FOOD: Wild harvest

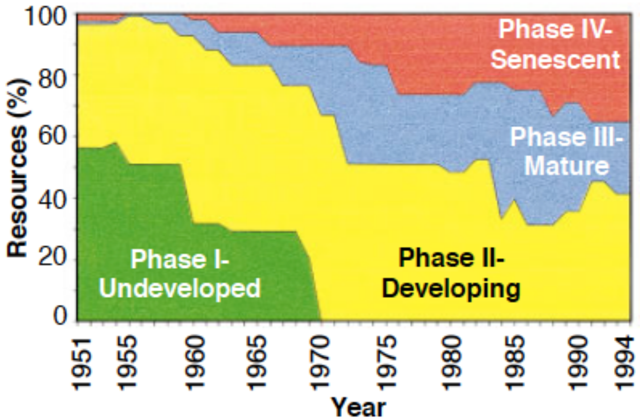


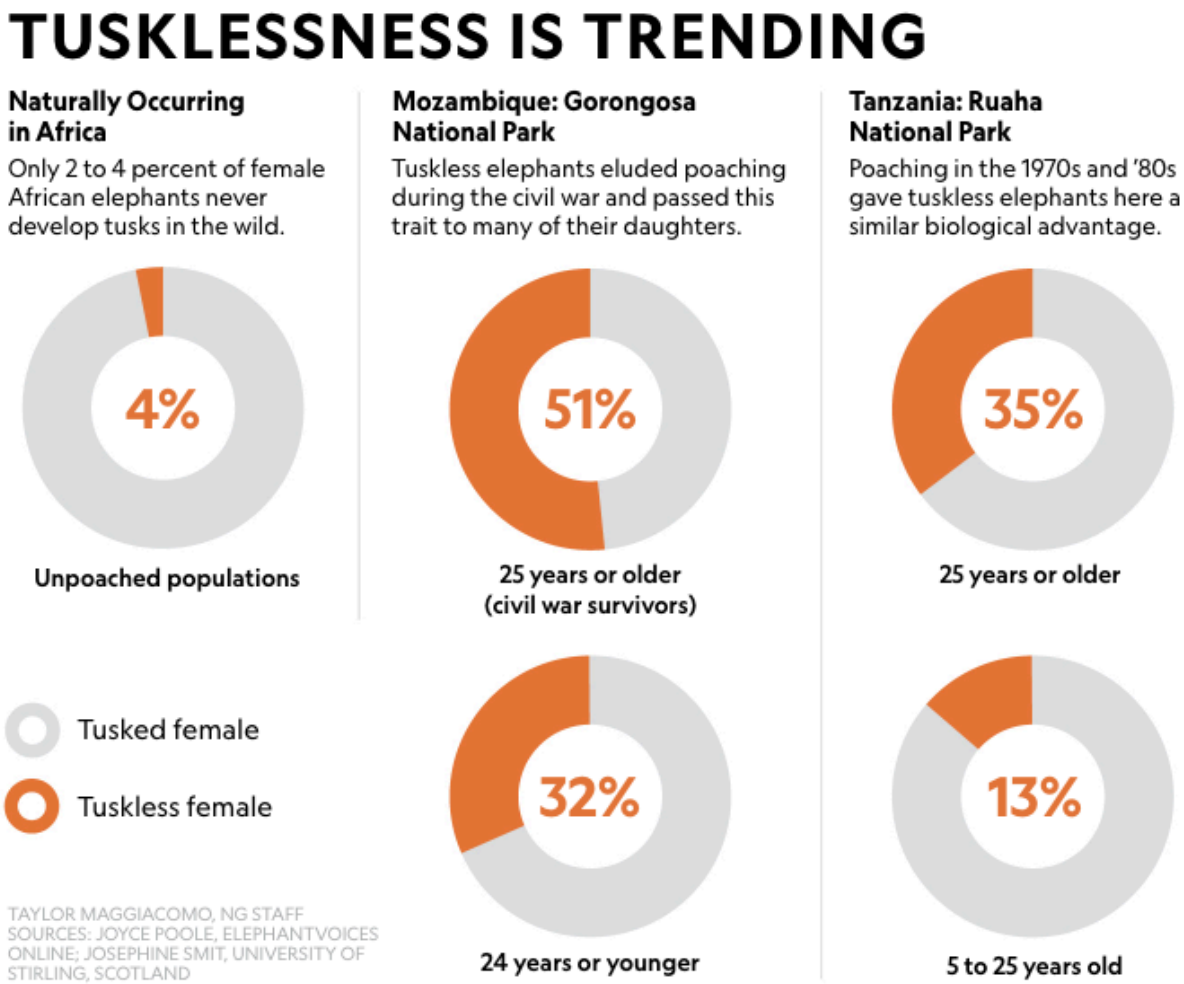
Fig. 3. Percentage of major world marine fish resources in different phases of development, 1951 to 1994 [from (*57*)]. Undeveloped = a low and relatively constant level of catches; developing = rapidly increasing catches; mature = a high and plateauing level of catches; senescent = catches declining from higher levels.

Vitousek et al., 1997

Harvest-induced evolutionary changes in marine and freshwater fish.

Evolutionary change	No. of species	No. of studies	Change % (*n*)
Maturation at lower age	6	10	23–24 (1)
Maturation at smaller size	7	13	20–33 (3)
Lower PMRN midpoint	5	10	3–49 (13)
Reduced annual growth	6	6	15–33 (3)
Increased fecundity	3	4	5–100 (3)
Loss of genetic diversity	3	3	21–22 (2)

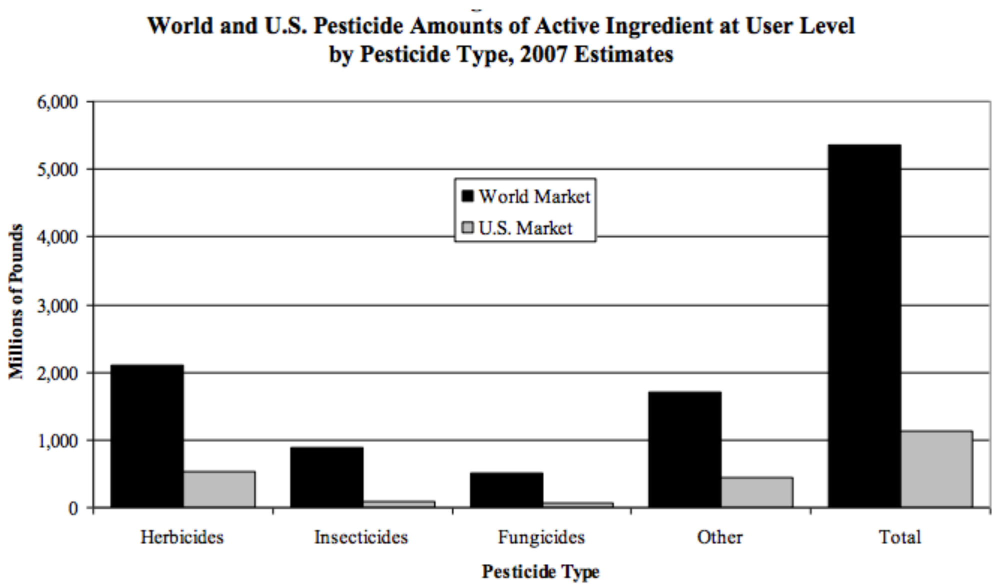
Jorgensen et al., 2007



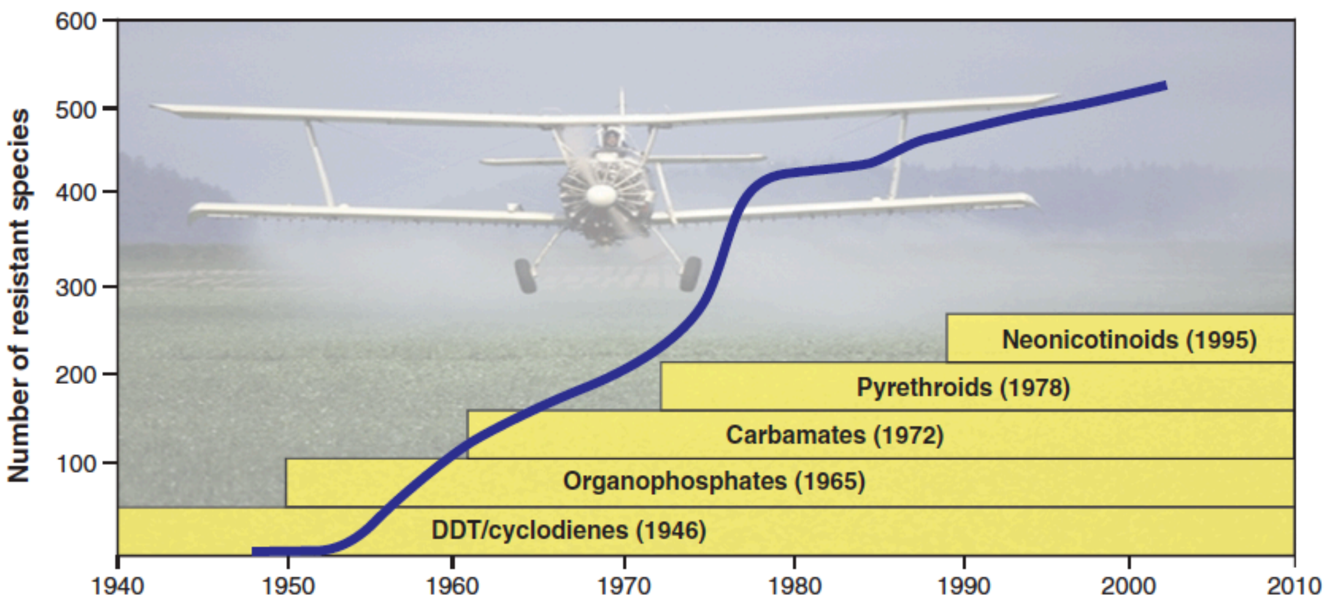
nationalgeographic.com

https://www.hhmi.org/biointeractive/selection-tuskless-elephants

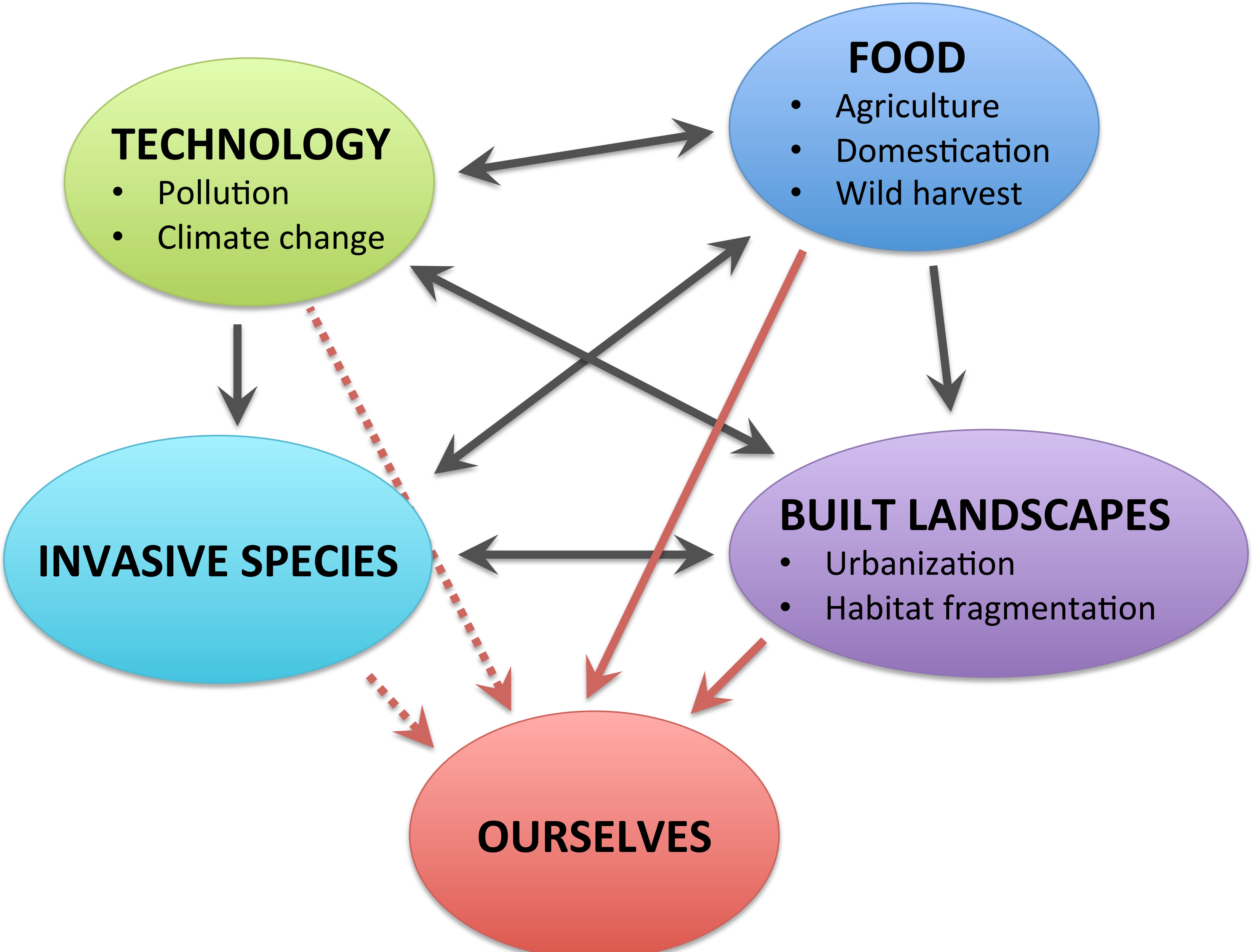
FOOD: Pests, and adaptation to pest control



