Uncertainty, Information and Evolution of Context Dependent Emigration

Greta Bocedi, Johannes Heinonen & Justin M. J. Travis

UNIVERSITY OF ABERDEEN

Background

INFORMED DISPERSAL

"... encapsulates the idea that individuals gather and exchange information at the different stages of dispersal" (Clobert et al. 2009)

✓ increases the probability of optimizing the trade-off between costs and benefits of dispersal

✓ better and more adaptive decisions than random decision making

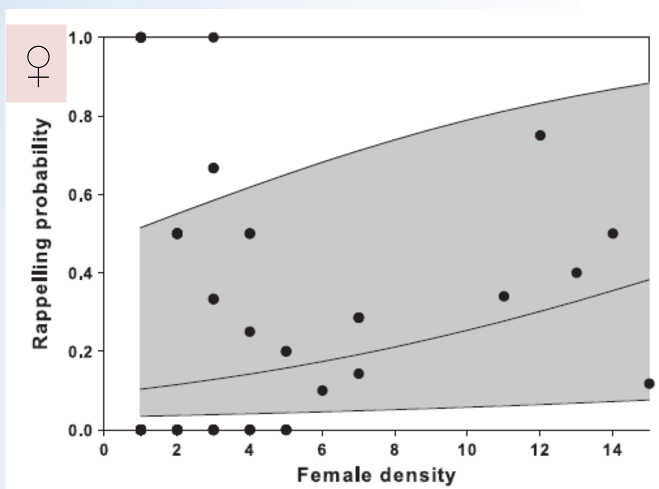
→ predicted to be favoured by natural selection

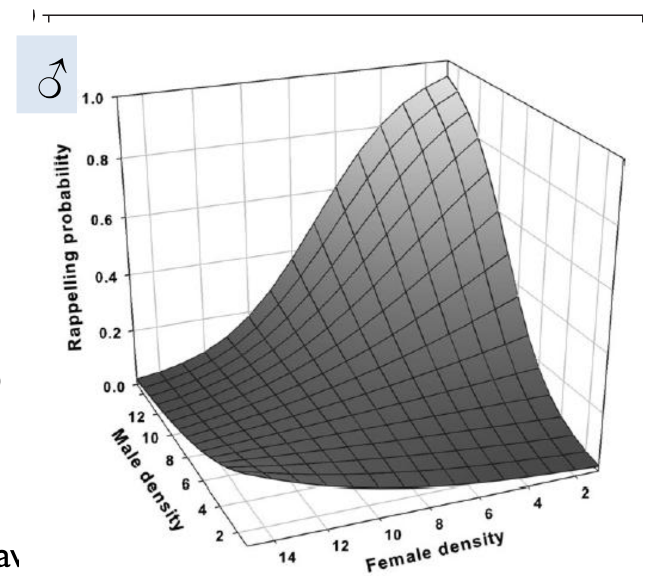
✓ Increasing empirical evidence

Erigone atra (De Meester & Bonte 2010)

density-related information **during development**
↓
increased **short** distance dispersal

density-related information **at the time of dispersal**
↓
increased **long** distance dispersal





A: av

#T: average tiptoe frequency

#B: average nr. balloning events

✓ Increasing empirical evidence

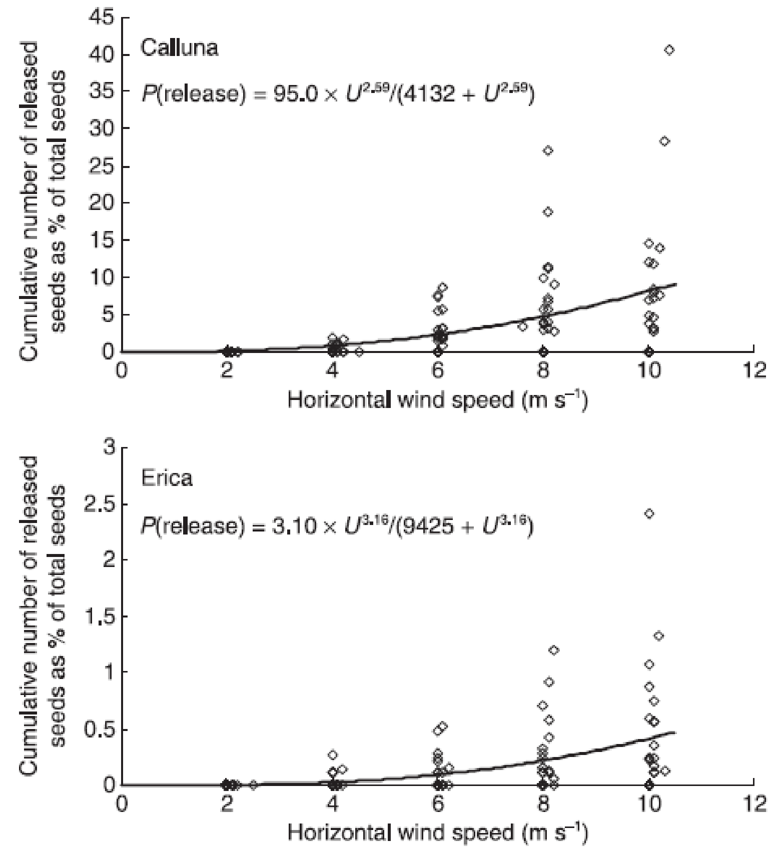
Erica cinerea *(Soons & Bullock 2008)*

Calluna vulgaris

non-random seeds abscission (more likely at higher wind speed)

