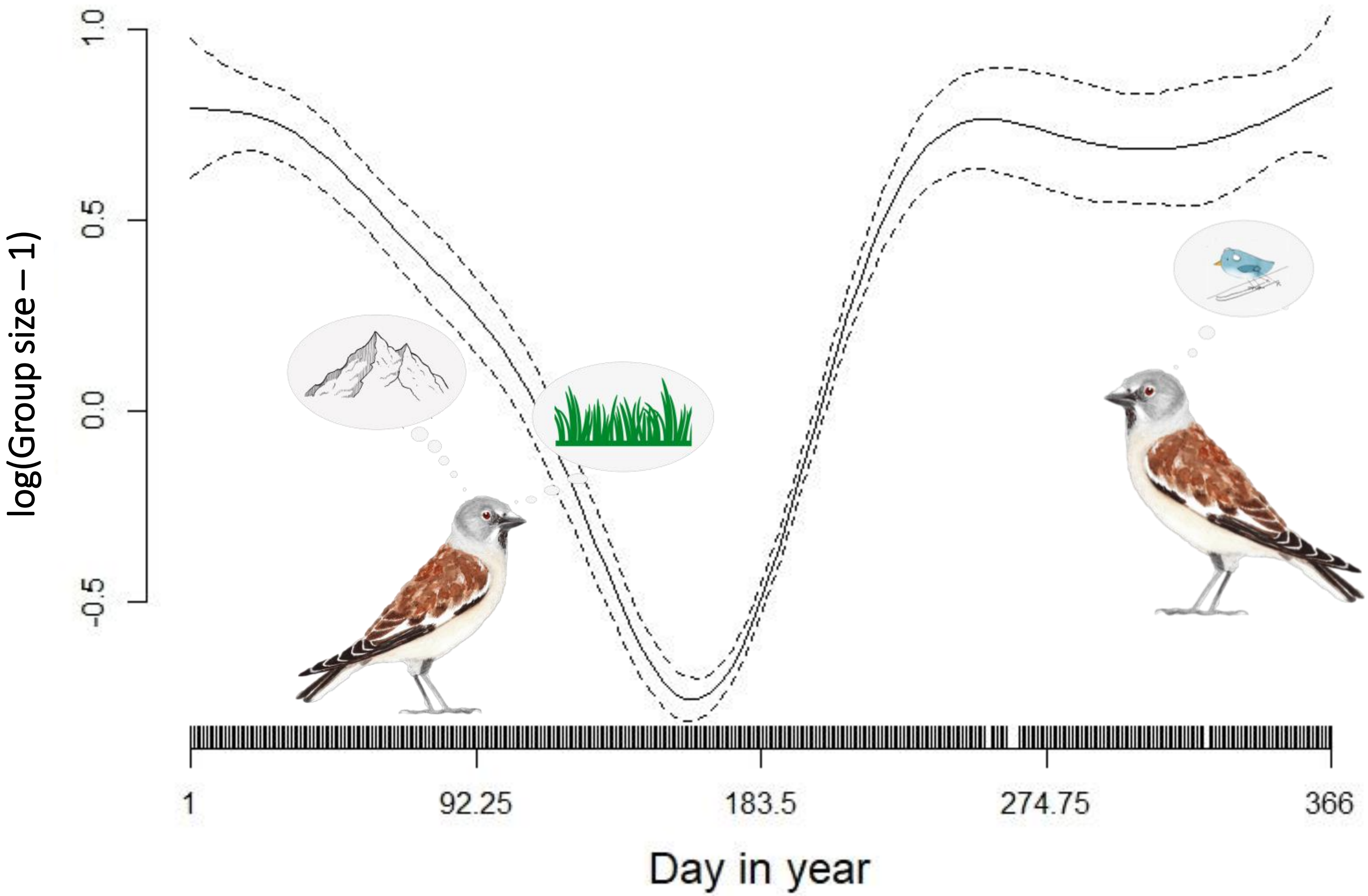
fisión

fusión

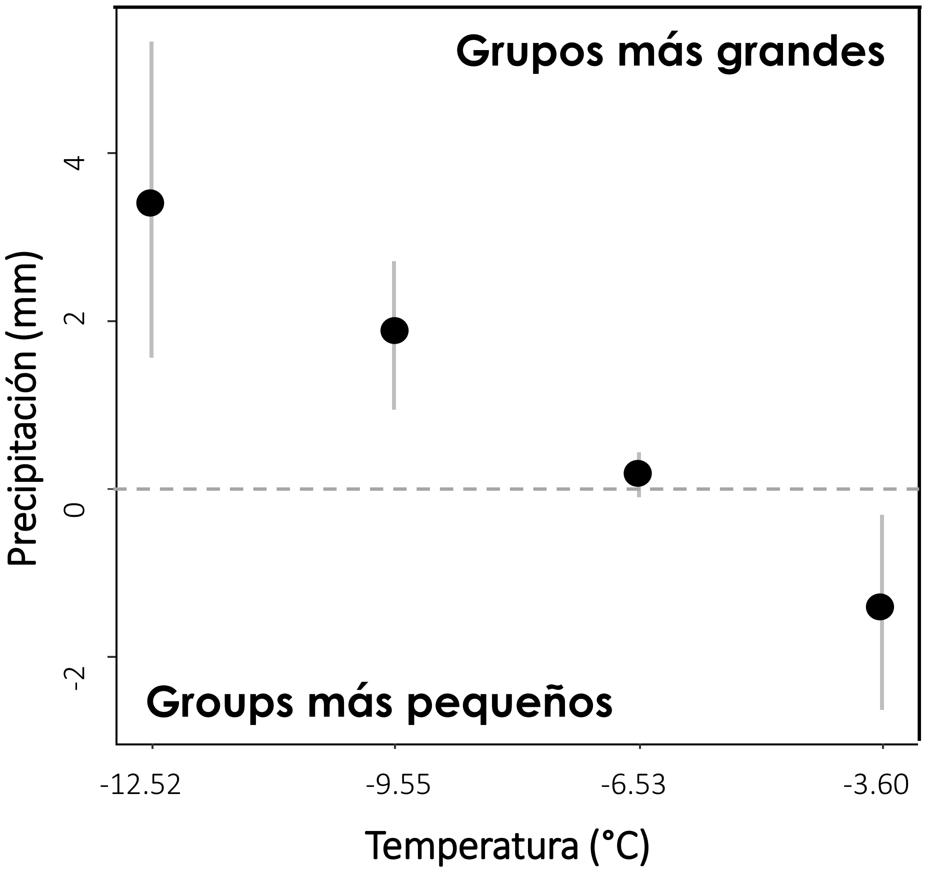
dinámica