US EPA

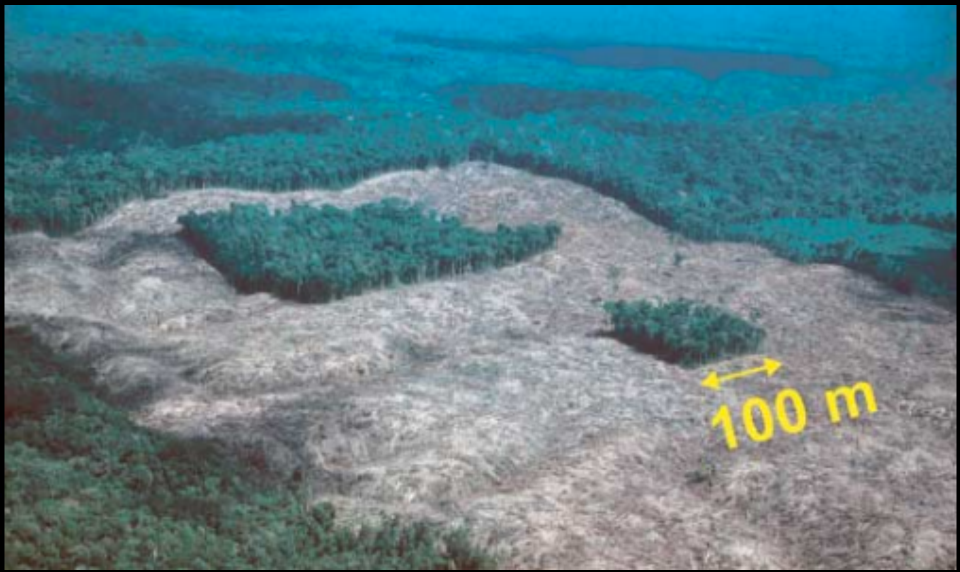


Denholm et al., 2002

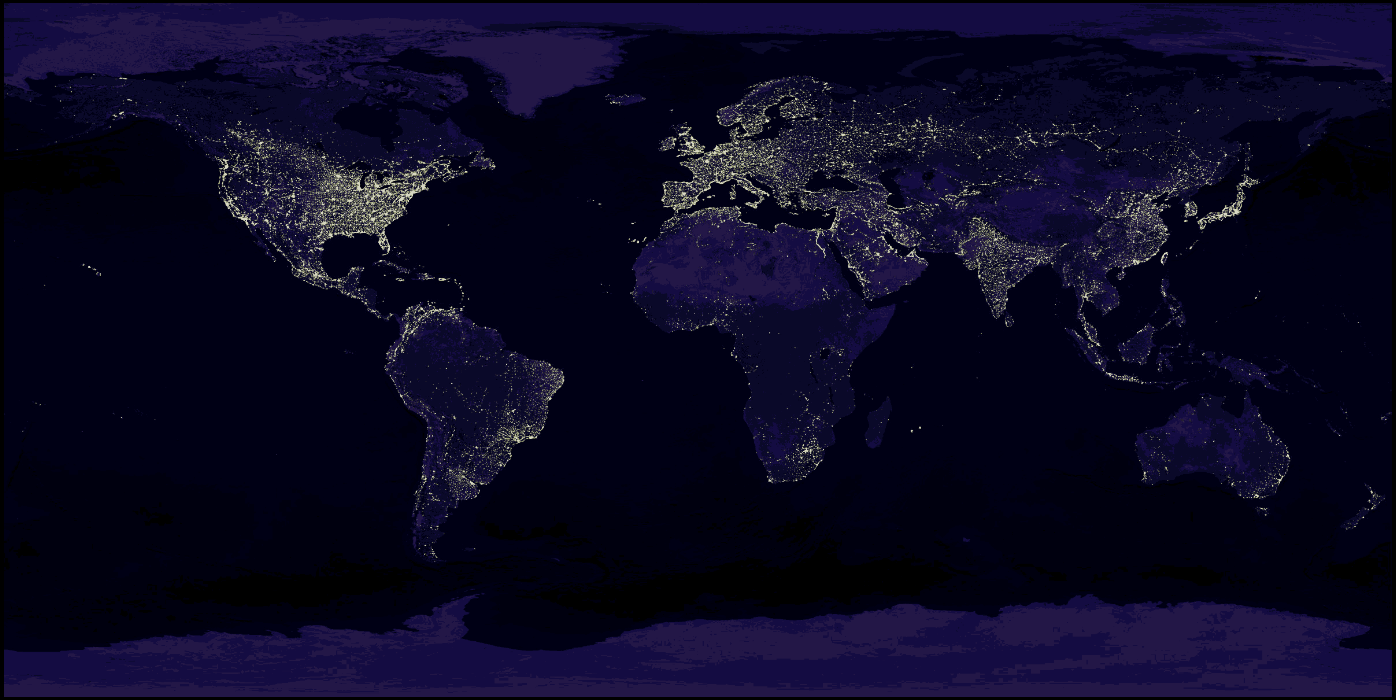


FOOD
Agriculture
Domestication
Wild harvest
TECHNOLOGY
Pollution
Climate change
INVASIVE SPECIES
BUILT LANDSCAPES
Urbanization
Habitat fragmentation
OURSELVES

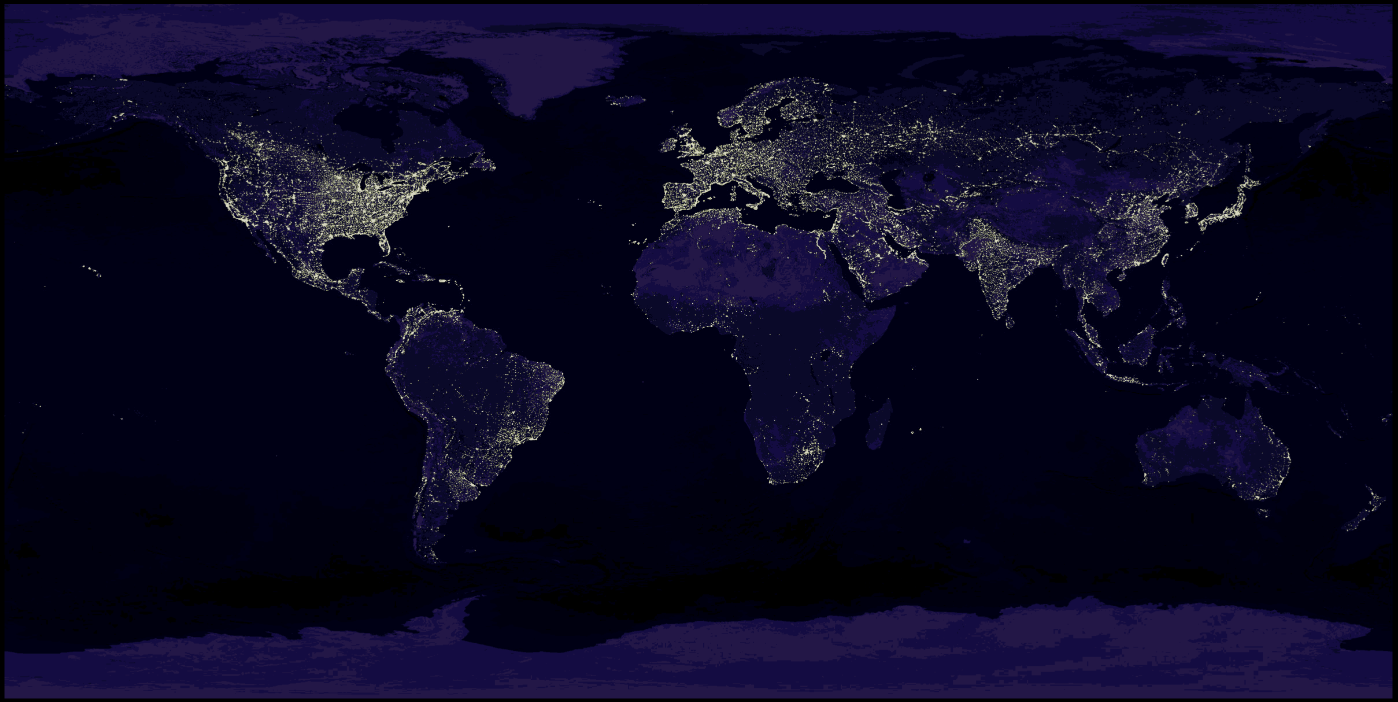
BUILT LANDSCAPES



BUILT LANDSCAPES

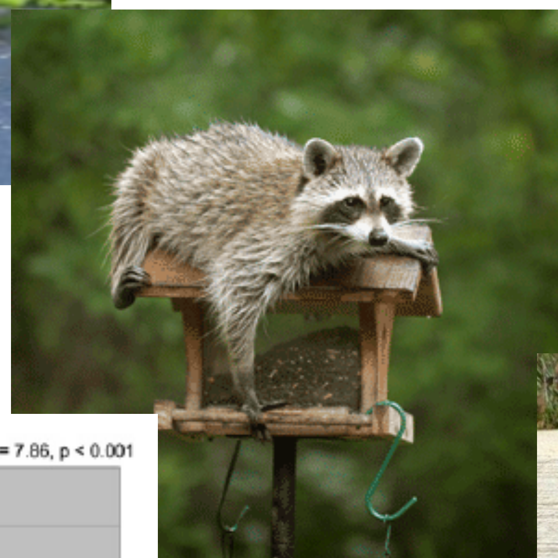


BUILT LANDSCAPES

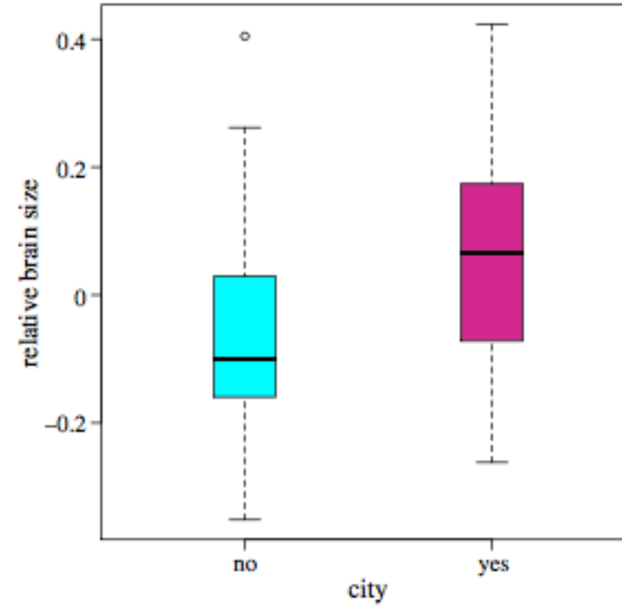


- Temperature (warmer)
- Lighting (artificial)
- High ambient noise & limited acoustic space
- Chemical pollution
- Little vegetation
- Exotic vegetation
- Solid surfaces
- Different parasites
- Different predators (e.g., domestic cats)
- Different food sources