↓

use of environmental cues for increasing dispersal distance



✓ Lack of theory

Evolution of Emigration Strategies

NO information

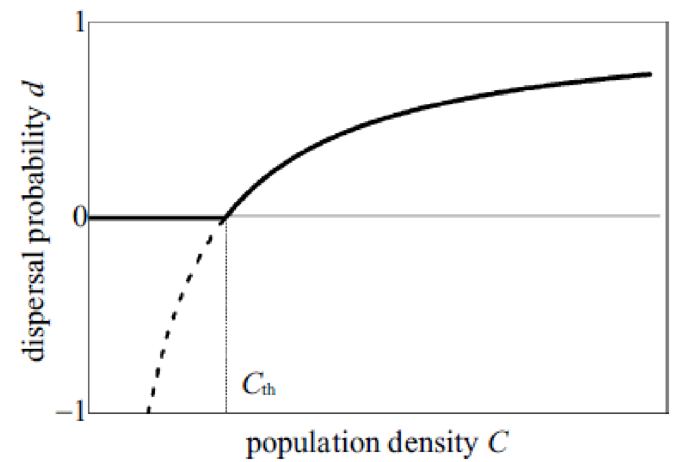
(e.g., Comins *et al.* 1980;
Olivieri *et al.* 1995;
Travis & Dytham 1998)

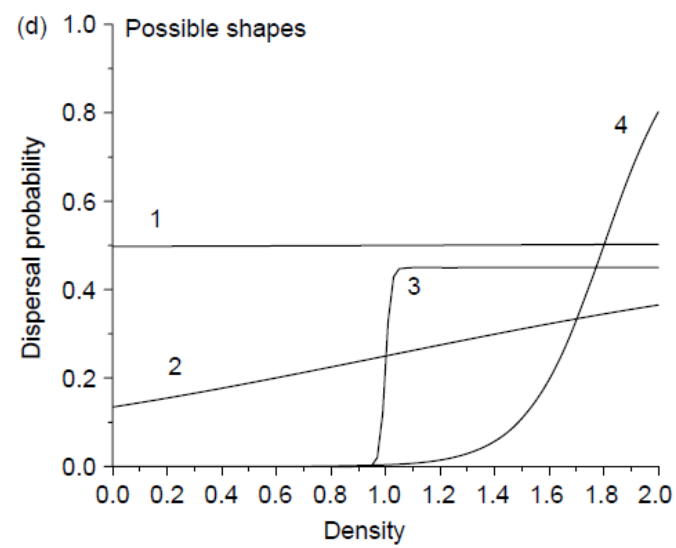
PERFECT information

density-dependent dispersal

Kun & Scheuring 2006

Poethke & Hovestadt 2002





✓ Lack of theory

Evolution of Emigration Strategies

UNCERTAIN

Information

Evolutionary Ecology Research, 2002, **4**: 227–238

The evolution of informed natal dispersal: inherent versus acquired information

Solveig Schjørring

Theor Ecol (2009) 2:105–117
DOI 10.1007/s12080-008-0032-2

ORIGINAL PAPER

Conditional dispersal, clines, and the evolution of dispersiveness

Paul R. Armsworth

Oikos 118: 291–299, 2009
doi: 10.1111/j.1600-0706.2008.16863.x,

Subject Editor: André de Roos. Accepted 29 July 2008

Research

The evolution of dispersal – the importance of information about population density and habitat characteristics

Karin Enfjäll and Olof Leimar

Objectives

✓ Effect of **information precision** on the **evolution of emigration** propensity

✓ Joint evolution of **costly information acquisition** and **density-dependent emigration**

environmental heterogeneity

cost of information

Methods

- ✓ Individual-based, spatially explicit and stochastic model
- ✓ grid of 20 by 20 cells
- ✓ heterogeneous habitat quality (carrying capacity, *K*)
- ✓ temporal environmental stochasticity affecting *K* at the cell scale

Species

- ✓ haploid species with discrete generations
- ✓ genotype defining the density-dependent emigration strategy and the investment in information acquisition (number of samples)

Sub-population dynamics

✓ Hassell & Comins (1976) single species population model – stochastic, individual-based formulation

$$Poisson\left(r(1+aN_{(x,y,t)})^{-b} - c\right)$$

$$a = (r^{1/b} - 1)/K_{(x,y,t)}$$

cost of information

Dispersal

- ✓ Emigration: density independent / dependent

$$d = \frac{D_0}{1 + Exp\left(-\left(\frac{\hat{N}_{(x,y,t)}}{K_{(x,y,t)}} - \beta\right) \cdot \alpha\right)}$$

mutation rate = 0.001

(Kun & Scheuring 2006)

estimated nr. of individuals in the natal cell

- ✓ Simultaneous emigration
- ✓ Dispersal to one of the 8 nearest neighbours (randomly chosen)
- ✓ Dispersal mortality = 0.1

