



CIPSEM 2024

Predictive Ecology:

What is it and why should you care?



TECHNISCHE
UNIVERSITÄT
DRESDEN

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<http://micheletti.science/>

Eliot McIntire, Samuel Hache, Dene First Nations, Frances Stewart, Diana Stralberg, Junior Tremblay, Mathieu Leblond, Alex Chubaty, James Hodson, Steve Cumming, Celine Boisvenue, Greg Paradis, Ian Eddy, Ceres Barros ... and many others!



Black Forest, Germany
by R Boed



CONTENT & STRUCTURE

Content

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Hands-on

SYLLABUS

1. CONTENT AND STRUCTURE

1.1. Content and Structure

1.2. Rules

1.3. Who am I?

Content

2. PART I – Predictive Ecology: what is it?

2.1. Ecology

2.2. Prediction

2.3. Predictive Ecology

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3. PART II – Predictive Ecology: The basics

3.1. Modelling

3.2. From data to ecological models

3.3. Applying ecological models in a predictive context

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SYLLABUS

4. PART III – Predictive Ecology: how can we do it right?

4.1. The PERFECT approach to Predictive Ecology

4.2. Important tools: the power of R and version control

4.3. SpaDES: the importance of reusability in science

5. PART IV – Predictive Ecology: a real example

1.1. The Western Boreal Initiative

6. Hands-on – Are birds a good umbrella for turtles in a changing world?

1.1. Game based exercise

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RULES – This is a participative discussion

- 1. Ask questions, just raise your hand at any time**
- 2. If a theme that was not planned emerges and is of interest, we go for it**
- 3. Please respect both me and your colleagues when they talk**
- 4. Try your best to engage during both the theoretical and practical parts**

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Who am I?



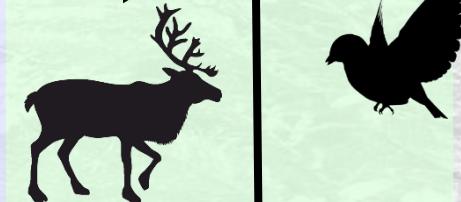
B.Sc.
2002-2007



PRIFFYGOL
BANGOR
UNIVERSITY



TECHNISCHE
UNIVERSITÄT
DRESDEN



PD & AR
2017-2024

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ANY QUESTIONS?

"It is not the answer that enlightens, but the question." – Eugene Ionesco

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PART I

Predictive Ecology: what is it?

Before we talk about Predictive Ecology...

What is *ECOLOGY* to you?

the study of the relationships between living organisms, including humans, and their physical environment, and the balances among these relationships.

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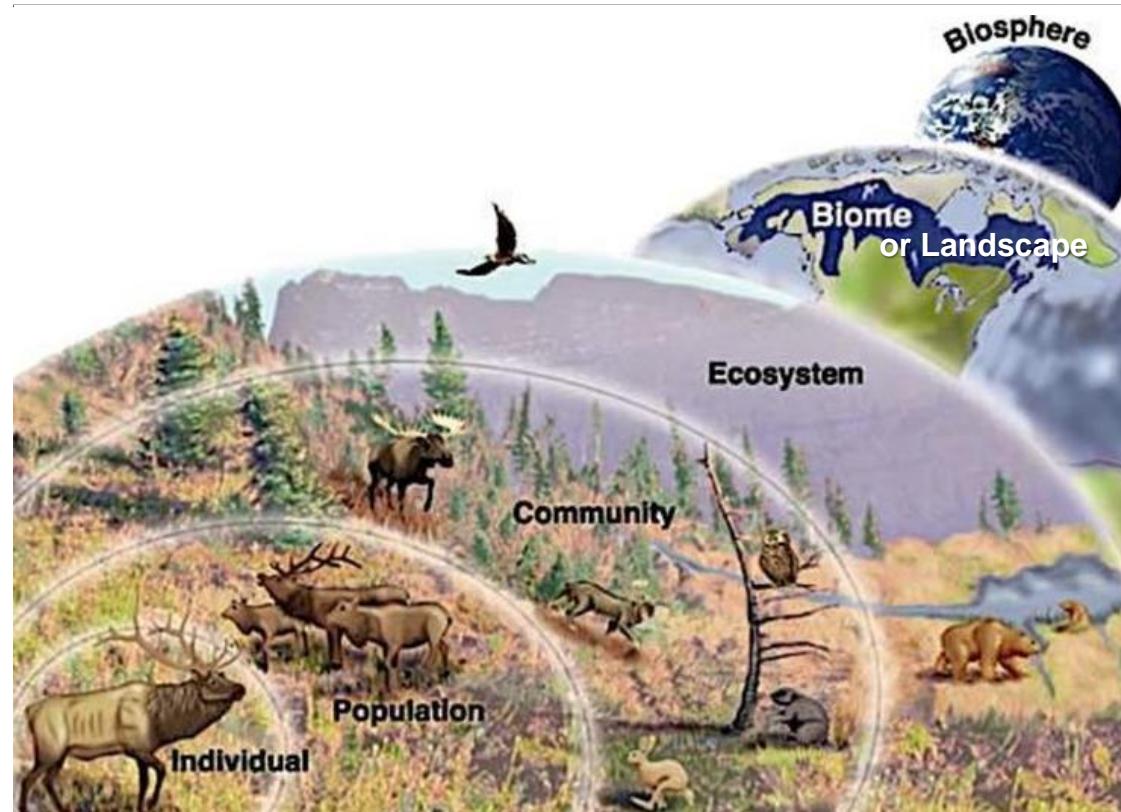
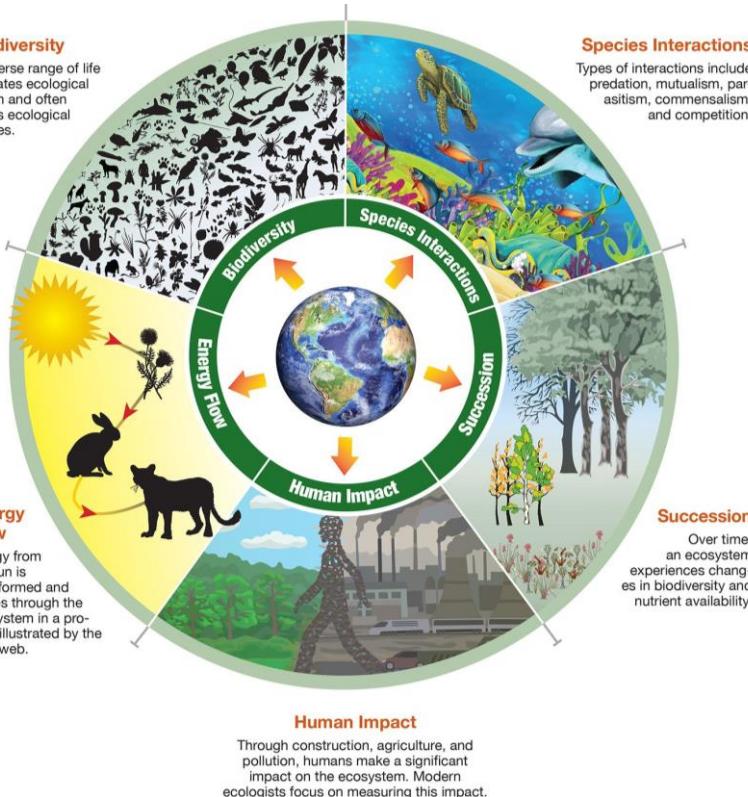
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Before we talk about Predictive Ecology...

Why is **ECOLOGY** important?

provides information about the benefits of ecosystems and how we can use Earth's resources in ways that leave the environment healthy for future generations.



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Before we talk about Predictive Ecology...

*What is **PREDICTION** to you?*

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predict [pri-dikt] [SHOW IPA](#)

See synonyms for: **predict / predicted / predicting / predicts** on
Thesaurus.com

verb (used with object)

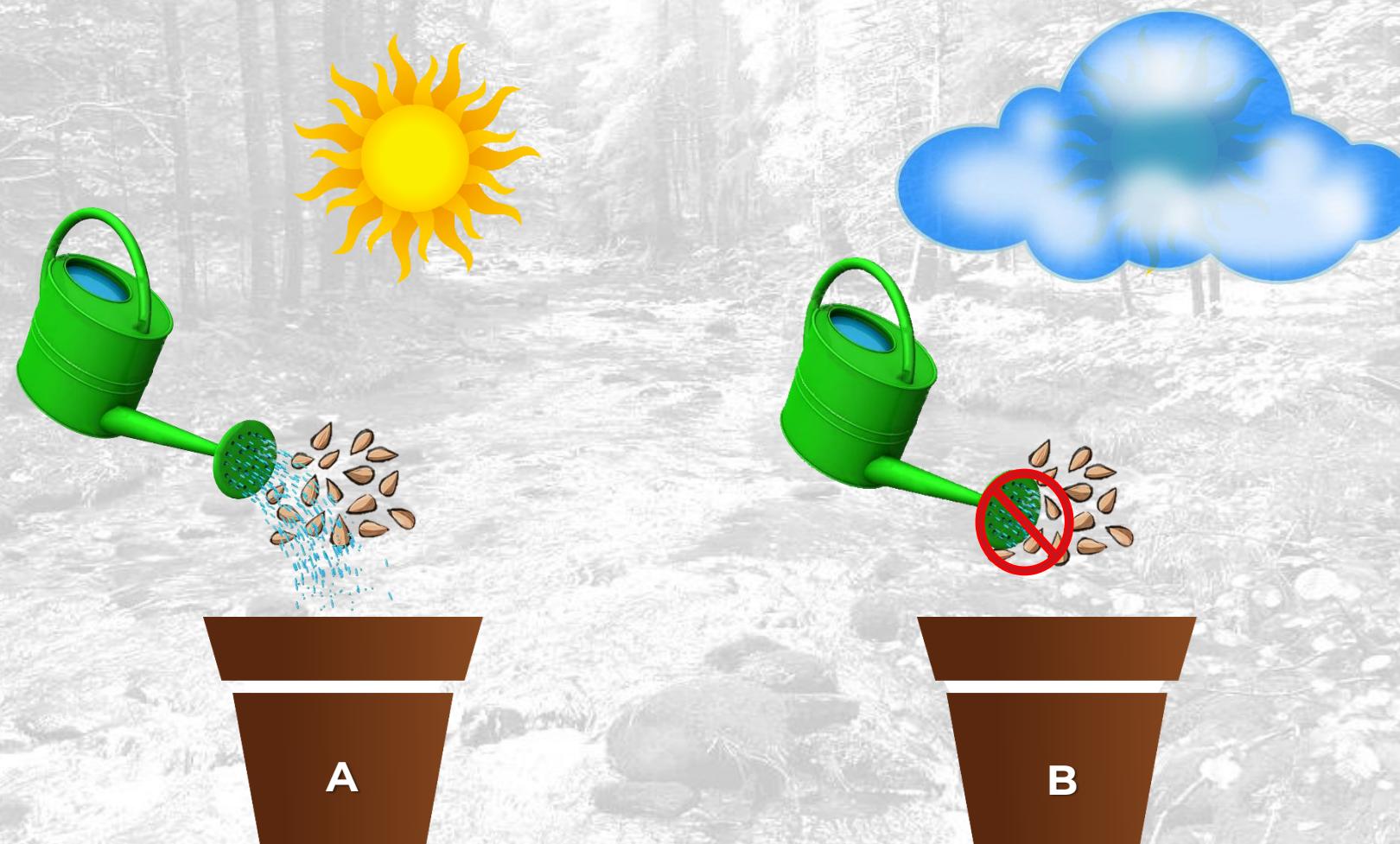
- 1 to declare or tell in advance; prophesy; foretell:
to predict the weather; to predict the fall of a civilization.