BUILT LANDSCAPES

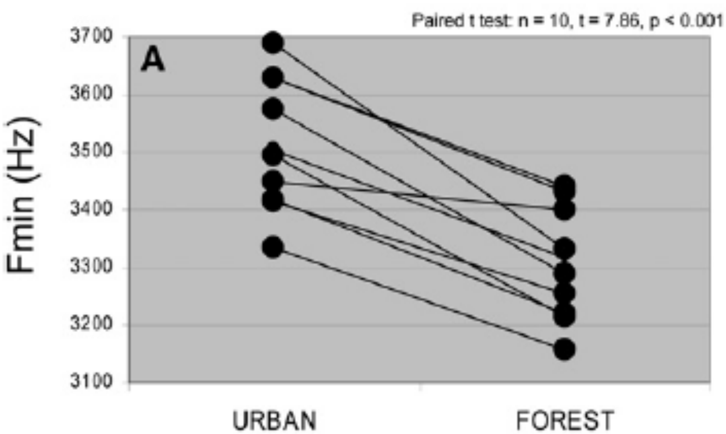


Cities favor bird species with bigger brains



Maklakov et al., 2011

City birds sing at higher frequencies



Slabbekoorn
& den Boer-Visser,
2006

BUILT LANDSCAPES

SURFACE

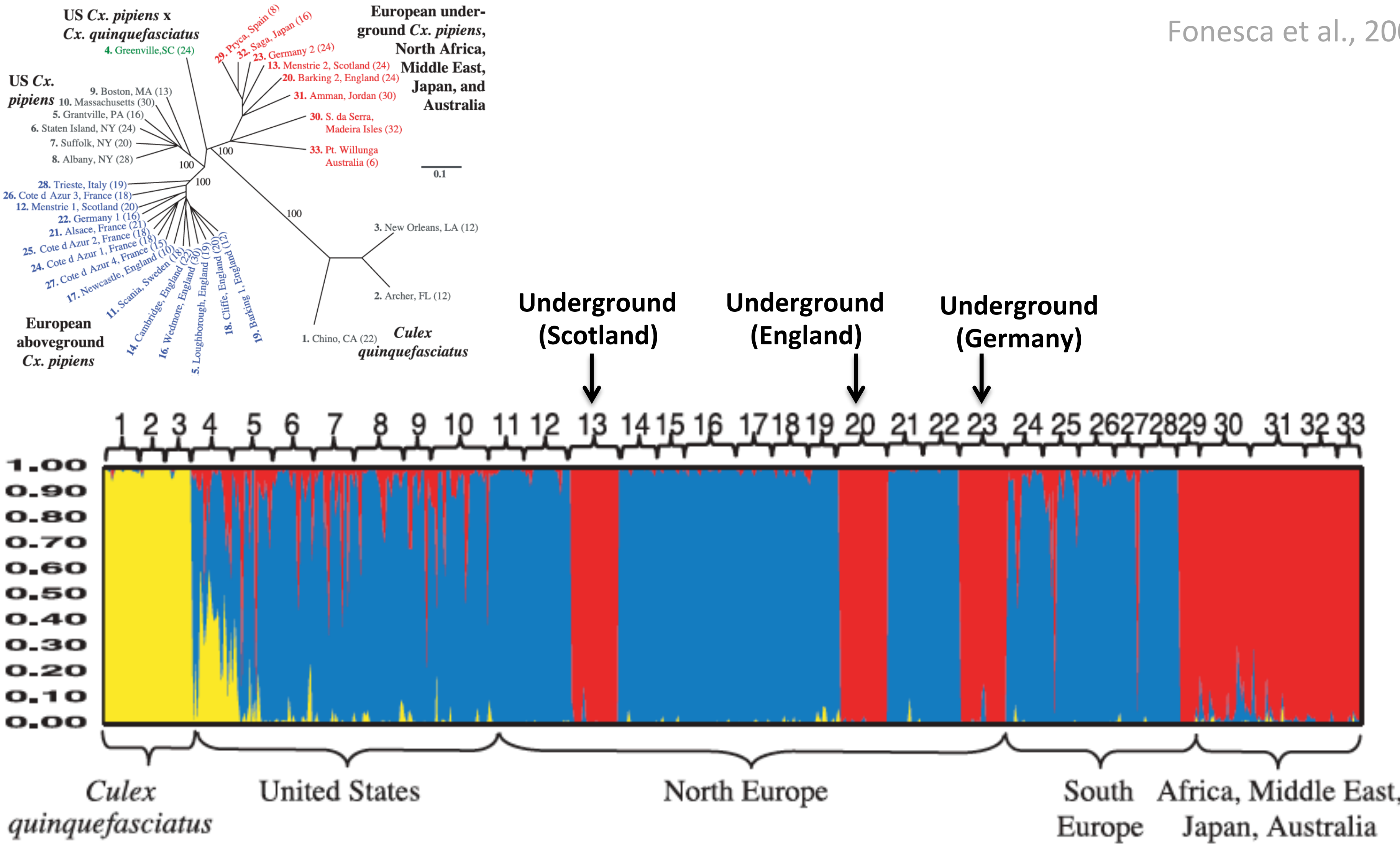
- Mate in large swarms in open areas
- Undergo seasonal (winter) diapause
- Get blood primarily from birds
- Require blood meal to reproduce

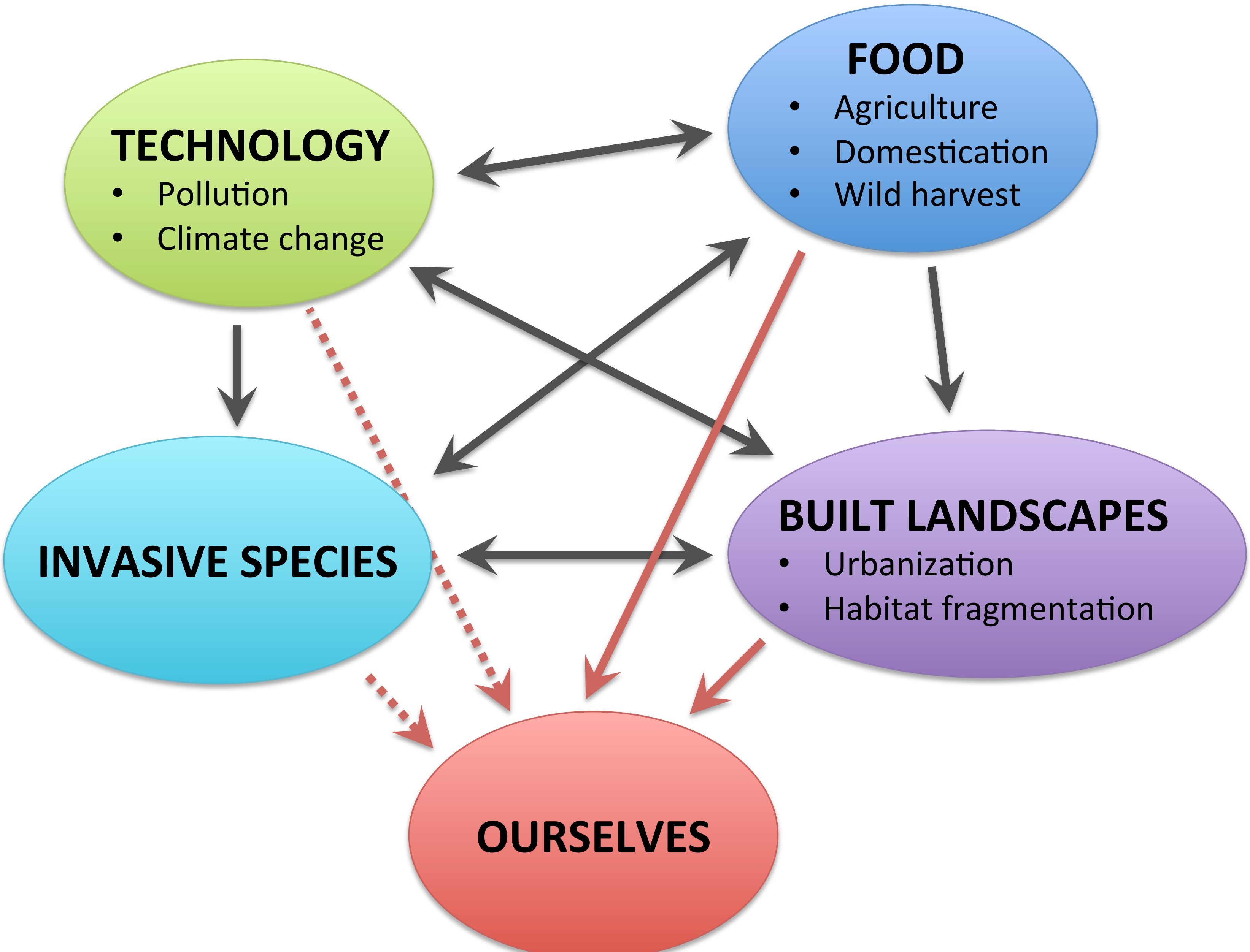
UNDERGROUND

- Mate in confined spaces
- No winter diapause
- Get blood mainly from mammals
- Do not require blood meal to reproduce

BUILT LANDSCAPES

Fonesca et al., 2004





TECHNOLOGY
• Pollution
• Climate change
FOOD
• Agriculture
• Domestication
• Wild harvest
INVASIVE SPECIES
BUILT LANDSCAPES
• Urbanization
• Habitat fragmentation
OURSELVES

TECHNOLOGY: Climate change

ENVIRONMENTAL CHALLENGES?

Changing PHENOLOGY

Leafing out earlier

Emerging earlier

Migration timing the same

- Populations of flycatcher have declined by 90% in areas where food peaks early in the season, and where birds are now mis-timed
- Population declines are greatest in areas where food peak is earliest

Both et al., 2006

TECHNOLOGY: Climate change

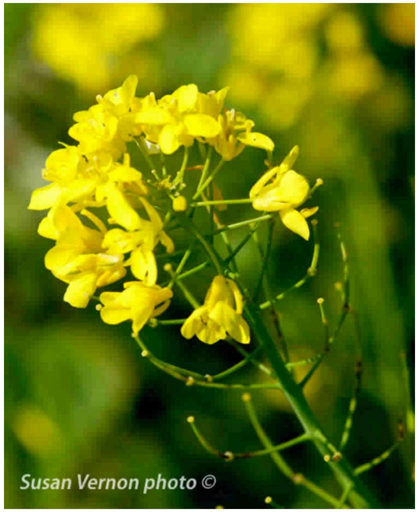
ENVIRONMENTAL CHALLENGES?