Information on natal patch

- ✓ No information (density independent *d*)
- ✓ Full information ($\hat{N}_{(x,y,t)} = N_{(x,y,t)}$)
- ✓ $\hat{N}_{(x,y,t)} = NegativeBinomial\left(N_{(x,y,t)}, \lambda\right)$
- ✓ $\hat{N}_{(x,y,t)} = Poisson\left(N_{(x,y,t)}\right)$

dispersion or "clumping" parameter

$$\sigma^2 = \mu + \frac{1}{\lambda}\mu^2$$

– σ^2 always greater than μ

– as $\lambda \rightarrow \infty$, $\sigma^2 \rightarrow \mu$ and the *Negative Binomial* converges to the *Poisson* distribution

varying λ allows to vary the estimate **PRECISION**

Information on natal patch

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Information gathering strategy

mutation rate = 0.001

- ✓ *n_samples:* time/energy spent in acquiring information
- ✓ $\hat{N}_{(x,y,t)}$ = mean of *n_samples*
- ✓ each sample taken has a cost c_s

$$Poisson\left(r(1 + aN_{(x,y,t)})^{-b} - c\right)$$

$$a = (r^{1/b} - 1) / K_{(x,y,t)}$$

$$c = c_s \cdot n\_samples$$

increasing ***n_samples*** increases the **ACCURACY** of the information but it also increases the total **COST**

Simulation experiments

Evolving emigration strategy

- ✓ 6 fixed information gathering strategies (1 sample) differing in the precision of obtainable information (*λ1, λ2, λ5, λ10, λ20* and *Poisson)*
- ✓ no cost for acquiring information
- ✓ 4 environmental scenarios (differing in temporal variability):

  1. stable environment, 2. red noise (high autocorrelation), 3. red noise (low autocorrelation), 4. white noise

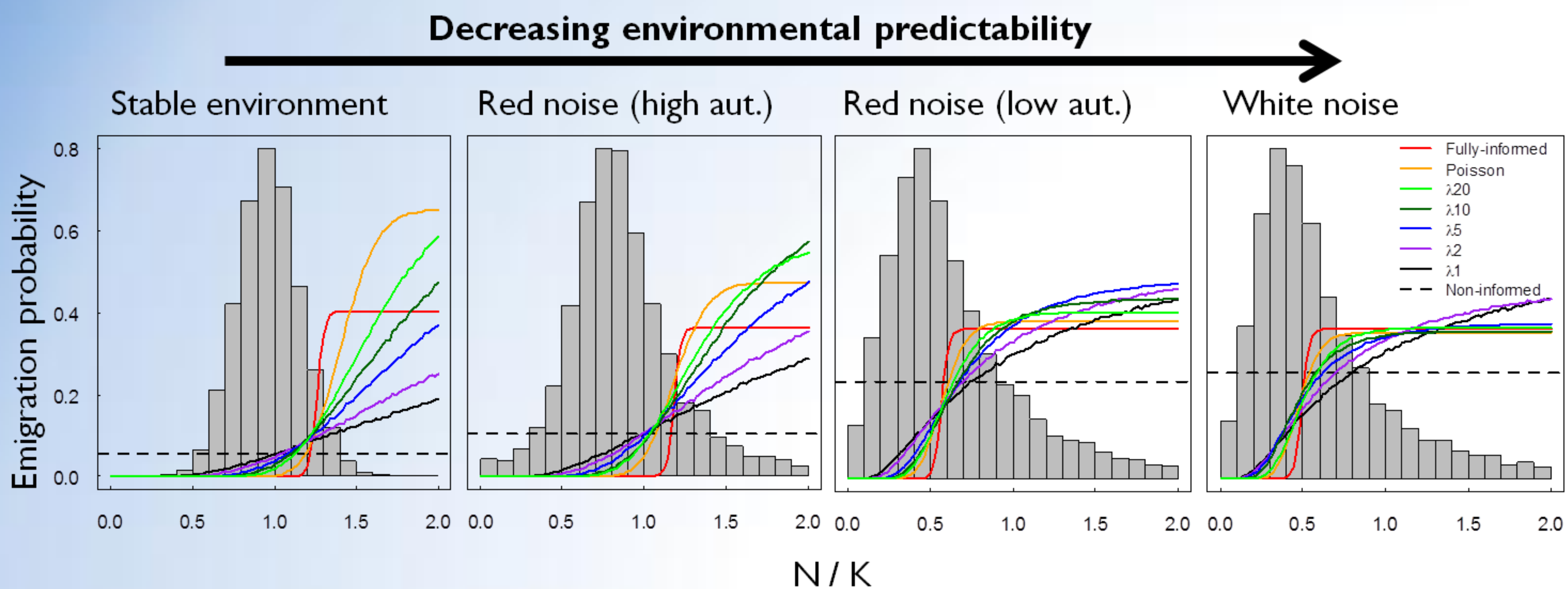
Evolving information gathering strategy

- ✓ same distributions as before but with evolving *n_samples*
- ✓ costly information acquisition
- ✓ 4 environmental scenarios
- ✓ 8 cost/sample scenarios