Sueur et al. 2011 Oikos

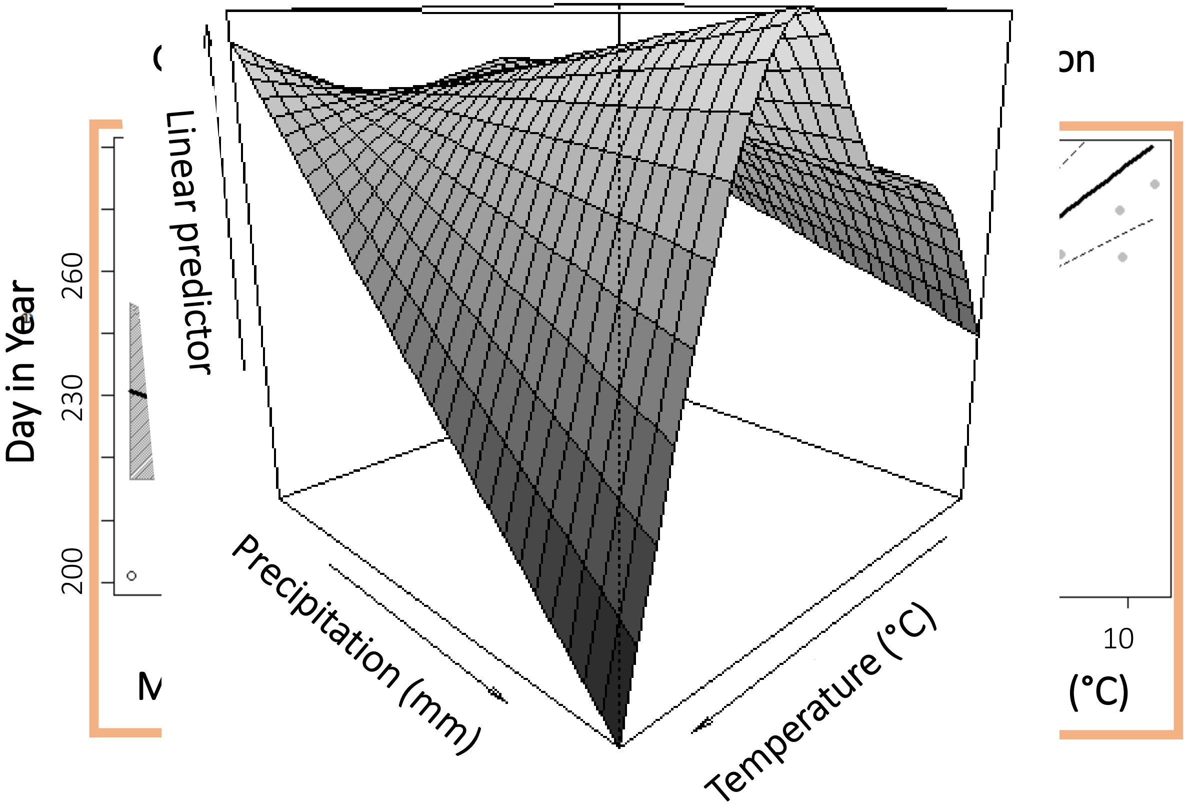
Fenología



Gradiente geográfico?