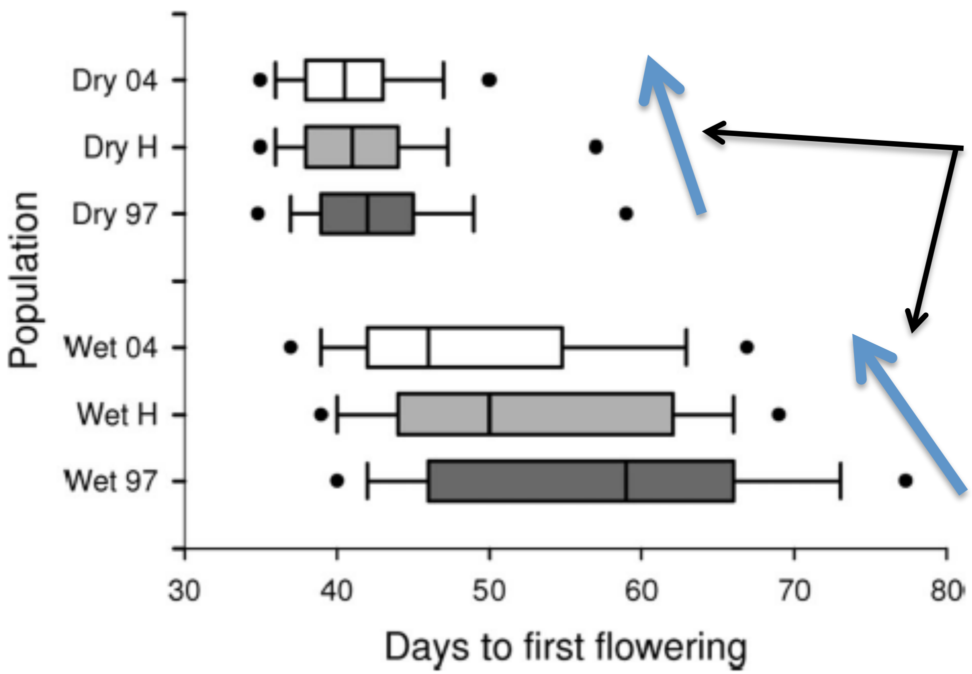
Meta-analysis of studies testing for shifts in the boundaries of species' ranges:

→ Analysis included 99 species of birds, butterflies, alpine plants

Type of change	Changed as predicted	Changed opposite to prediction	*P*-value
Distributional changes			
At poleward/upper range boundaries	81%	19%	–
At equatorial/lower range boundaries	75%	25%	–
Community (abundance) changes			
Cold-adapted species	74%	26%	–
Warm-adapted species	91%	9%	–
$N = 460/(920)$	81% ($n = 372$)	19% ($n = 88$)	$<0.1 \times 10^{-12}$
Meta-analyses			
Range-boundaries ($N = 99$)	$6.1\ \mathrm{km\,m^{-1}}$ per decade northward/upward shift*		0.013
Phenologies ($N = 172$)	2.3 days per decade advancement*		<0.05

TECHNOLOGY: Climate change



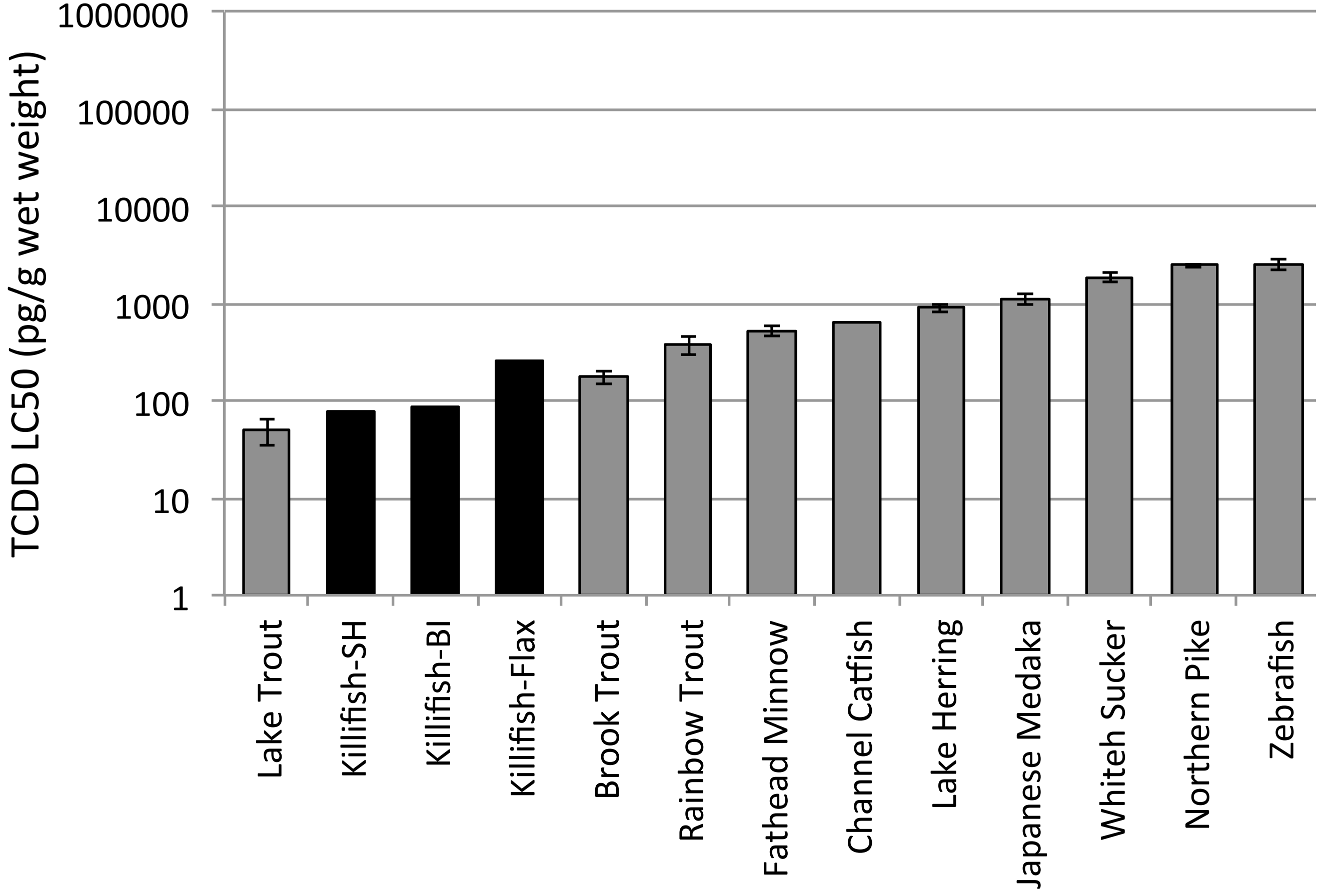


Shifts toward earlier flowering

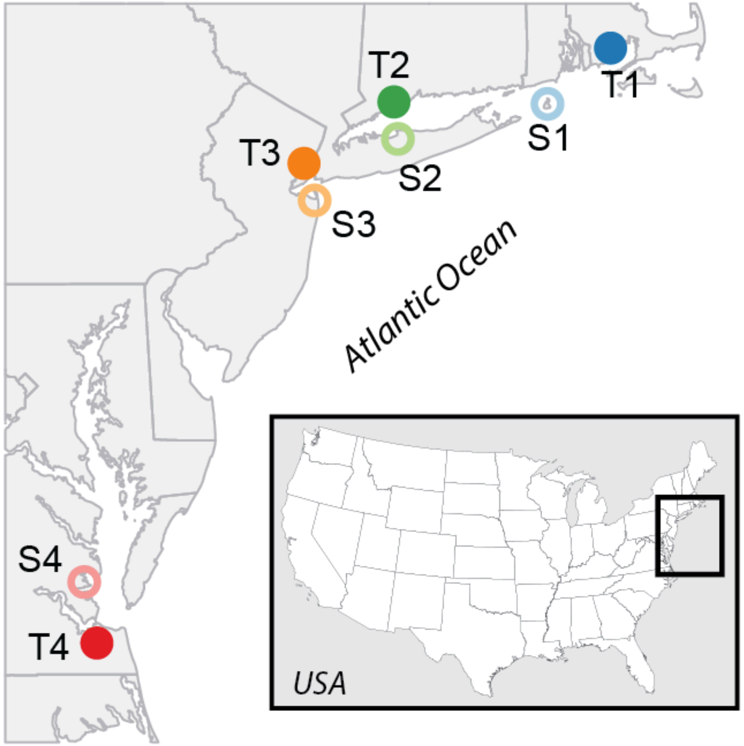
Temporal trends within Wet and Dry populations = rapid evolutionary change