Results

Evolution of Emigration Strategy

Effect of information PRECISION & ENVIRONMENTAL NOISE

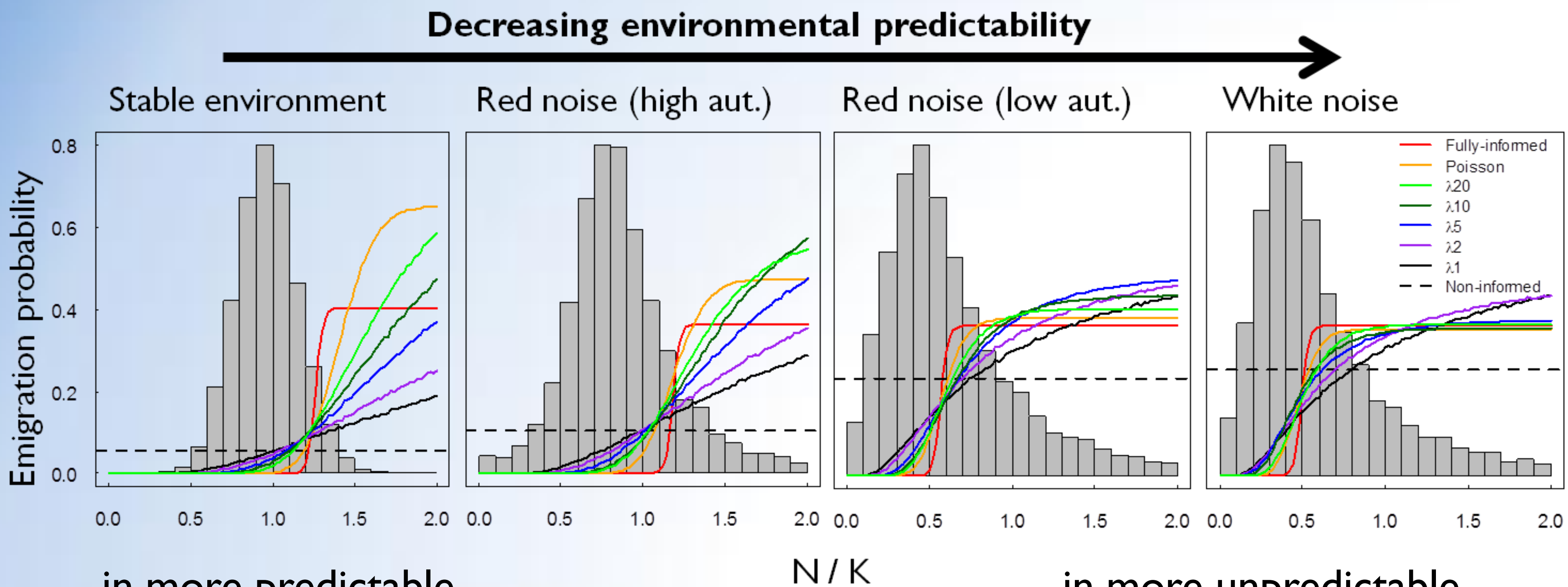


- ➢ Threshold behaviour only when individuals are omniscient.
- ➢ Selection for dispersal is higher in temporally variable environments.
- ➢ **Effect of precision mediated by the type of environment.**