verb (used without object)

- 2 to foretell the future; make a prediction.

Before we talk about Predictive Ecology...

How to make PREDICTIONS?



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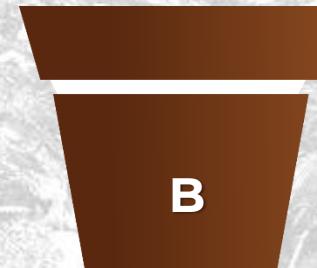
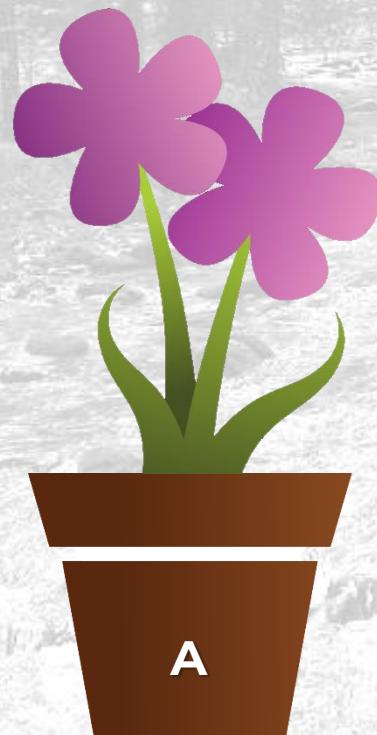
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Before we talk about Predictive Ecology...

How to make PREDICTIONS?



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Before we talk about Predictive Ecology...

*How to make **PREDICTIONS**?*

- Knowledge about how plants grow
- Knowledge about what plants need
- Knowledge about what happens when plants get what they need
- Knowledge about what happens when plants don't get what they need

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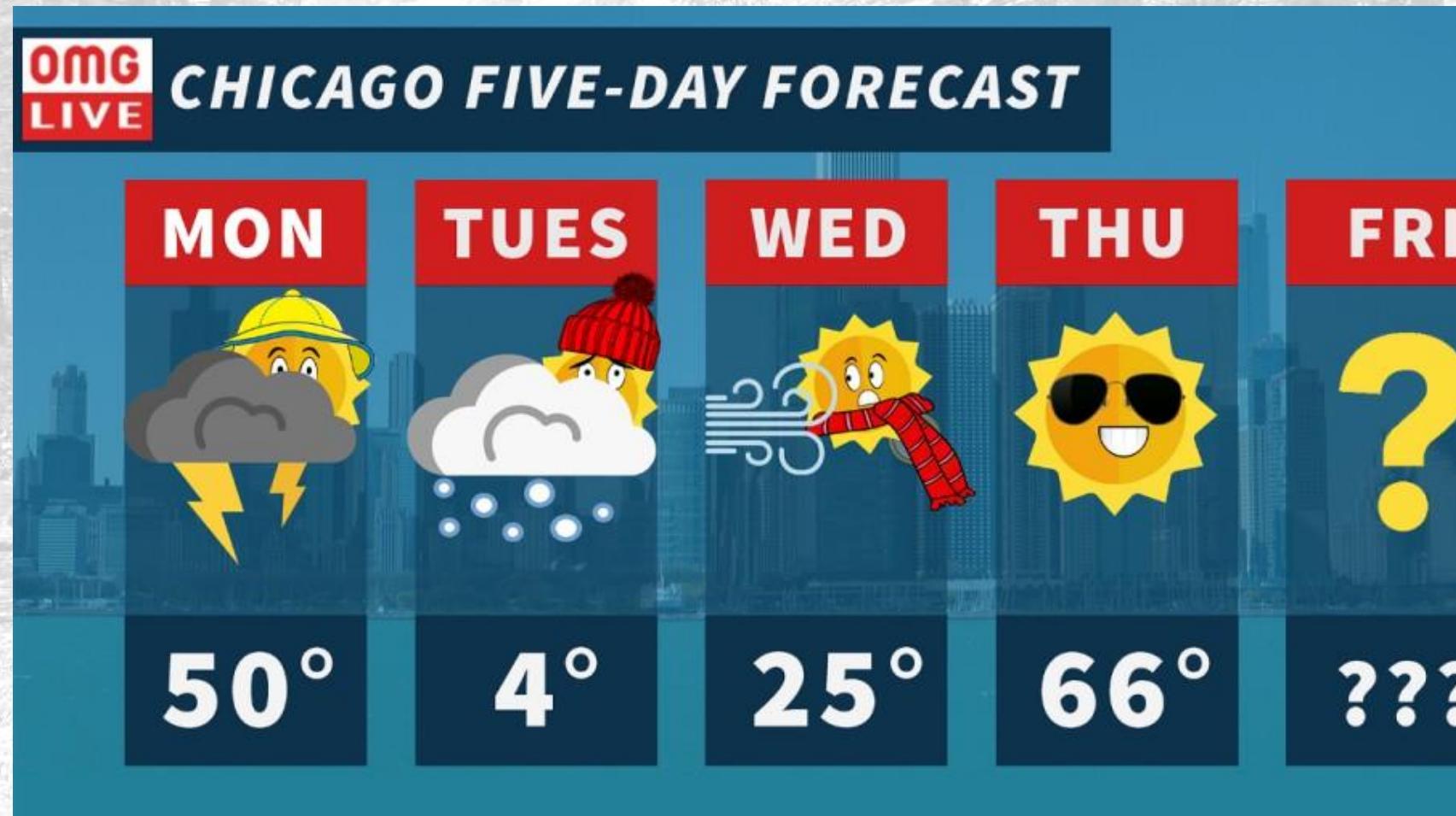
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**Use the knowledge about relationships
to guess the future**

Hands-on

Do you care about Predictive Sciences?

Why do you care about weather forecast?



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Do you care about Predictive Sciences?

Why do you care about weather forecast?

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So, what is Predictive Ecology?

Ecology + Prediction = Predictive Ecology



Knowledge of a given relationship



Use this understanding to infer what might happen

In other words...

Predictive Ecology is an approach to studying ecological systems that relies on predicting outcomes that have not yet happened. -- Dr. Eliot McIntire



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So, why should you care about Predictive Ecology?

Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time.

IPCC, 2019

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Predictive Ecology can take ecology one step further and help us solve problems as quickly as possible, monitor the outcomes of our actions, and iteratively improve our actions to keep our goals on sight.

ANY QUESTIONS?

"It is not the answer that enlightens, but the question." – Eugene Ionesco

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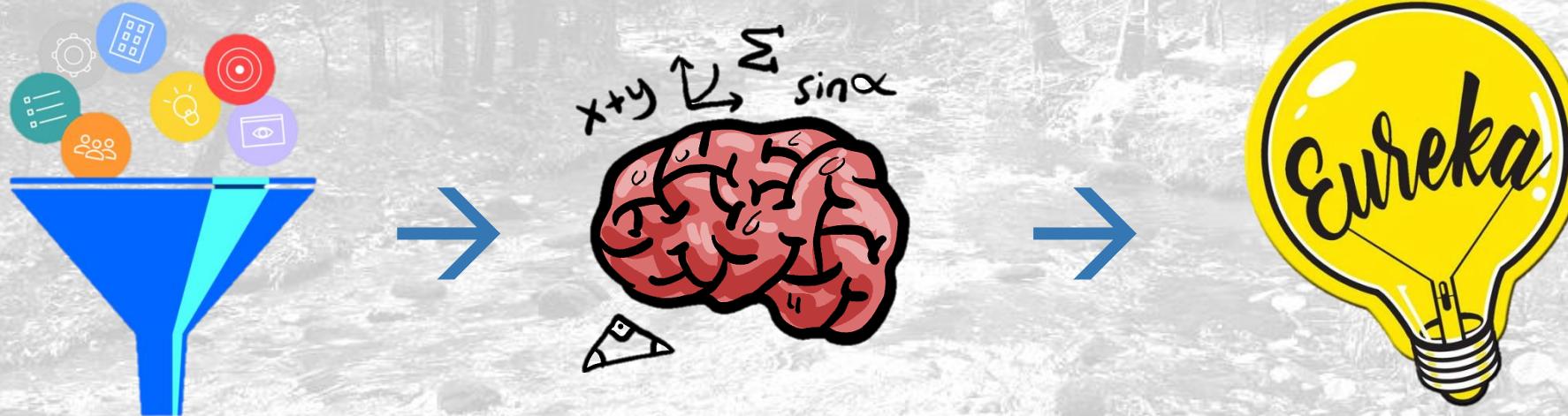
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Predictive Ecology: The basics

Predictive Ecology: The basics

What is modelling?