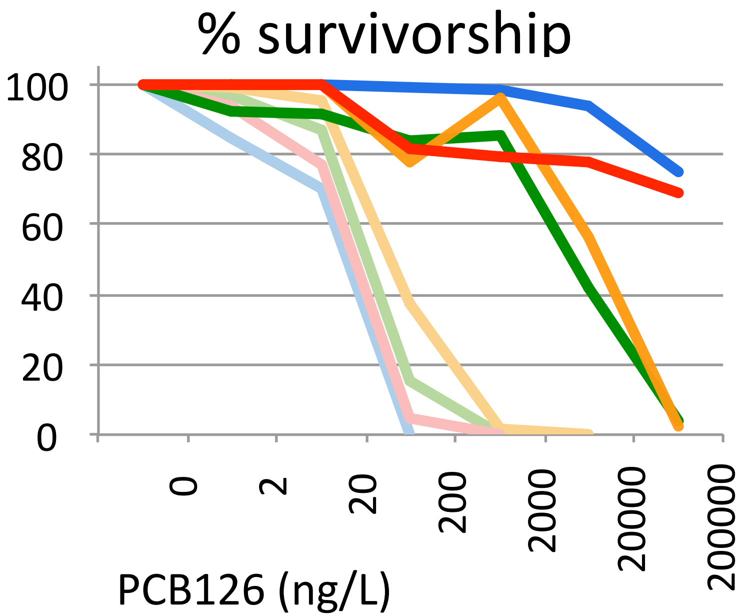
Franks et al., 2007

TECHNOLOGY: Pollution



TECHNOLOGY: Pollution

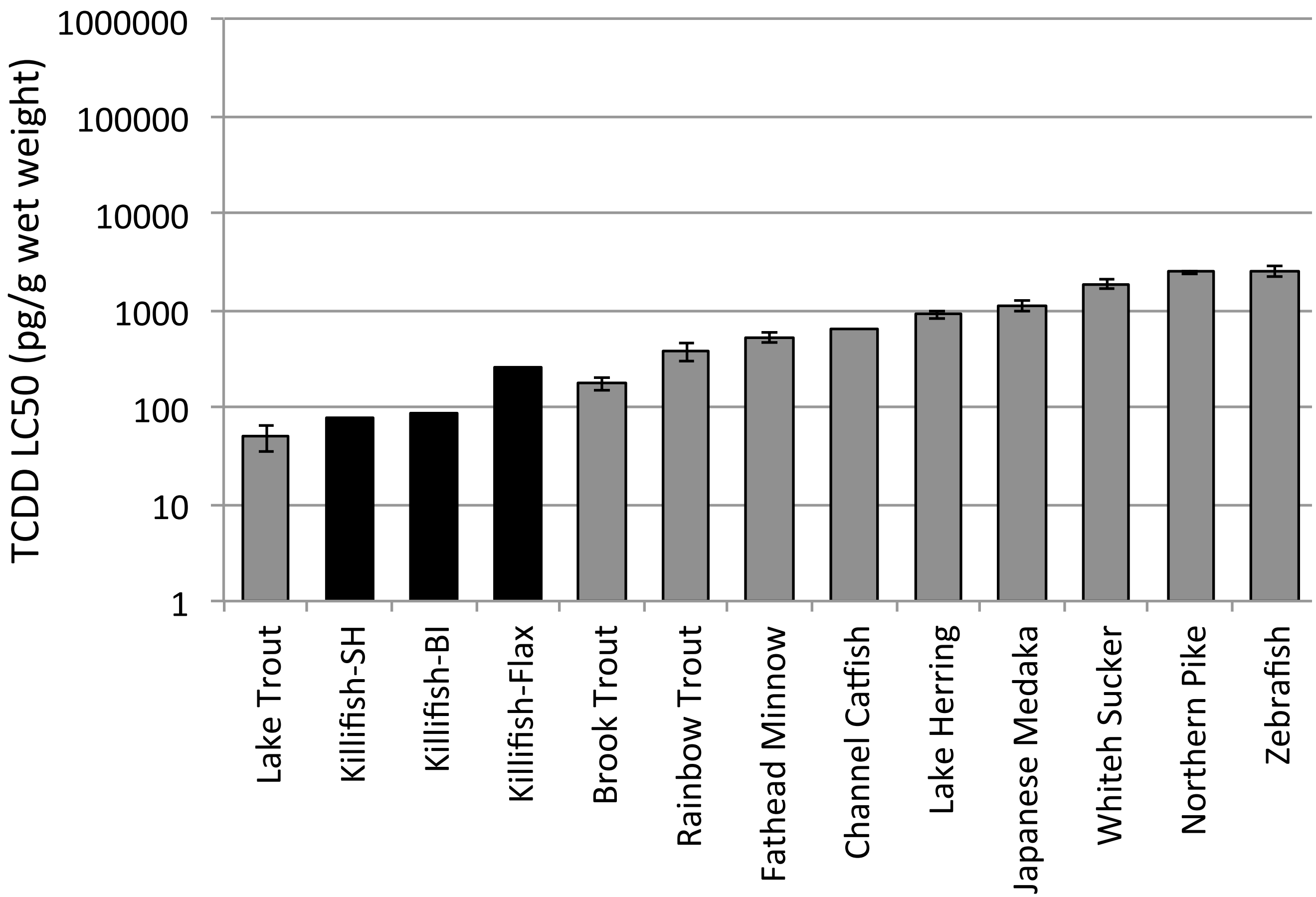




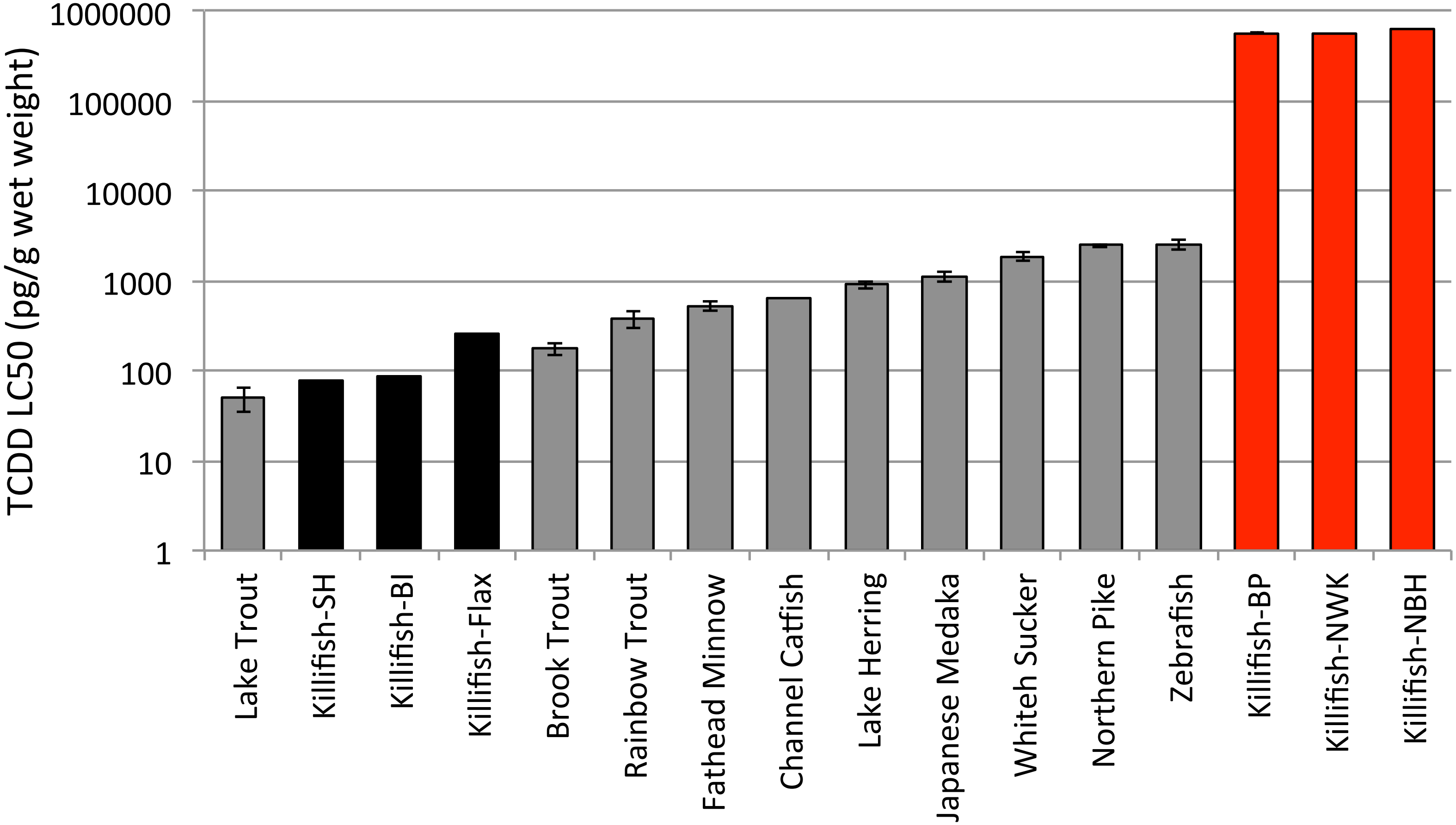
Whitehead et al., *Proc. Roy. Soc. B.*, 2012