Results

Evolution of Emigration Strategy

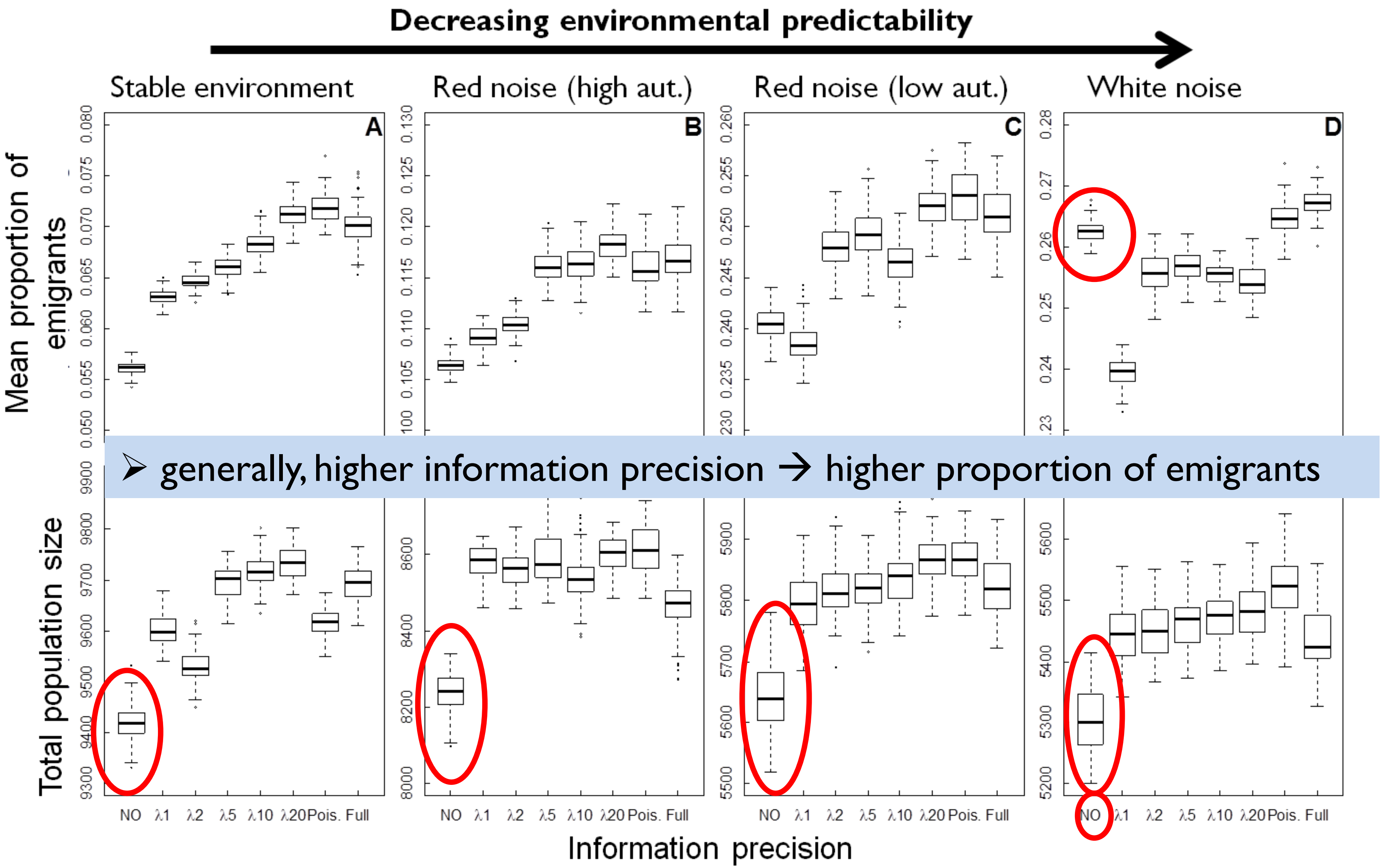
Effect of information PRECISION & ENVIRONMENTAL NOISE



in more predictable environments:
informed individuals →
higher emigration probability

in more unpredictable environments:
informed individuals
→ lower emigration probability