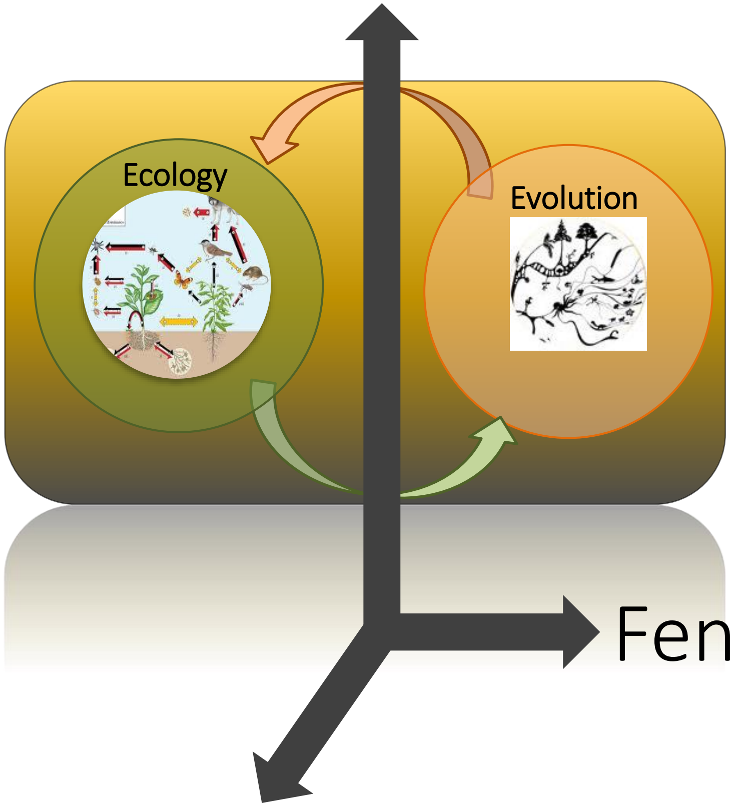


Respuestas a los cambios en el clima durante el invierno



Cambio climático

Movimientos

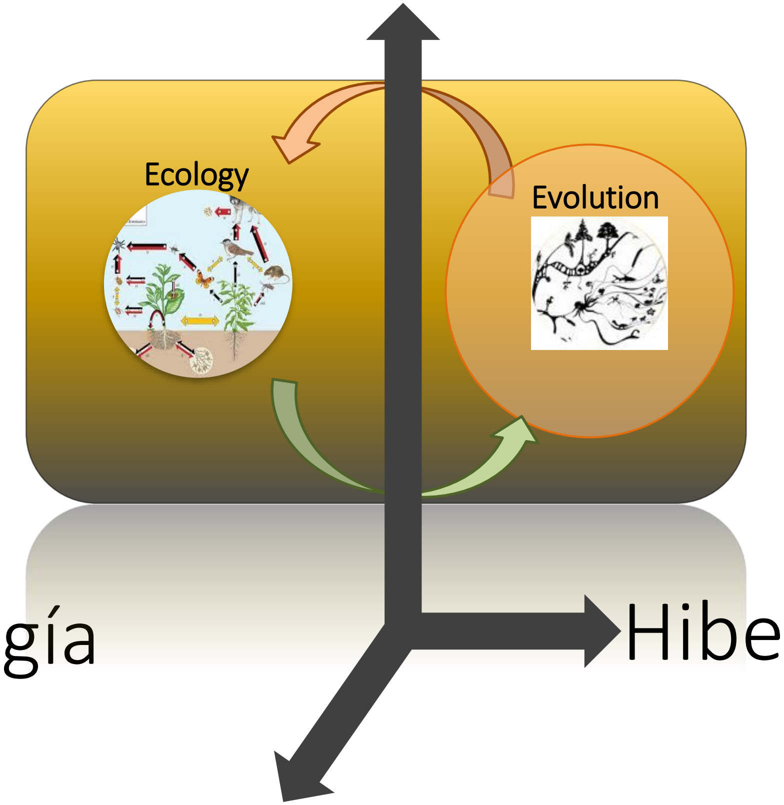

Ecology
Evolution

Fenología

Fisiología

Invierno

Migración