- A model is a representation of a phenomenon, or of a system. It is a logical way of presenting a process.



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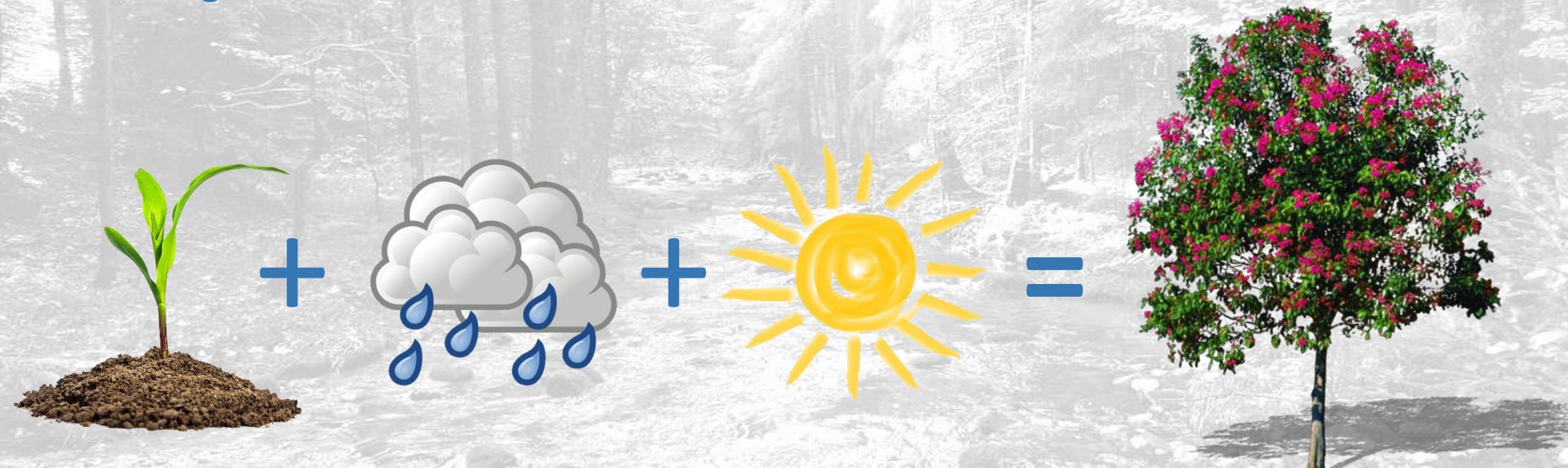
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Predictive Ecology: The basics

What is modelling?

- Plant growth model:



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Predictive Ecology: The basics

What does ecological modelling mean?

the construction and analysis of mathematical models of ecological processes, including both purely biological and combined biophysical models.

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Predictive Ecology: The basics

A more complex example: a community model

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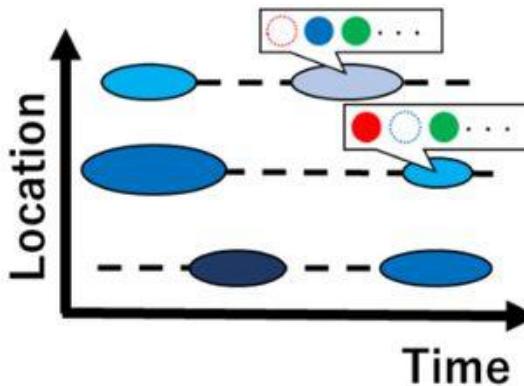
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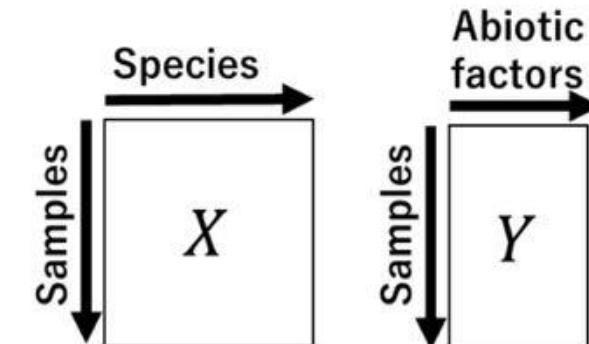
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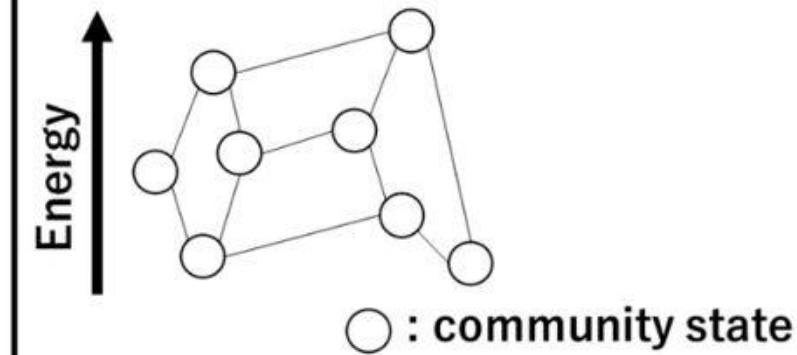
(A) Ecological communities



(B) Observational data



(D) Energy landscape analysis



(C) Fitting parameters of a pairwise maximum entropy model

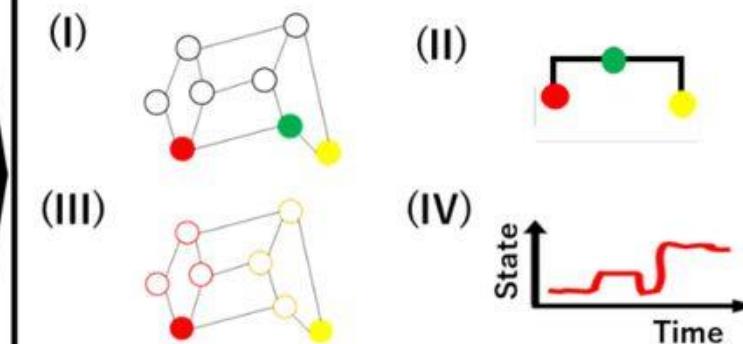
$$P(\sigma^{(k)}) \propto \left[\begin{matrix} \text{Implicit} \\ \text{Abiotic} \\ \text{factors} \end{matrix} \right] + \left[\begin{matrix} \text{Explicit} \\ \text{Abiotic} \\ \text{factors} \end{matrix} \right] + \left[\begin{matrix} \text{Biotic} \\ \text{interactions} \end{matrix} \right].$$

(I)

(III)

(II)

(IV)

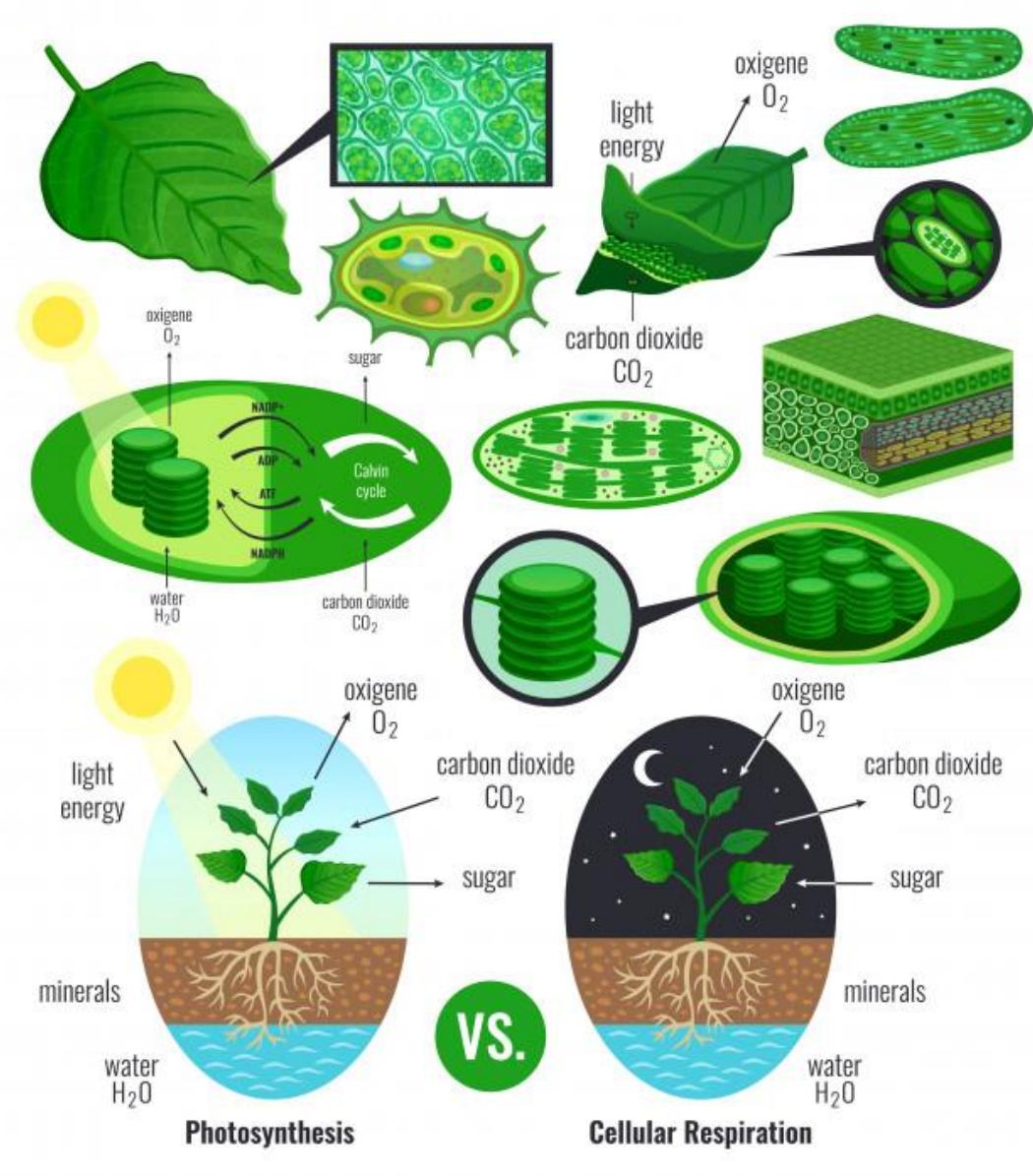


Predictive Ecology: The basics

Two types of models:

1. ANALYTICAL:

- Focus on explaining processes, based on inputs and outputs;
- Example: photosynthesis and respiration of a plant



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Predictive Ecology: The basics

Two types of models:

1. ANALYTICAL:

- Focus on explaining processes, based on inputs and outputs;
- Example: photosynthesis and respiration of a plant

**All models are wrong;
some are useful**

George Box
1951



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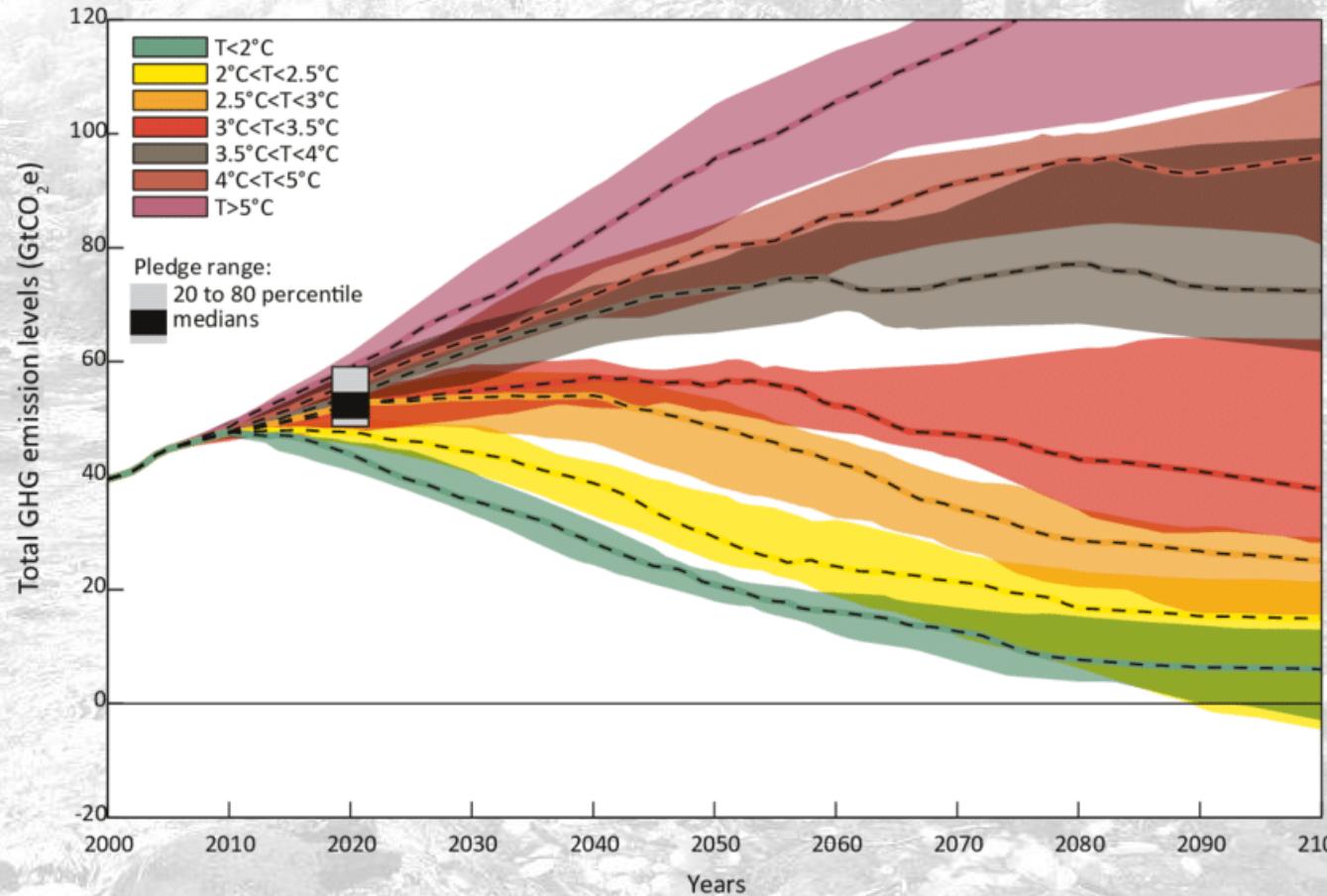
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Predictive Ecology: The basics

Two types of models:

2. SIMULATION:

- Focus on predicting results;
- Example: climate models from IPCC



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Predictive Ecology: The basics

Two types of models:

2. SIMULATION:

- Focus on predicting results;
- Example: climate models from IPCC

All models are right;
most are useless



Thaddeus Tarpey
2009

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Predictive Ecology: The basics

*How can we make
models more
useful?*

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ANY QUESTIONS?

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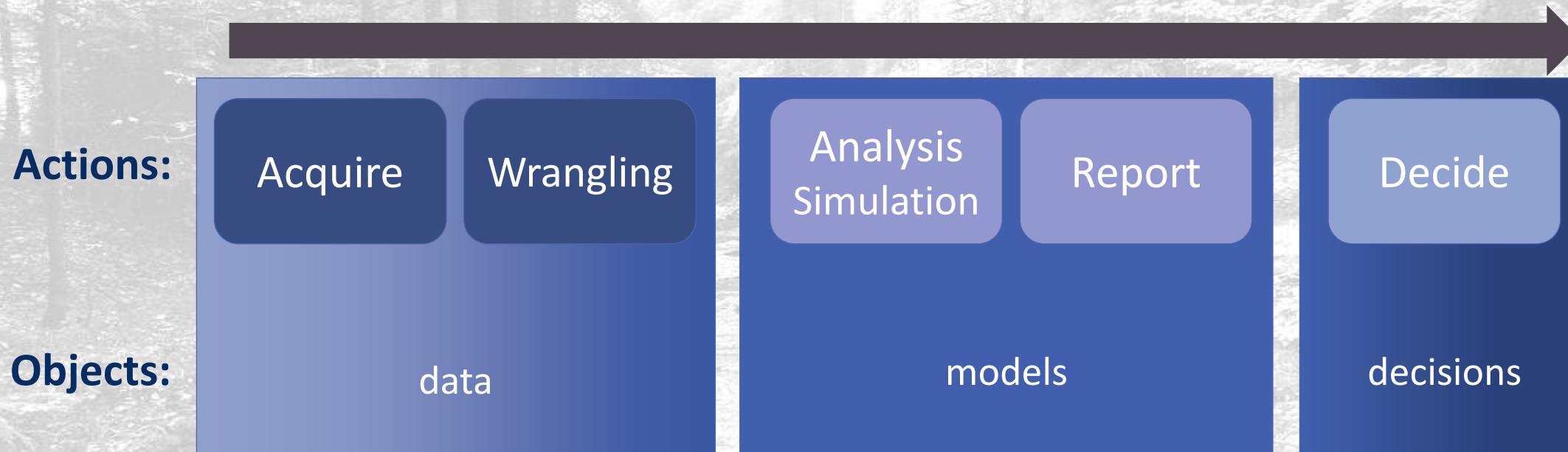
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Predictive Ecology: how can we do it right?

We need fast and informed decisions...



disjunct and performed in separate chunks

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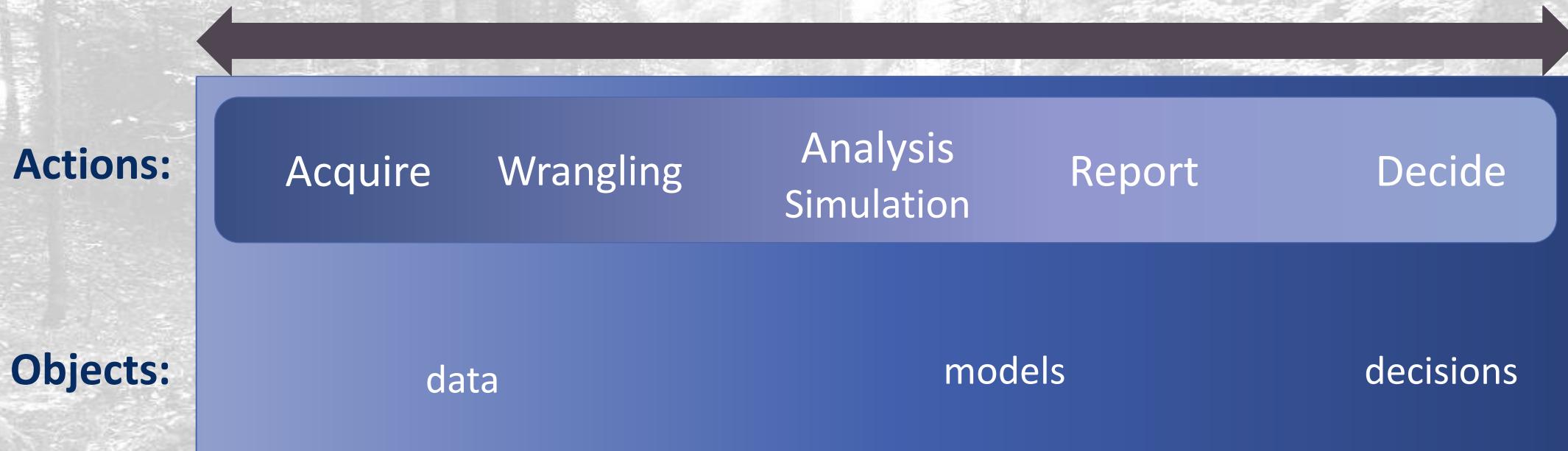
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We need fast and informed decisions...



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disjunct and performed in separate chunks

For that, we need a better framework!