Evolution of Emigration Strategy

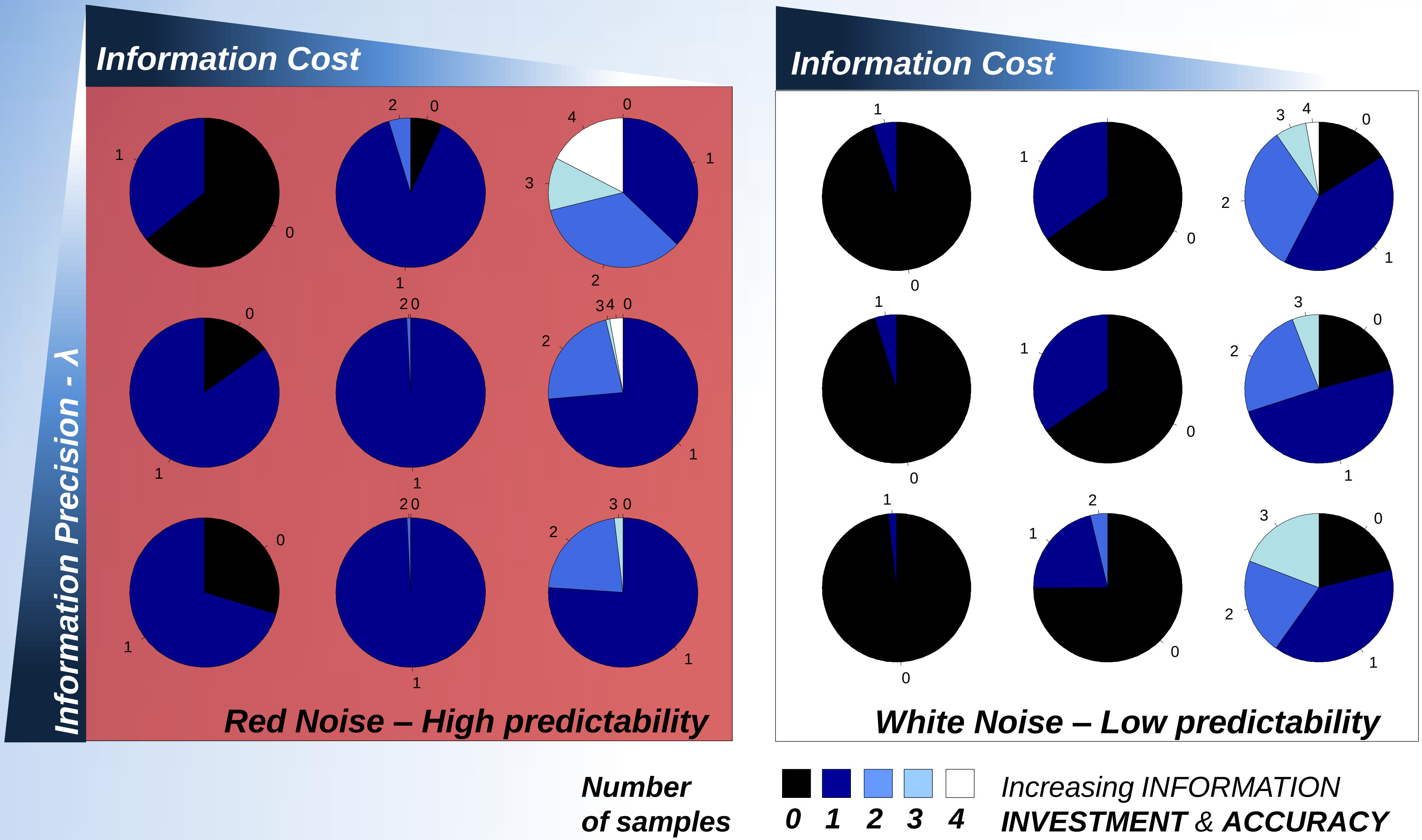


➢ generally, higher information precision → higher proportion of emigrants

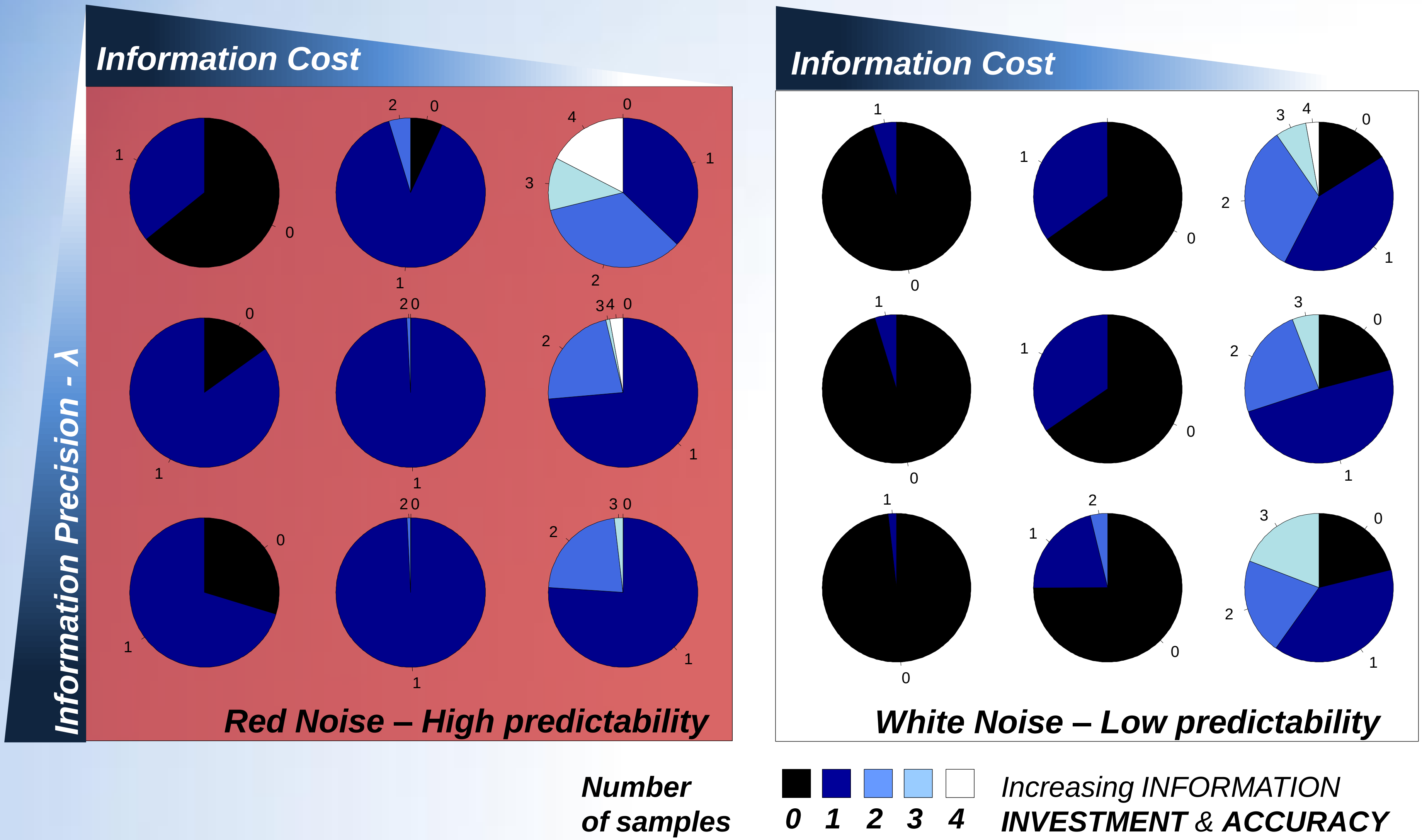
➢ non-informed strategy → lower average population size