Extreme tolerance phenotype

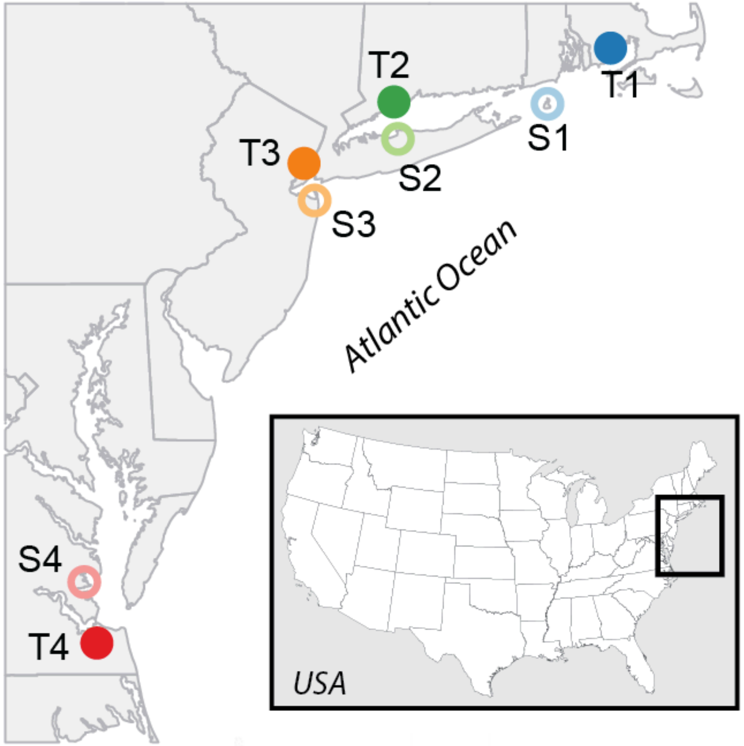
TECHNOLOGY: Pollution

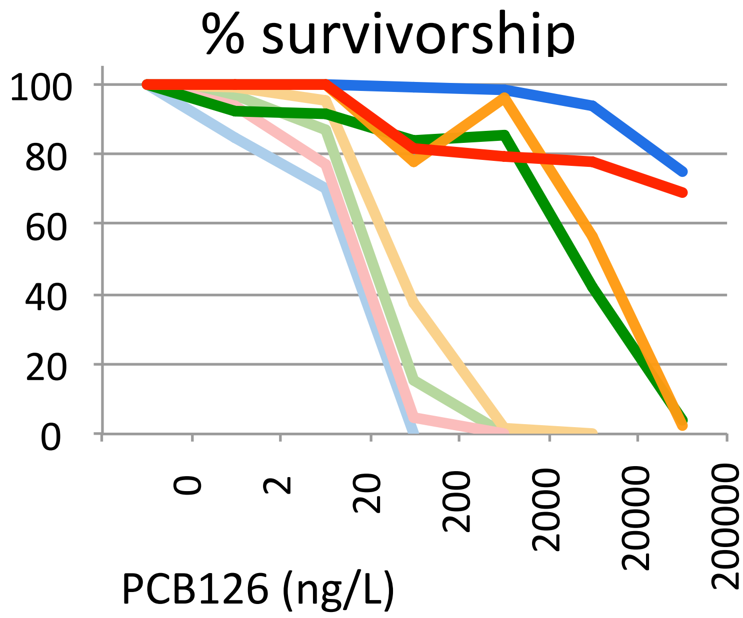


TECHNOLOGY: Pollution

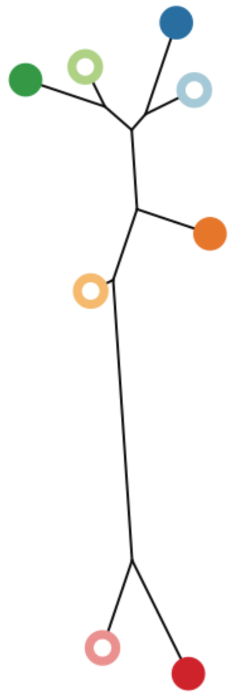


TECHNOLOGY: Pollution

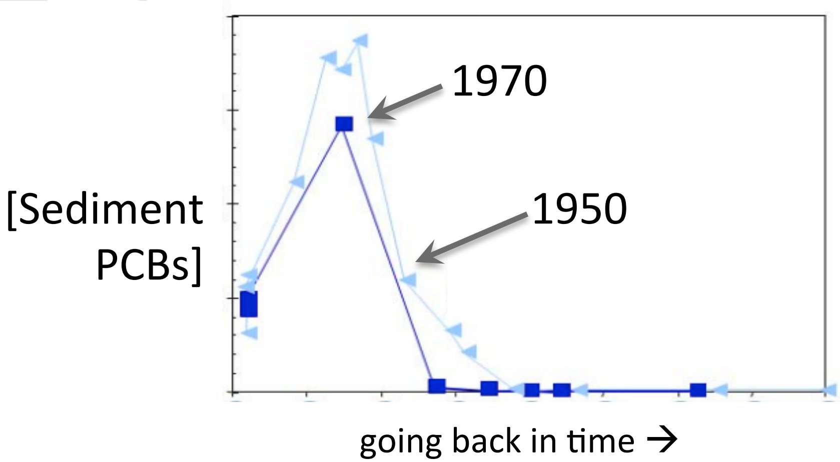




Whitehead et al., *Proc. Roy. Soc. B.*, 2012



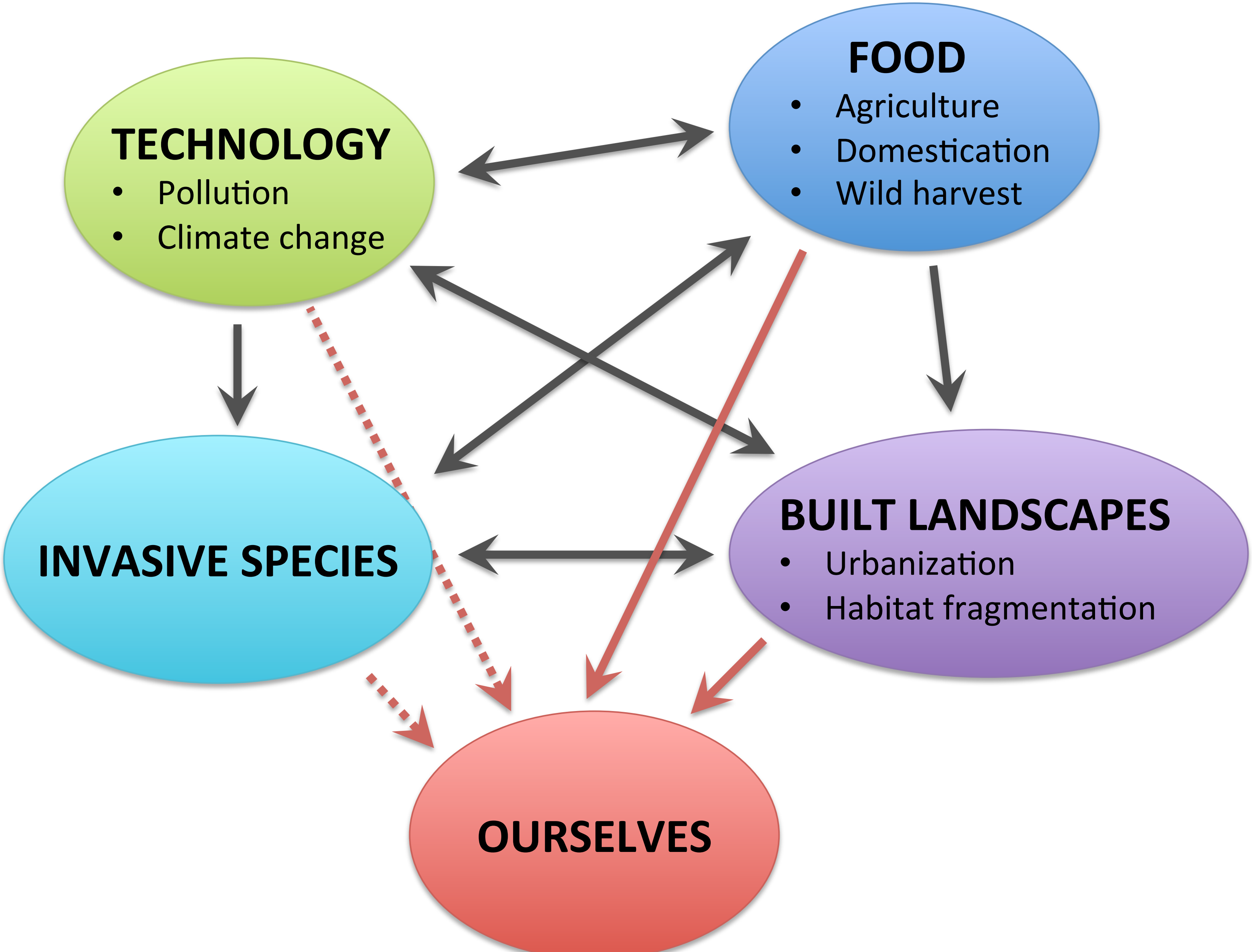
Reid et al., *Science*, 2016



Extreme tolerance phenotype

Evolved independently

Evolved quickly


TECHNOLOGY
• Pollution
• Climate change
FOOD
• Agriculture
• Domestication
• Wild harvest
INVASIVE SPECIES
BUILT LANDSCAPES
• Urbanization
• Habitat fragmentation
OURSELVES

INVASIVE SPECIES

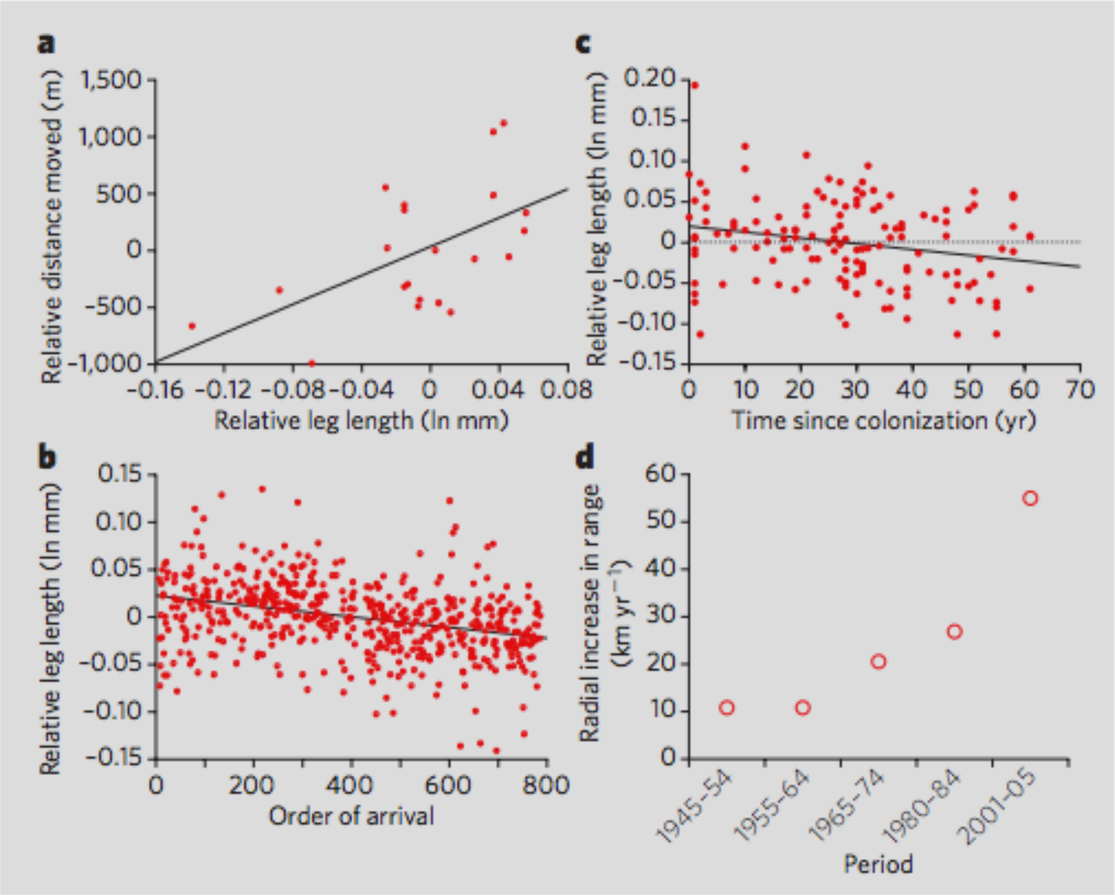
CANE TOAD

INVASIVE SPECIES

CANE TOAD

Longer-legged toads can move farther

Longer-legged toads lead the invasion front



Recent populations have longer legs

Pace of invasion has increased substantially

→ Rate of invasion is increasing because of adaptive evolution at the expanding front that favors traits (leg length) that increase dispersal

Phillips et al., 2006

INVASIVE SPECIES

CANE TOAD

Red-bellied Black Snake poisoned by a cane toad

Death Adder killed by a cane toad

Snake species that are toad-vulnerable:

- Evolved reduction in gape size
- Evolved decreased preference for toads as prey
- Evolved increased resistance to toad toxicity

http://www.canetoadsinoz.com; Phillips & Shine, 2004;

INVASIVE SPECIES

Introduction
of alien species

time

early **later**

Changes in behavior
- Avoidance of novel predator
- Adoption of new host
- Track changes in available prey

Evolutionary change
- Life history
- Physiology & morphology

Early plastic (e.g., behavioral) responses
- Enable early persistence
- Sets the stage for rapid evolution in many traits

Change in community composition

Strauss et al., 2006

HUMANS

what was different in human environment in ancient times (before neolithic) compared to today?

Diet before agriculture

- Lean meat, fruit, roots, nuts, seeds
- Little sugar, refined starch, less salt, no milk after weaning

Microbiome before hygiene and antibiotics

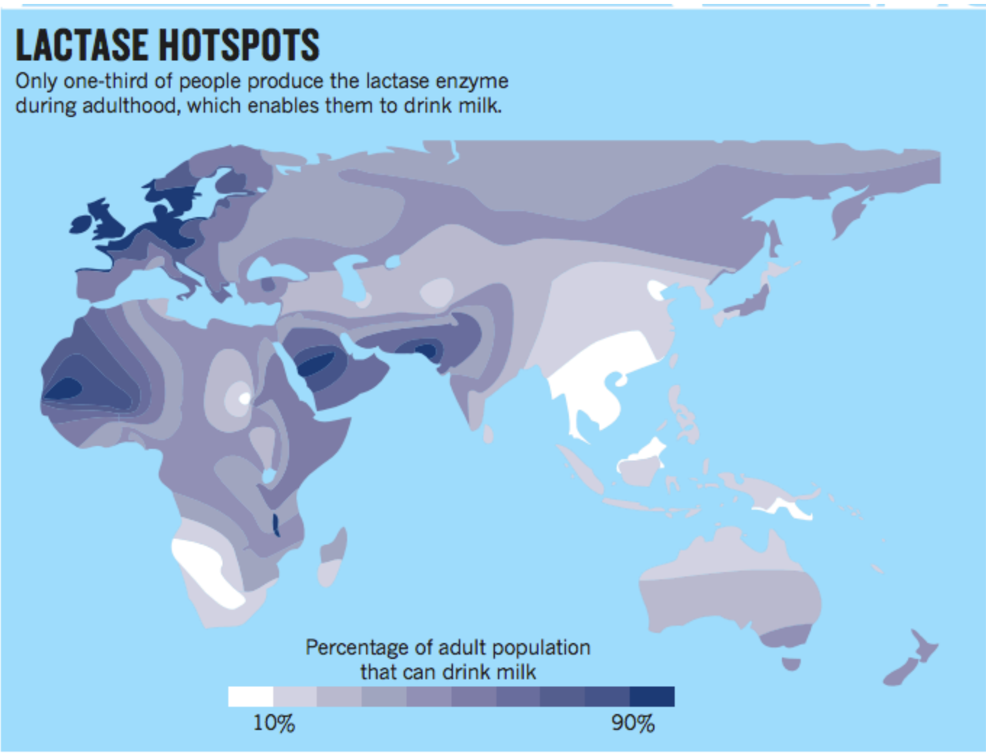
- Almost everyone had worms
- Our gut flora was diverse and often helpful

Addictive substances & technologies rare or absent

- No tobacco, alcohol, heroin, cocaine…
- No TV, email, Facebook…
- No horses, bicycles, cars, planes…

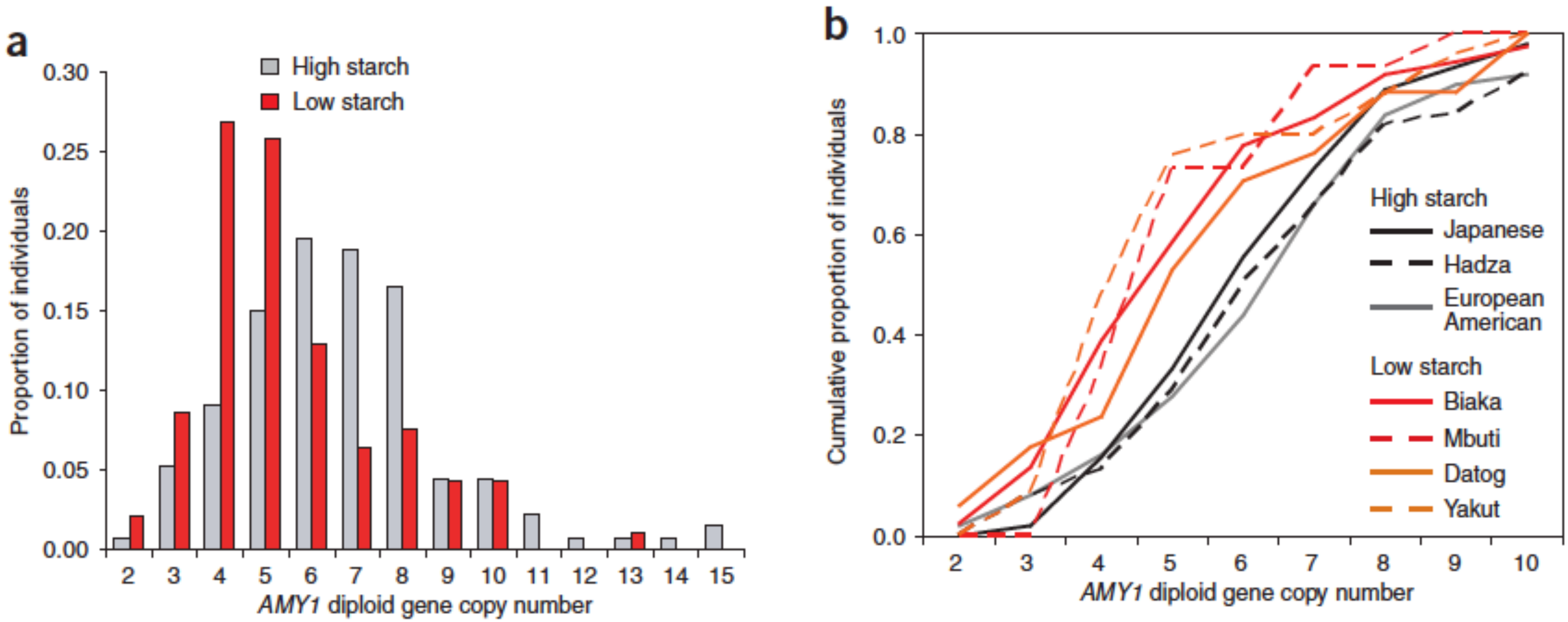
More movement, less sitting

HUMANS: Diet (milk)