Methods in Ecology and Evolution



RESEARCH ARTICLE | Open Access | CC BY SA

Empowering ecological modellers with a PERFECT workflow: Seamlessly linking data, parameterisation, prediction, validation and visualisation

Ceres Barros ✉, Yong Luo, Alex M. Chubaty, Ian M. S. Eddy, Tatiane Micheletti, Céline Boisvenue, David W. Andison, Steven G. Cumming, Eliot J. B. McIntire

First published: 20 December 2022 | <https://doi.org/10.1111/2041-210X.14034> | Citations: 2

Handling Editor: Rachel McCrea

 PDF  TOOLS  SHARE

Abstract

EN FR

1. Modelling is widely used in ecology and its utility continues to increase as scientists, managers and policy-makers face pressure to effectively manage ecosystems and meet conservation goals with limited resources. As the urgency to forecast ecosystem responses to global change grows, so do the number and complexity of predictive ecological models and the value of iterative prediction, both of which demand validation and cross-model comparisons. This challenges ecologists to provide predictive models that are reusable, interoperable, transparent and able to accommodate updates to both data and algorithms.
2. We propose a practical solution to this challenge based on the PERFECT principles (frequent Predictions and Evaluations of Reusable, Freely accessible, Interoperable models, built within Continuous workflows that are routinely Tested), using a modular and integrated framework. We present its general implementation across seven common components of ecological model applications—(i) the modelling toolkit; (ii) data acquisition and treatment; (iii) model parameterisation and calibration; (iv) obtaining predictions; (v) model validation; (vi) enclosing and

ECOLOGY LETTERS

VIEWPOINT | Open Access | CC BY

PERFECT: A Re-imagined foundation for predictive ecology

Eliot J. B. McIntire ✉, Alex M. Chubaty, Steven G. Cumming, Dave Andison, Ceres Barros, Céline Boisvenue, Samuel Haché, Yong Luo, Tatiane Micheletti, Frances E. C. Stewart

First published: 22 March 2022 | <https://doi.org/10.1111/ele.13994> | Citations: 3

 PDF  0 COMMENTS  TOOLS  SHARE

Abstract

Making predictions from ecological models—and comparing them to data—offers a coherent approach to evaluate model quality, regardless of model complexity or modelling paradigm. To date, our ability to use predictions for developing, validating, updating, integrating and applying models across scientific disciplines while influencing management decisions, policies, and the public has been hampered by disparate perspectives on prediction and inadequately integrated approaches. We present an updated foundation for Predictive Ecology based on seven principles applied to ecological modelling: make frequent Predictions, Evaluate models, make models Reusable, Freely accessible and Interoperable, built within Continuous workflows that are routinely Tested (PERFECT). We outline some benefits of working with these principles: accelerating science; linking with data science; and improving science-policy integration.

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The PERFECT approach to Predictive Ecology

How can we make predictive models more useful?

- Predict frequently,
- Evaluate models, make models
- Reusable
- Freely accessible and
- Interoperable built within
- Continuous workflows that are routinely
- Tested

REPRODUCIBLE?



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The PERFECT approach to Predictive Ecology

What are the benefits of this approach?

1. Accelerating science:

- **Occam's razor:** Assessing right model complexity by comparing models;
- **Informative priors:** Bringing results from previous studies to new ones (Northrup & Gerber, 2018);
- **Forecast horizon:** Iterative forecasts with new data and models (Petchey et al., 2015);
- **Community of contributors:** Enables large projects with many contributors and updates(Fer et al., 2021)
- **Predictive validation:** Using future data to test models (Power, 1993)
- **Rewriting models:** Using widely known languages increases access (Thiele & Grimm, 2015)
- **Many eyes:** Understandable and open models more easily allow for fixing bugs and identifying improvements

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The PERFECT approach to Predictive Ecology

What are the benefits of this approach?

2. Bridging to Data Science:

- **Building on data science tools:** Facilitating cloud computing and repositories, user access control and data caching improves access to modelling process
- **Data quality and quantity:** Building data-model-validation pipelines from reusable components allowing for assessment of different data sources (White et al., 2019)
- **Linking models to data:** Maintaining linkages between canonical data sources and models for rapid re-parameterization and updating with continuous testing (Micheletti et al., 2021)

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The PERFECT approach to Predictive Ecology

What are the benefits of this approach?

3. Improving science-policy integration:

- **Cross disciplinarity:** Lessening the technological, data and cultural barriers that make cross-disciplinary work challenging (Chassé et al., 2020)
- **Regular reporting:** Reducing the effort required to produce regular updates for policy reporting
- **IPCC-like process:** Allows lower budget projects to achieve IPCC-like integration (Masson-Delmotte et al., 2021)
- **Different users:** Allows for all types of expertise to interact (Ferraz et al., 2021)
- **Web and decision support applications:** Allows for the development of generic web and decision support tools—“dashboards”—that can be reused widely
- **Coping with contradictions:** Opening the science informed decision-making and policy-making process to shed light on cases where models contradict one another and offering an objective way to resolve those contradictions

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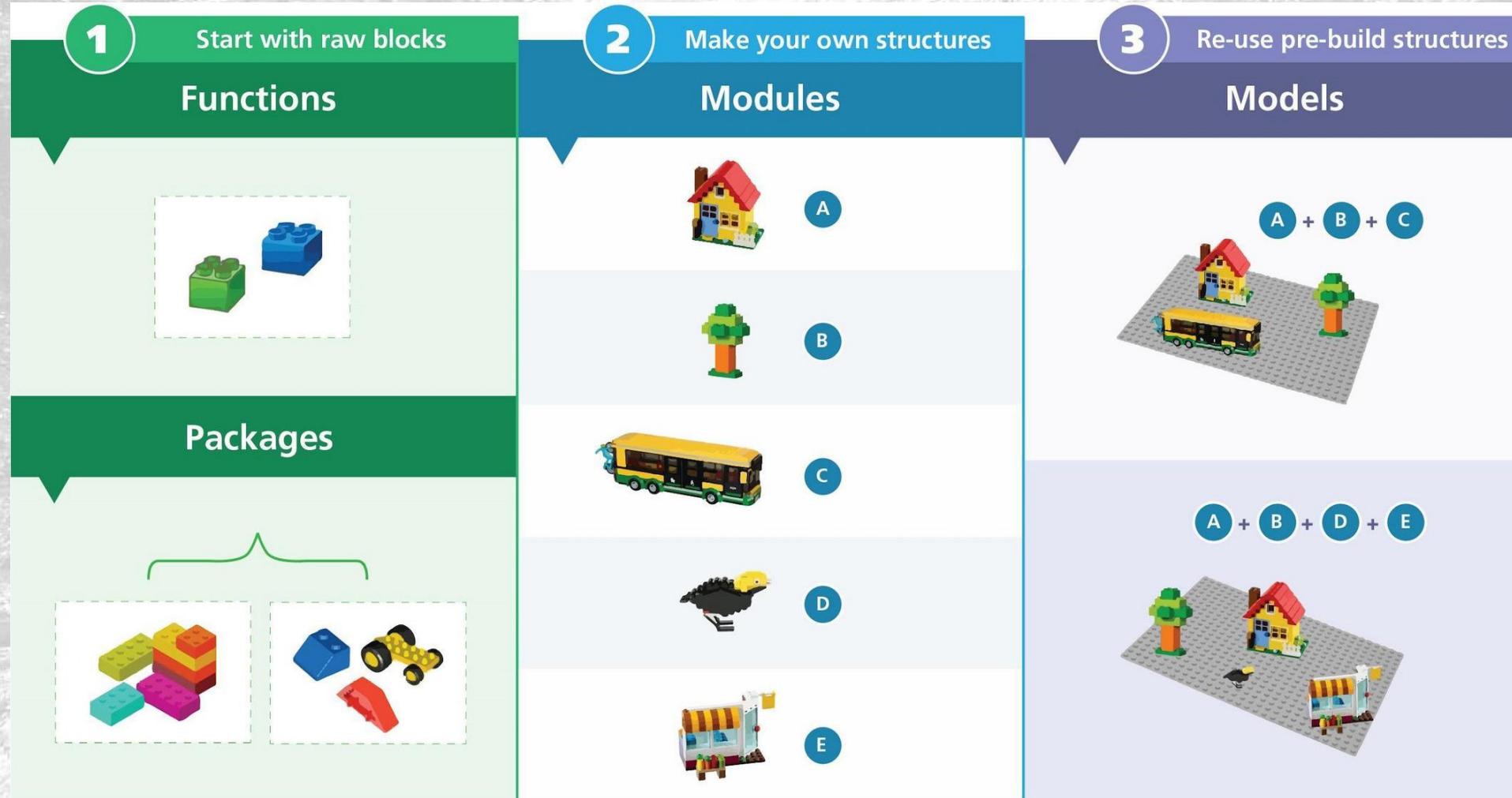
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The PERFECT approach to Predictive Ecology

But how can we do this in practice?