Evolution of Information gathering strategy

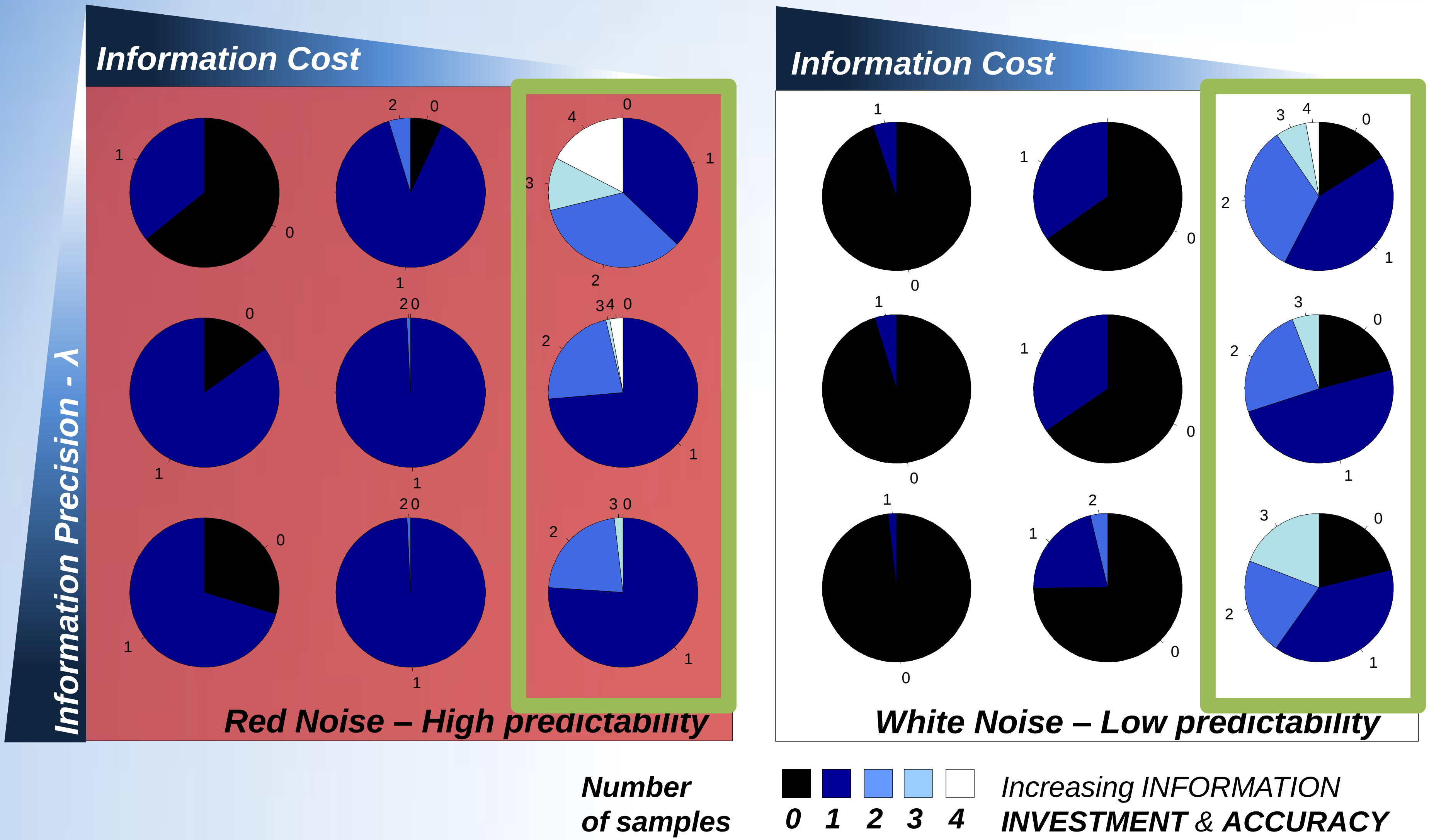
Information PRECISION, COST & ENVIRONMENTAL NOISE