Curry, 2013

HUMANS: Diet (starch)



Perry et al., 2007

HUMANS: Disease

Ancestral-Susceptibility Model for Disease

Gene CAPN10 *("thrifty gene" hypothesis)*

→ Involved in insulin regulation; variant influences risk of type 2 diabetes
→ Risk allele is ancestral, derived allele is protective
→ Pattern of mutation of derived allele indicates recent positive (adaptive) evolution

Gene AGT *("sodium retention" hypothesis)*

→ Involved in sodium homeostasis; variant influences risk of hypertension
→ Risk allele is ancestral, derived allele is protective
→ Pattern of mutation of derived allele indicates recent positive (adaptive) evolution

Nakajima et al., 2004; Vander Molen et al., 2005; Di Rienzo & Hudson, 2005

HUMANS: Genes under recent selection

Table 2 | **Genes identified as having been subject to recent rapid selection and their inferred cultural selection pressures**

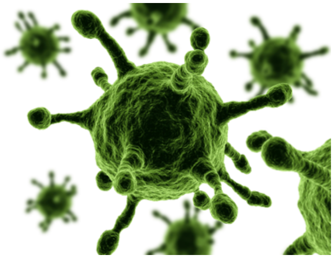
Genes	Function or phenotype	Inferred cultural selection pressure	Refs
LCT, MAN2A1, SI, SLC27A4, PPARD, SLC25A20, NCOA1, LEPR, LEPR, ADAMTS19, ADAMTS20, APEH, PLAU, HDAC8, UBR1, USP26, SCP2, NKX2-2, AMY1, ADH, NPY1R, NPY5R	Digestion of milk and dairy products; metabolism of carbohydrates, starch, proteins, lipids and phosphates; alcohol metabolism	Dairy farming and milk usage; dietary preferences; alcohol consumption	6,7,16,41,63, 102,118, 144,145
Cytochrome P450 genes (*CYP3A5, CYP2E1, CYP1A2* and *CYP2D6*)	Detoxification of plant secondary compounds	Domestication of plants	6,63,146,147
CD58, APOBEC3F, CD72, FCRL2, TSLP, RAG1, RAG2, CD226, IGJ, TJP1, VPS37C, CSF2, CCNT2, DEFB118, STAB1, SP1, ZAP70, BIRC6, CUGBP1, DLG3, HMGCR, STS, XRN2, ATRN, G6PD, TNFSF5, HbC, HbE, HbS, Duffy, α-globin	Immunity, pathogen response; resistance to malaria and other crowd diseases	Dispersal, agriculture, aggregation and subsequent exposure to new pathogens; farming	6–8,14,16,50, 63,148,149
LEPR, PON1, RAPTOR, MAPK14, CD36, DSCR1, FABP2, SOD1, CETP, EGFR, NPPA, EPHX2, MAPK1, UCP3, LPA, MMRN1	Energy metabolism, hot or cold tolerance; heat-shock genes	Dispersal and subsequent exposure to novel climates	14,150
SLC24A5, SLC25A2, EDAR, EDA2R, SLC24A4, KITLG, TYR, 6p25.3, OCA2, MC1R, MYO5A, DTNBP1, TYRP1, RAB27A, MATP, MC2R, ATRN, TRPM1, SILV, KRTAPs, DCT	The externally visible phenotype (skin pigmentation, hair thickness, eye and hair colour, and freckles)	Dispersal and local adaptation and/or sexual selection	9,14,63,97, 101,151
CDK5RAP2, CENPJ, GABRA4, PSEN1, SYT1, SLC6A4, SNTG1, GRM3, GRM1, GLRA2, OR4C13, OR2B6, RAPSN, ASPM, RNT1, SV2B, SKP1A, DAB1, APPBP2, APBA2, PCDH15, PHACTR1, ALG10, PREP, GPM6A, DGKI, ASPM, MCPH1, FOXP2	Nervous system, brain function and development; language skills and vocal learning	Complex cognition on which culture is reliant; social intelligence; language use and vocal learning	6,7,14,63, 68–70,78,149
BMP3, BMPR2, BMP5, GDF5	Skeletal development	Dispersal and sexual selection	6,63
MYH16, ENAM	Jaw muscle fibres; tooth-enamel thickness	Invention of cooking; diet	80,113

Laland et al., 2010

WINNERS and LOSERS

Critters we want to **kill** tend to **evolve/adapt**

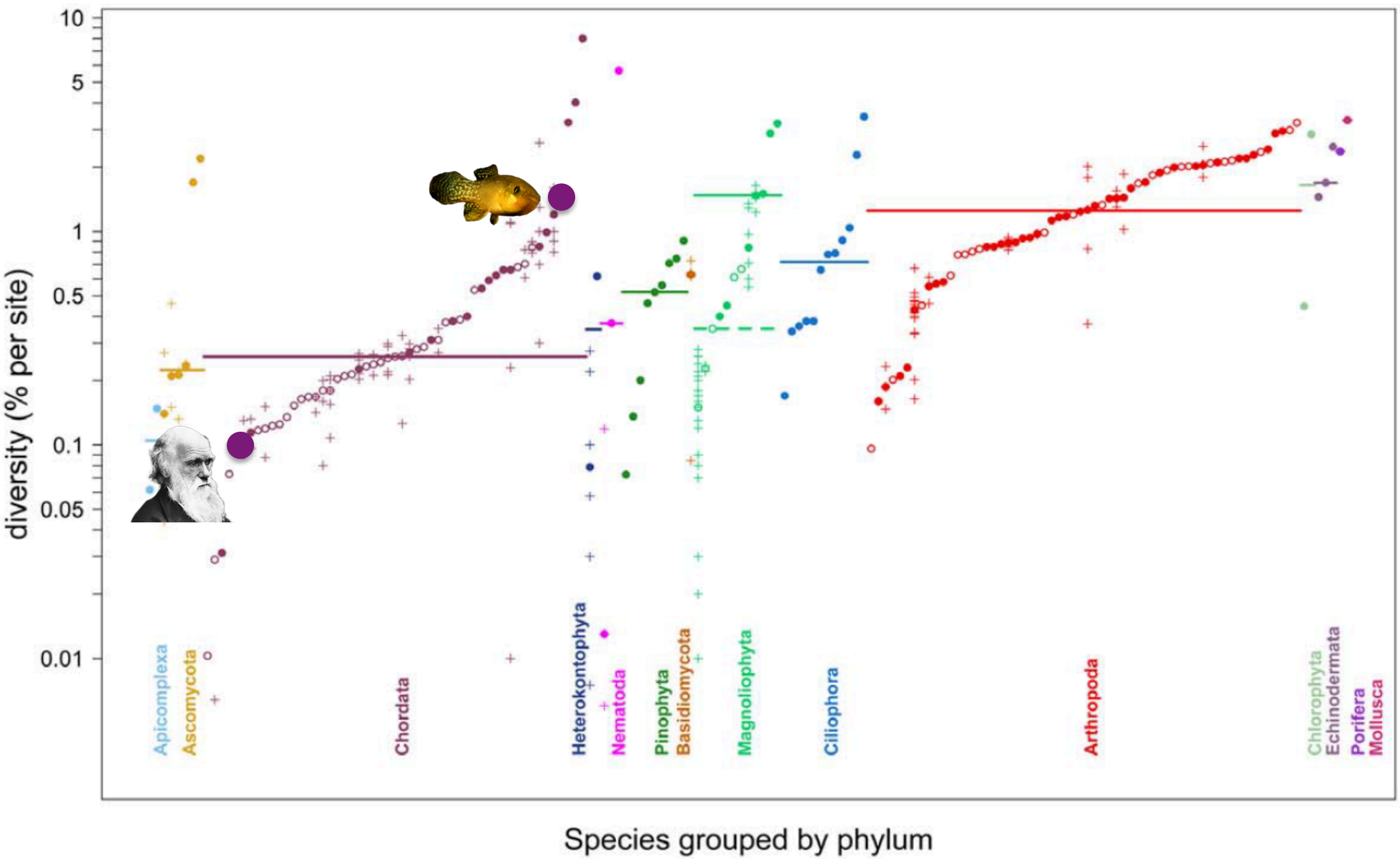
- Large population size
- High genetic diversity
- Rapid generation time
- Exposed to simple challenges



Critters we want to **conserve** tend to go **extinct**

- Small population size
- Low genetic diversity
- Long generation time
- Exposed to complex challenges

GENETIC DIVERSITY: Raw material for evolution



Modified from Leffler et al., 2012

EVOLUTION can CONTRIBUTE to SOLUTIONS

EVOLUTION can CONTRIBUTE to SOLUTIONS

Improving habitat connectivity

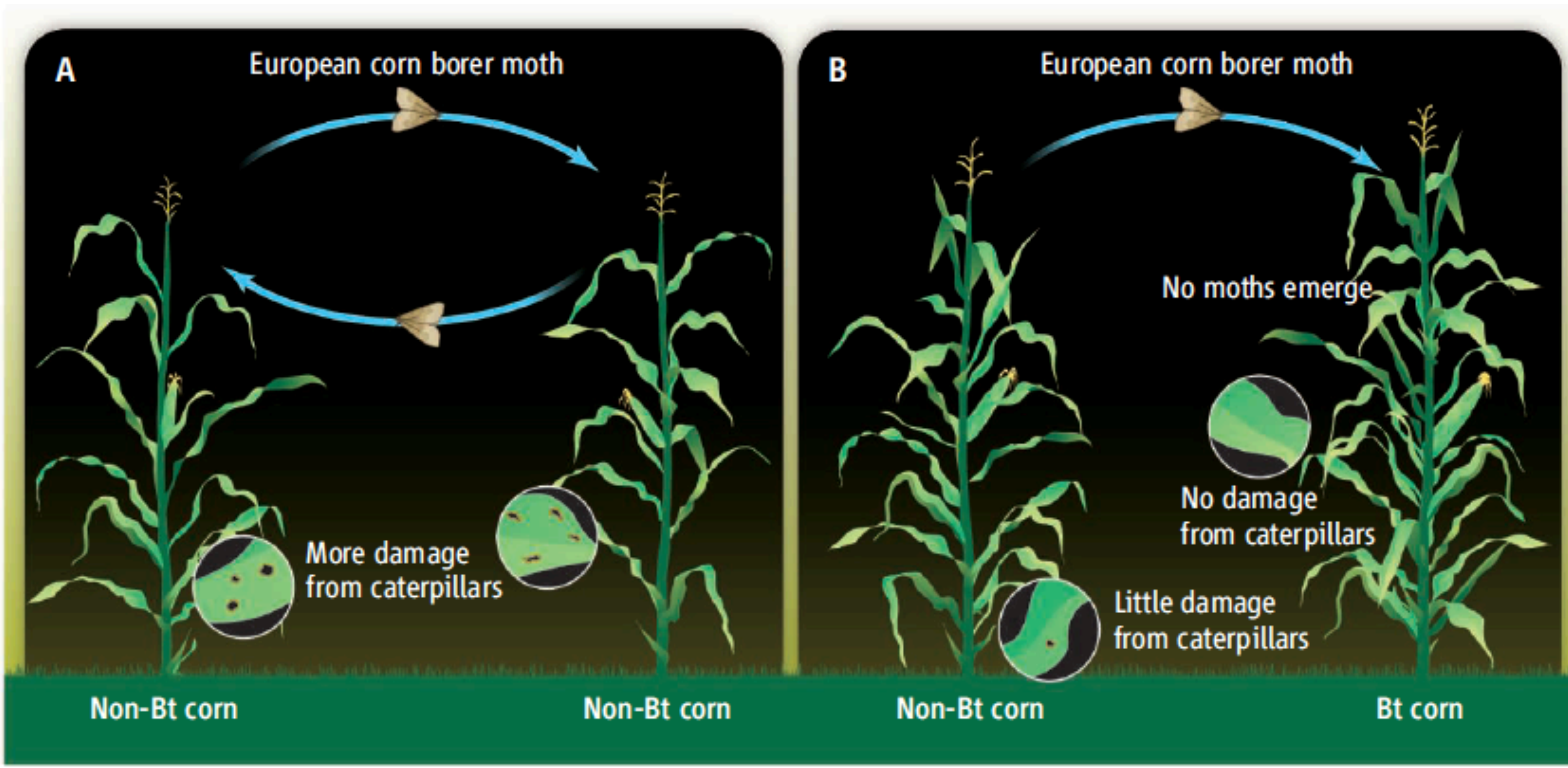
Small patch size = smaller population size
Isolation of patches = diminished migration between patches