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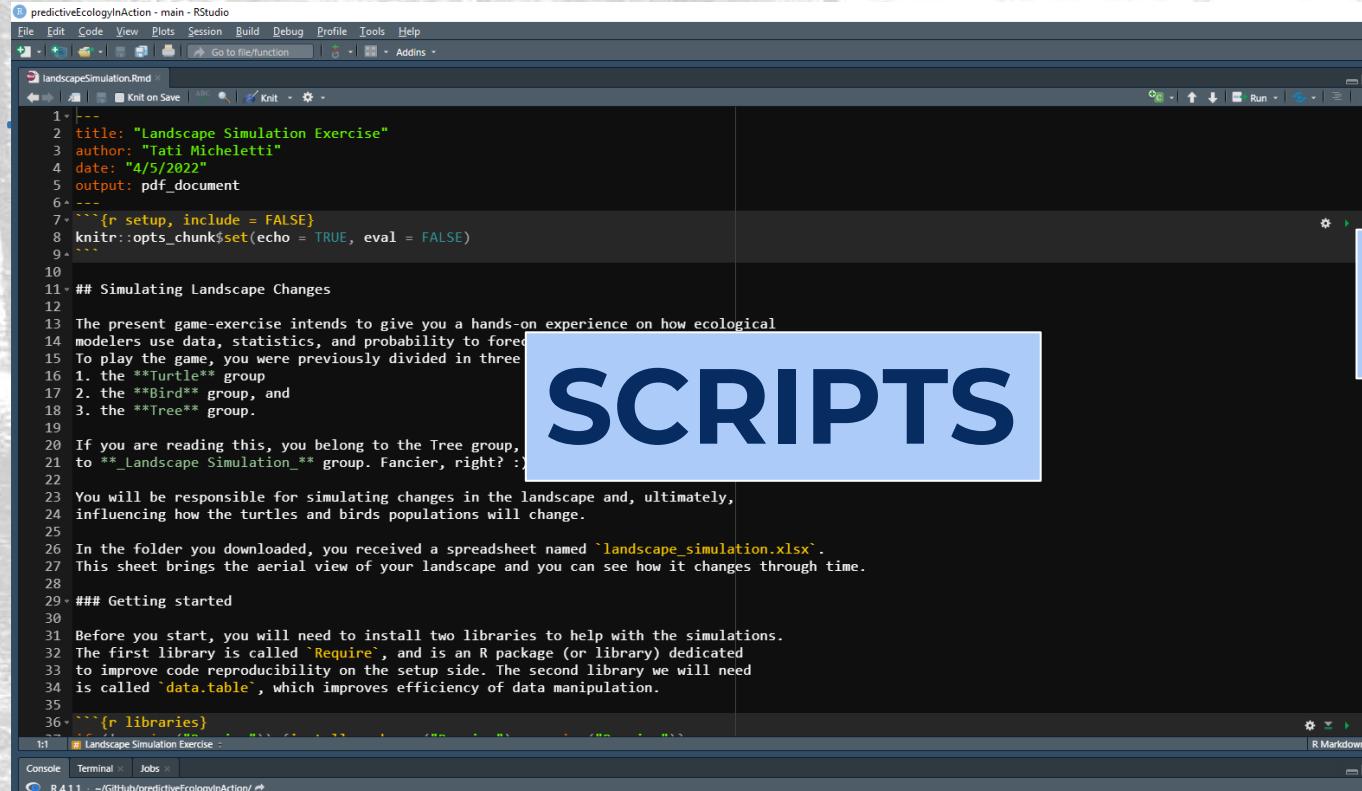
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Important tools: the power of R and version control

SCRIPTS



```

1 ---  

2 title: "Landscape Simulation Exercise"  

3 author: "Tati Micheletti"  

4 date: "4/5/2022"  

5 output: pdf_document  

6 ---  

7 ```{r setup, include = FALSE}  

8 knitr::opts_chunk$set(echo = TRUE, eval = FALSE)  

9 ---  

10 ## Simulating Landscape Changes  

11  

12 The present game-exercise intends to give you a hands-on experience on how ecological  

13 modelers use data, statistics, and probability to forecast  

14 To play the game, you were previously divided in three  

15 1. the **Turtle** group  

16 2. the **Bird** group, and  

17 3. the **Tree** group.  

18  

19 If you are reading this, you belong to the Tree group,  

20 to **_Landscape Simulation_** group. Fancier, right? :)  

21  

22 You will be responsible for simulating changes in the landscape and, ultimately,  

23 influencing how the turtles and birds populations will change.  

24  

25 In the folder you downloaded, you received a spreadsheet named `landscape_simulation.xlsx`.  

26 This sheet brings the aerial view of your landscape and you can see how it changes through time.  

27  

28 ### Getting started  

29  

30 Before you start, you will need to install two libraries to help with the simulations.  

31 The first library is called `Require`, and is an R package (or library) dedicated  

32 to improve code reproducibility on the setup side. The second library we will need  

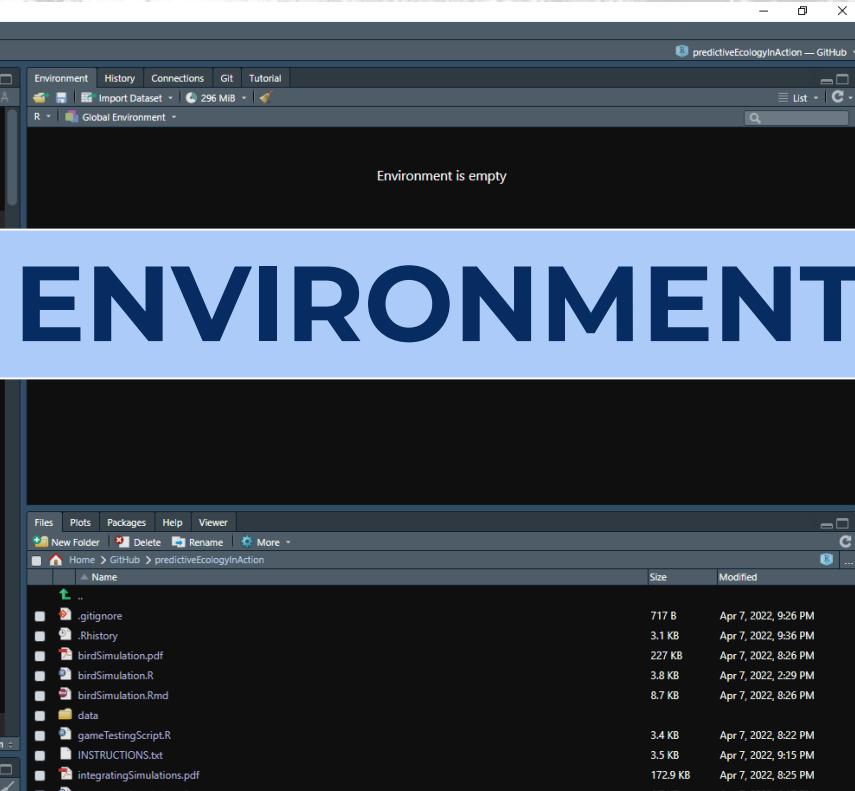
33 is called `data.table`, which improves efficiency of data manipulation.  

34  

35 ```{r libraries}

```

ENVIRONMENT



Environment is empty

CONSOLE

```

R version 4.1.1 (2021-08-10) -- "Kick Things"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line
'help.start()' for an HTML browser interface to help
Type 'q()' to quit R.

```

FILES, GRAPHS, HELP



Name	Size	Modified
..	717 B	Apr 7, 2022, 9:26 PM
.gitignore	3.1 KB	Apr 7, 2022, 9:36 PM
.Rhistory	227 KB	Apr 7, 2022, 8:26 PM
birdSimulation.pdf	3.8 KB	Apr 7, 2022, 2:29 PM
birdSimulation.R	8.7 KB	Apr 7, 2022, 8:26 PM
birdSimulation.Rmd		
data		
gameTestingScript.R	3.4 KB	Apr 7, 2022, 8:22 PM
INSTRUCTIONS.txt	3.5 KB	Apr 7, 2022, 9:15 PM
integratingSimulations.pdf	172.9 KB	Apr 7, 2022, 8:25 PM
integratingSimulations.R	6.7 KB	Apr 7, 2022, 8:17 PM

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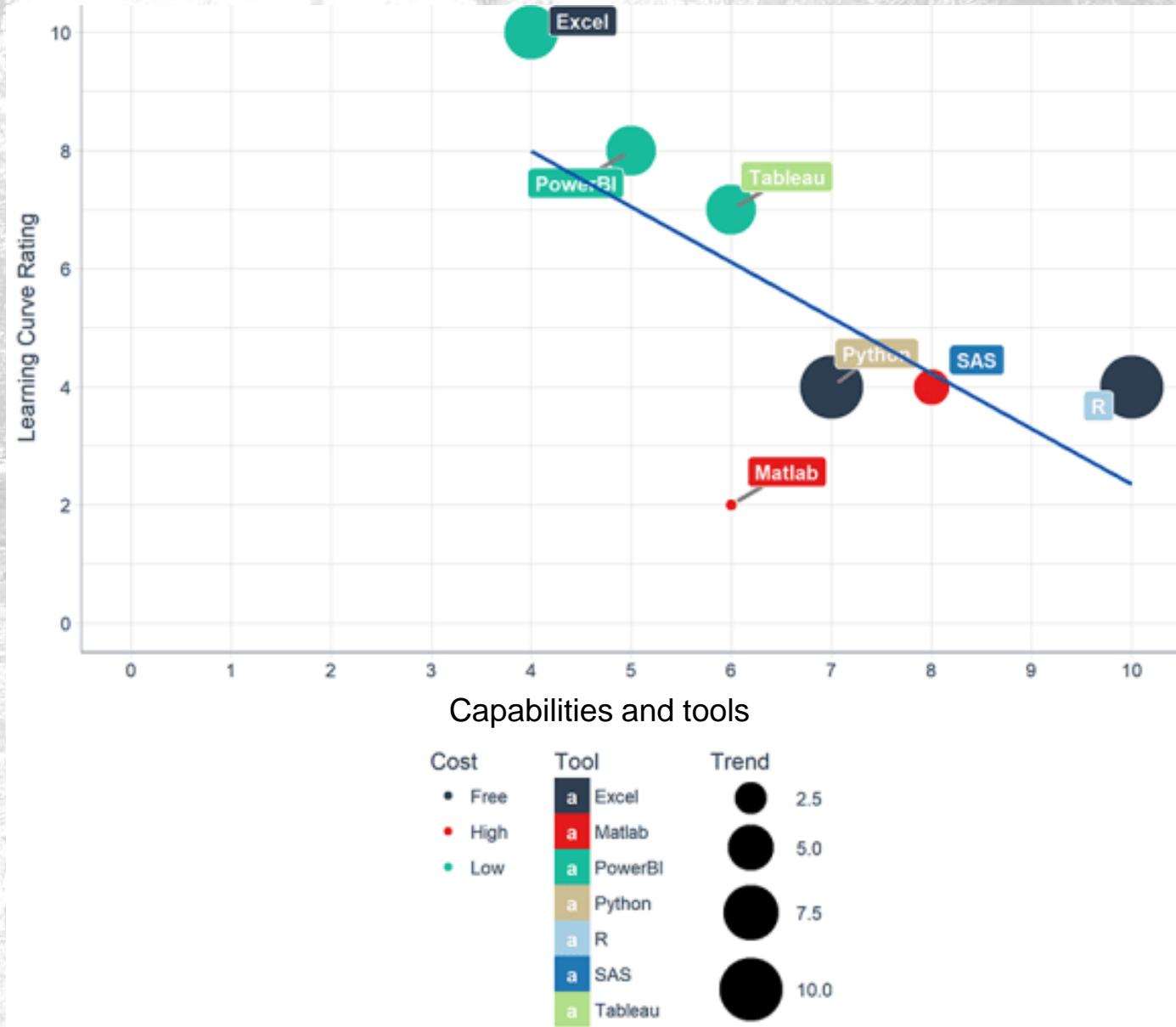
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Important tools: the power of R and version control

- What is  ?
- Why  ?