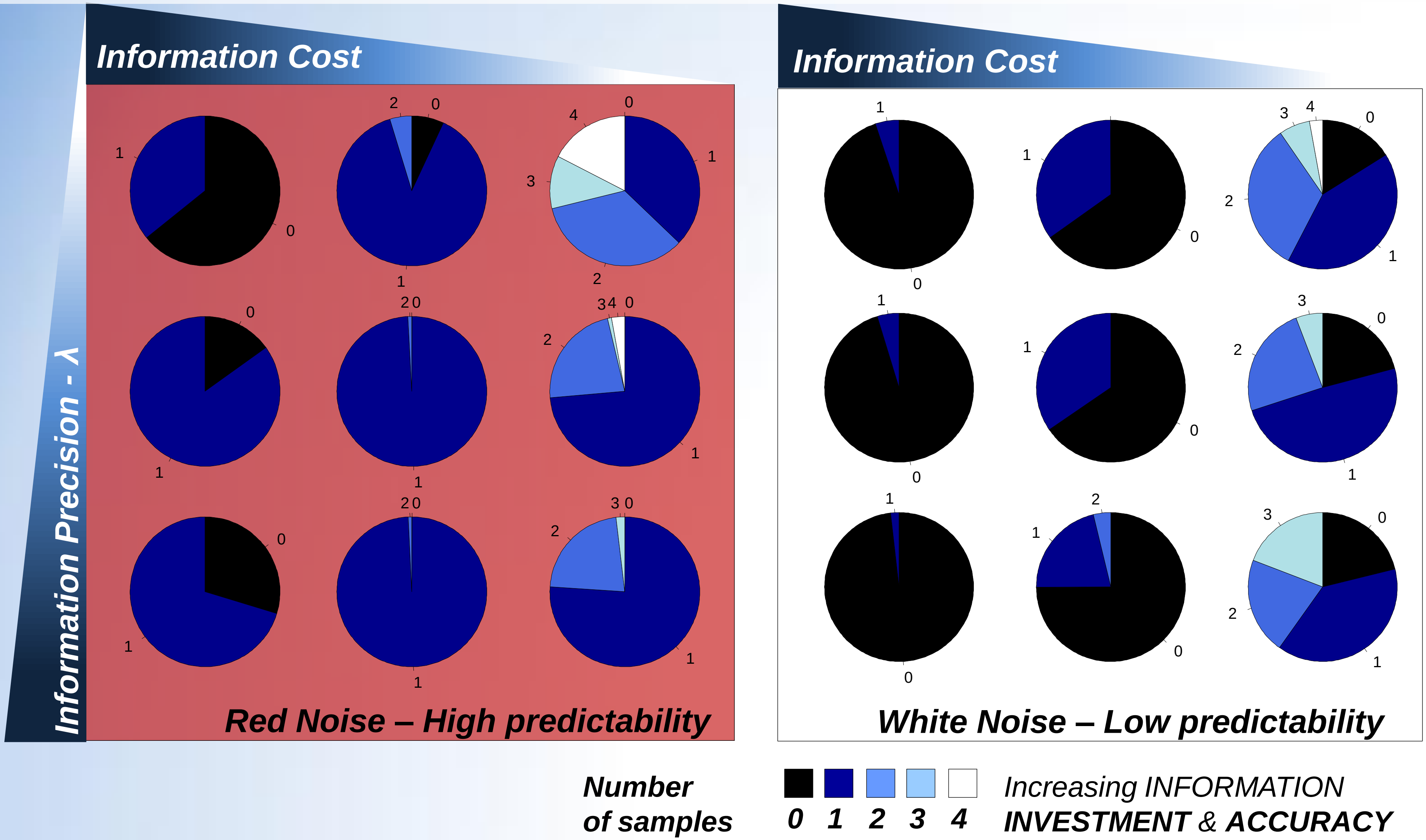
➢ The evolution of **information gathering strategy** depends upon the combined effect of ***precision*** *of information*, *information* **cost** and *type of* ***environment***



➢ If the information was very **imprecise**, strategies that **increase the accuracy** by paying higher costs are favoured, especially in more predictable environments.



- In very **unpredictable environments** (white noise), the information value is lower and paying a cost to increase its accuracy was less adaptive than in more stable ones and,
- there is always a proportion of individuals adopting a non-informed strategy.



Conclusions

✓ **Uncertainty in information** plays an important role in the evolution of emigration decisions

✓ this role is influenced by both the **cost** of acquiring information and by the temporal variability of the **environment**

✓ **Environmental predictability** is a crucial factor in determining the 'adaptive value' of informed-strategies and hence how much individuals invest in acquiring information

✓ In most cases informed dispersal strategies are selected for

✓ but in many scenarios a consistent proportion of individuals adopt a non-informed strategy

✓ **Information use can impact dispersal in a complex manner**

✓ **Information acquisition behaviours can themselves come under strong selection**

Perspectives

- ❖ sequential emigration
- ❖ information gathering / use in all the **three phases of dispersal** (emigration, transfer and settlement)
- ❖ different possible **sources / types of information** and their interactions
- ❖ how decision-making is further influenced by the internal state, or phenotype, of the individual, and by the motivation for dispersing, resulting in **individual heterogeneity** in dispersal even under the same external conditions
- ❖ the interplay between **phenotypic plasticity** and **dispersal syndromes** and their evolution
- ❖ **spatial autocorrelation** in the environmental variability

Modelling the evolution of dispersal needs to consider **information acquisition and use as an integral part of a complex process** that needs to be investigated in the light of **individual heterogeneity** and across all its different phases.

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Greta Bocedi,[*,†] Johannes Heinonen,[*] and Justin M. J. Travis