Yellowstone to Yukon Conservation Initiative: http://y2y.net/
https://www.youtube.com/watch?v=eqHinMdejEc

Fahrig, 2003

EVOLUTION can CONTRIBUTE to SOLUTIONS

Slowing pesticide resistance through "Halo" effect



Tabashnik, 2010

EVOLUTION can CONTRIBUTE to SOLUTIONS

Integrative Pest Management

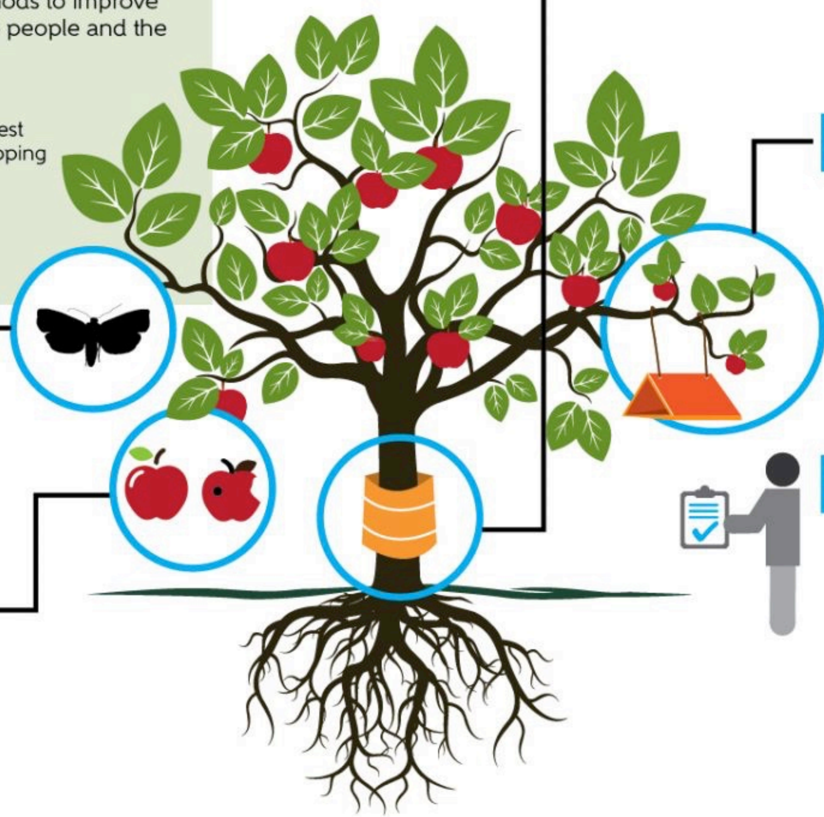
What is IPM?

Integrated Pest Management is a science-based approach that combines a variety of techniques. By studying their life cycles and how pests interact with the environment, IPM professionals can manage pests with the most current methods to improve management, lower costs, and reduce risks to people and the environment.

IPM tools include:
- Alter surroundings
- Add beneficial insects/ organisms
- Grow plants that resist pests
- Disrupt development of pest
- Prevention of pest problem developing
- Disrupt insect behaviors
- Use pesticides

1 IDENTIFY/ MONITOR
Determine the causal agent and its abundance (contact your local extension agent for help).

2 EVALUATE
The results from monitoring will help to answer the questions: Is the pest causing damage? Do we need to act? As pest numbers increase toward the economic threshold further treatments may be necessary.



3 PREVENT
Some pest problems can be prevented by using resistant plants, planting early, rotating crops, using barriers against climbing pests, sanitation, and sealing cracks in buildings.

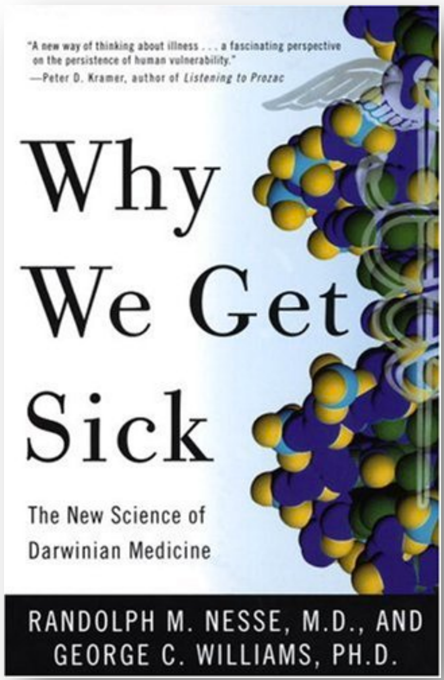
4 ACTION
IPM uses multiple tools to reduce pests below an economically damaging level. A careful selection of preventive and curative treatments will reduce reliance on any one tactic and increase likelihood of success.

5 MONITOR
Continue to monitor the pest population. If it remains low or decreases, further treatments may not be necessary, but if it increases and exceeds the action threshold, another IPM tool should be used.

National Pesticide Information Center: http://npic.orst.edu

EVOLUTION can CONTRIBUTE to SOLUTIONS

Medicine



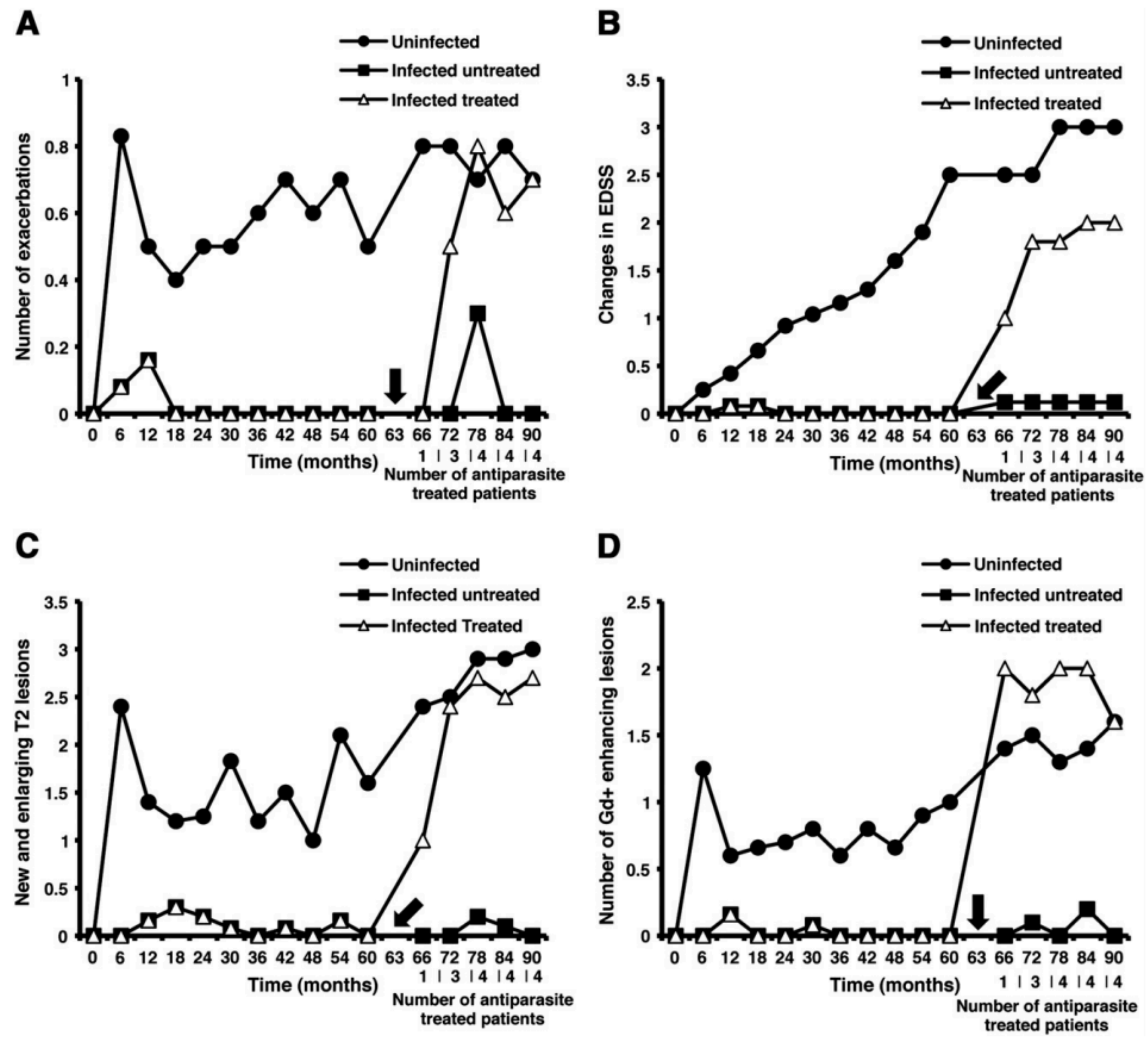


Fig. 1. Number of exacerbations (A) and changes in EDSS (B), and MRI parameters (C and D) observed over time in parasite infected MS patients, uninfected MS patients, and parasite infected MS patients under anti-parasite treatment. Arrows indicate onset of treatment with anti-parasite drugs. For all panels, data shown represents average values observed at each time point.

Correale & Farez, 2011

EVOLUTION can CONTRIBUTE to SOLUTIONS

Medicine & Agriculture

Table 3. The success of evolutionary engineering: mechanisms that reduce evolution can and do work on all three parts of the evolutionary engine.

MECHANISMS THAT WORK TO SLOW EVOLUTION

Method of slowing evolution	Example
Reduce variation in a fitness-related trait	
Drug overkill with multiple drugs	Triple-drug therapy for AIDS
	Pesticide pyramiding
Ensure full dosage	Direct observation therapy of tuberculosis
Reduce appearance of resistance mutations	Engineer RT gene of HIV-1
Reduce pest population size	Integrated pest management of resistant mutants
	Nondrug sanitary practices
Reduce directional selection	
Vary selection over time	Herbicide rotation
	Vary choice of antibiotics, pesticides or antiretrovirals
Use nonchemical means of control	Integrated pest management
Limit exposure of pests to selection	Withhold powerful drugs, e.g., restricted vancomycin use
Avoid broad-spectrum antibiotics	Test for drug or pesticide susceptibility before treatment of infections or fields
Reduce heritability of a fitness-related trait	
Dilute resistance alleles	Refuge planting

Palumbi 2001

EVOLUTION can CONTRIBUTE to SOLUTIONS

"Rapid evolution occurs so commonly that it is, in fact, the expected outcome for many species living in human-dominated systems.

Evolution in the wake of human ecological change should be the default prediction and should be part of every analysis of the impact of new drugs, health policies, pesticides, or biotechnology products.

By admitting the speed and pervasiveness of evolution, predicting evolutionary trajectories where possible, and planning mechanisms in advance to slow evolutionary change, we can greatly reduce our evolutionary impact on species around us and ameliorate the economic and social costs of evolution.

Ignoring the speed of evolution requires us to play an expensive catch-up game when chemical control agents and medications fail.

Because our impact on the biosphere is not likely to decline, we must use our knowledge about the process of evolution to mitigate the evolutionary changes we impose on species around us."

Palumbi 2001