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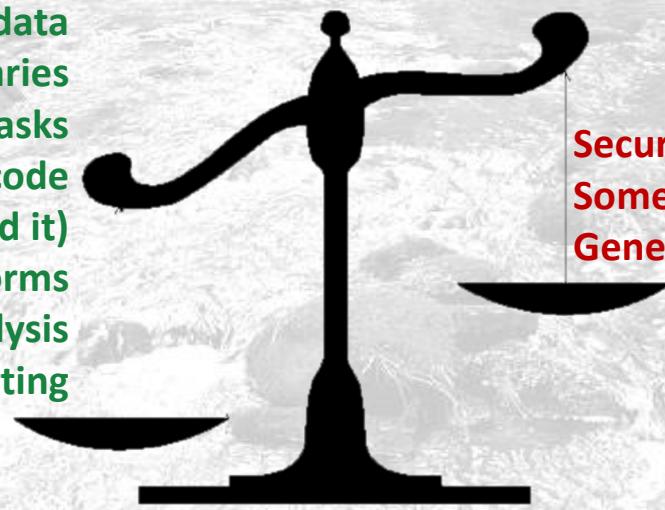
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Important tools: the power of R and version control

- What is  ?
- Why  ?
- Advantages and disadvantages of 

Lots of packages
Huge community
Free and open-source
Handles all sorts of data
Several graphical libraries
Easier automation of tasks
Fast if you know how to code
Logical Language (once you learned it)
Compatible with most other platforms
Powerful with more complex statistical analysis
Handles the full workflow from data to reporting



Security
Some packages' quality
Generally harder to learn than Excel or Tableau

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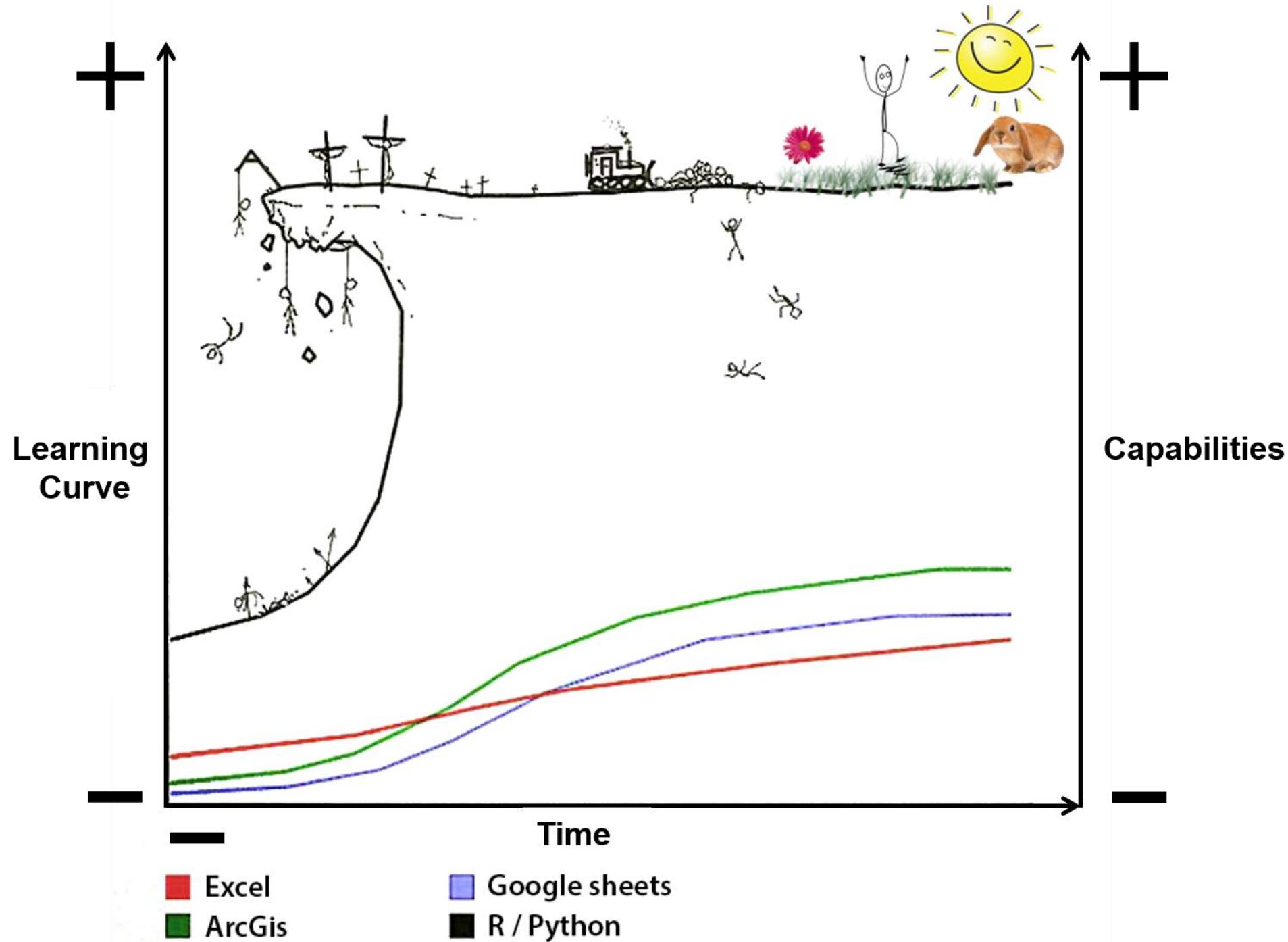
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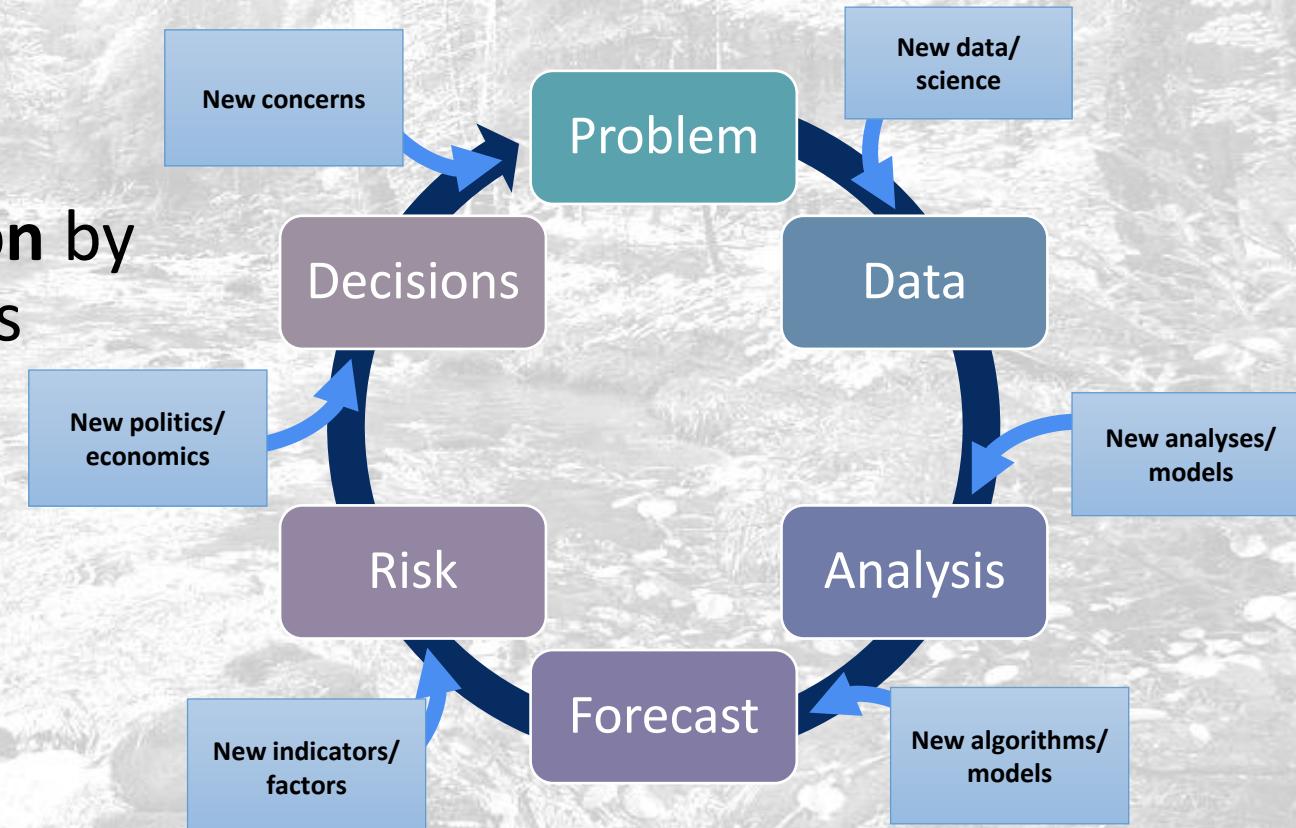
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SpaDES: the importance of reusability in science

- ♠ **Modelling tool:** set of R Packages
- ♠ **Framework:** continuous adaptive management
- ♠ **Metadata** is mandatory
- ♠ Promotes easier **integration** by declared inputs and outputs



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Big projects with management focus?