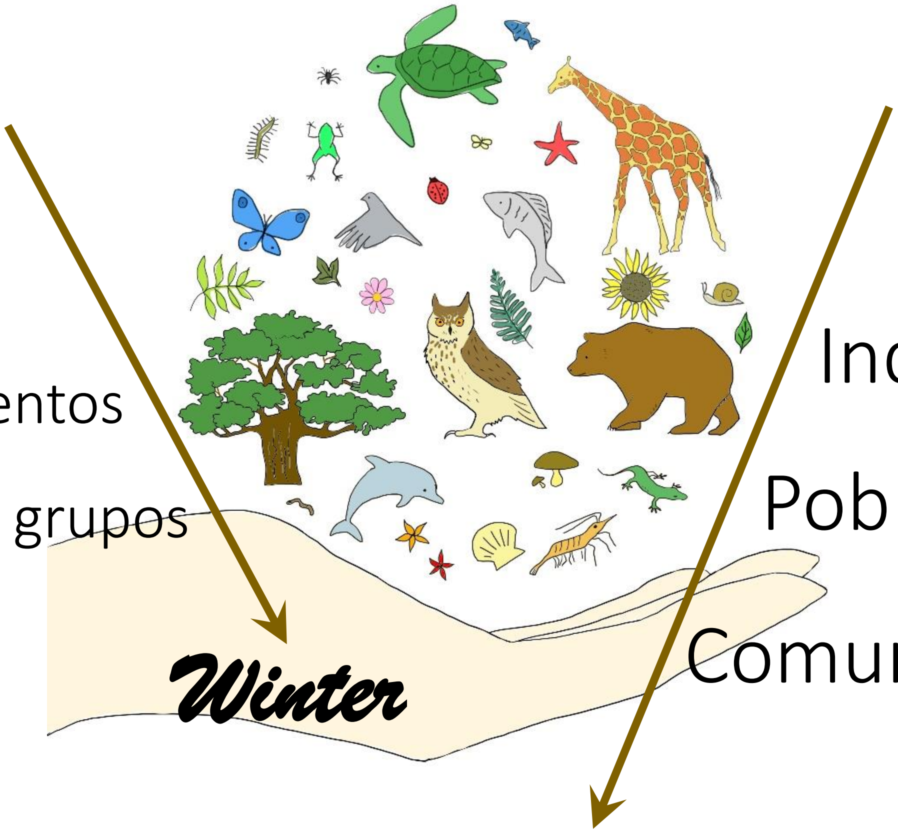

Ecology
Evolution

Hibernación

Resistencia

Cleland et al (2009) Ecology Letters

Impactos del cambio climático



Fisiología

Movimientos

Dinámicas de grupos

Individuos

Poblaciones

Comunidades

Biodiversidad