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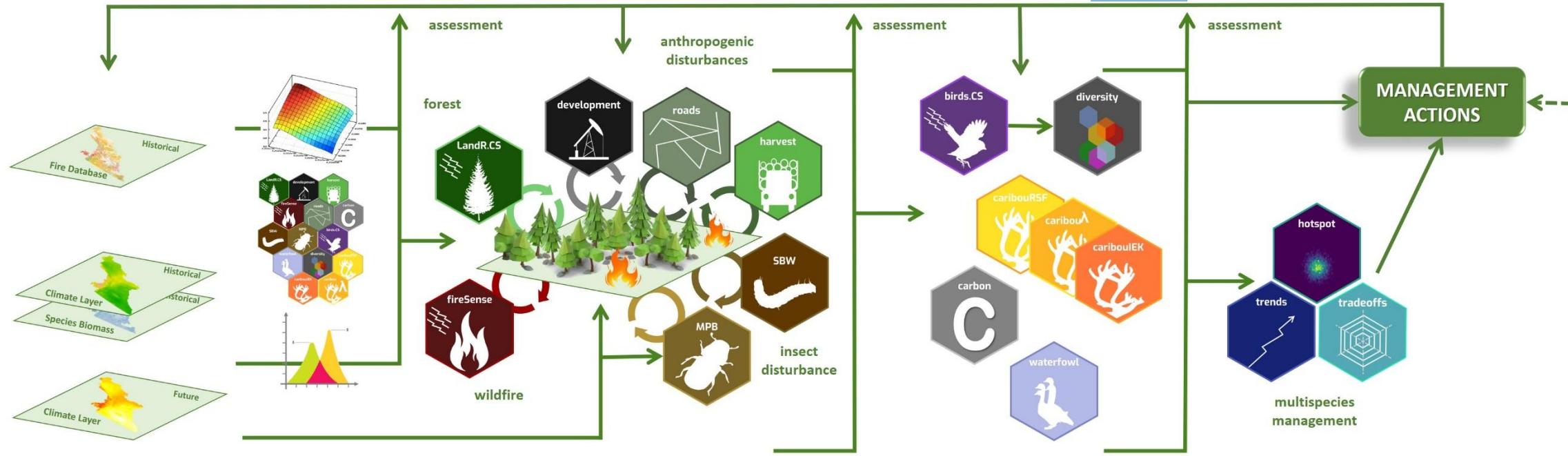
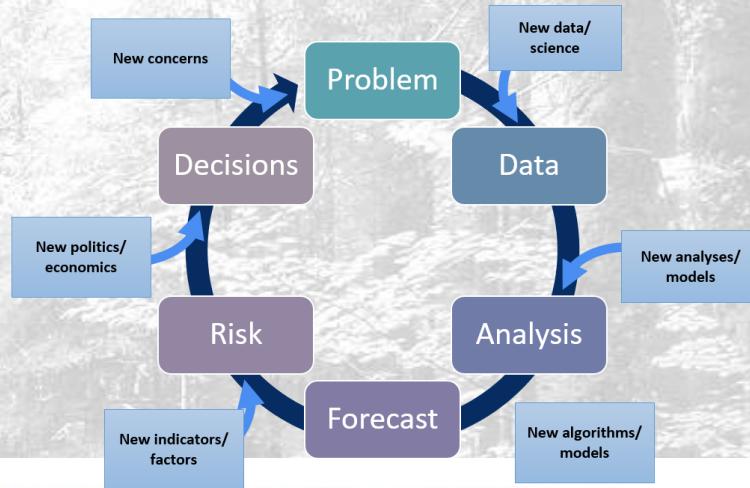
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data processing

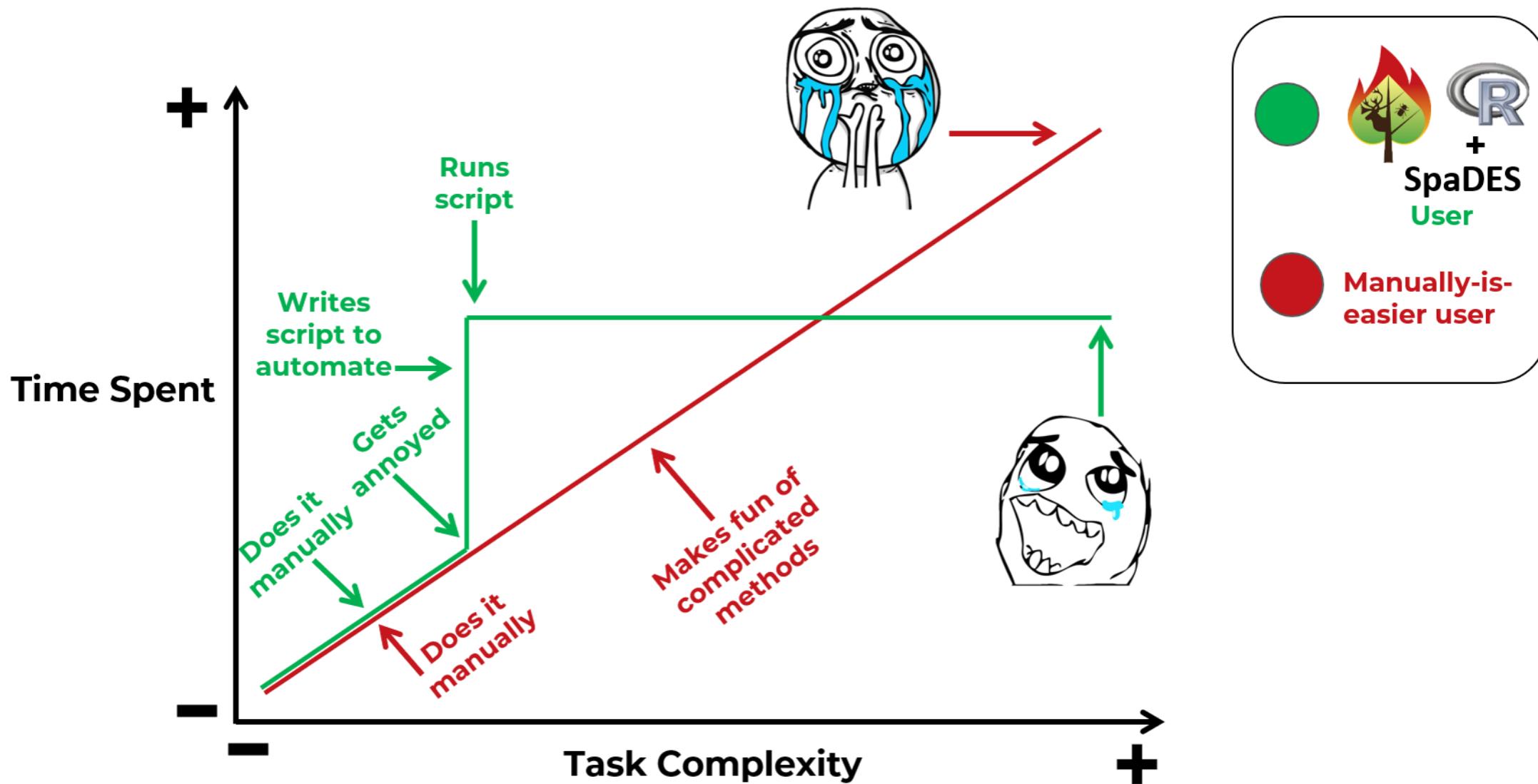
landscape simulation

valued ecosystem components

valued outcomes

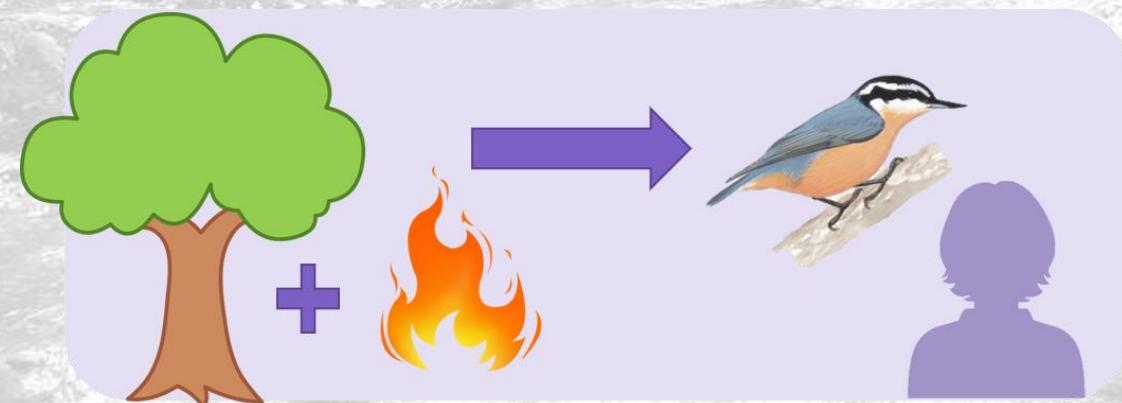
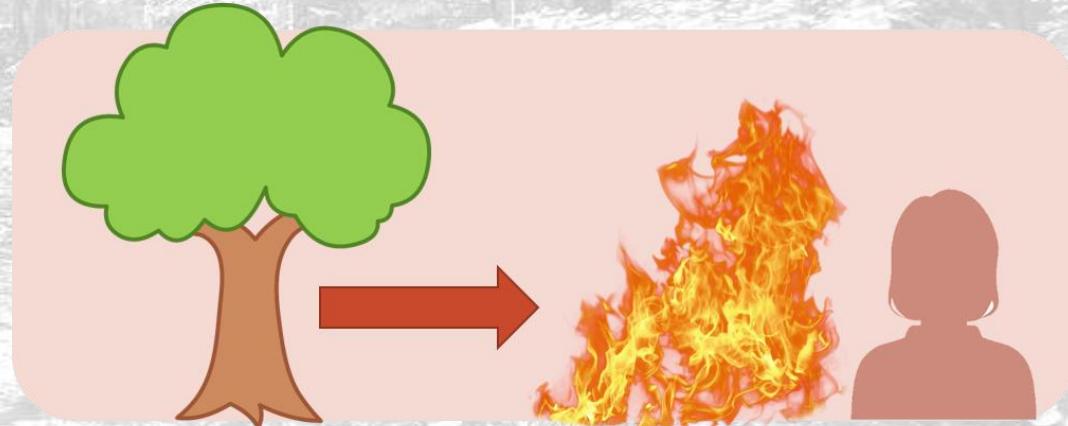
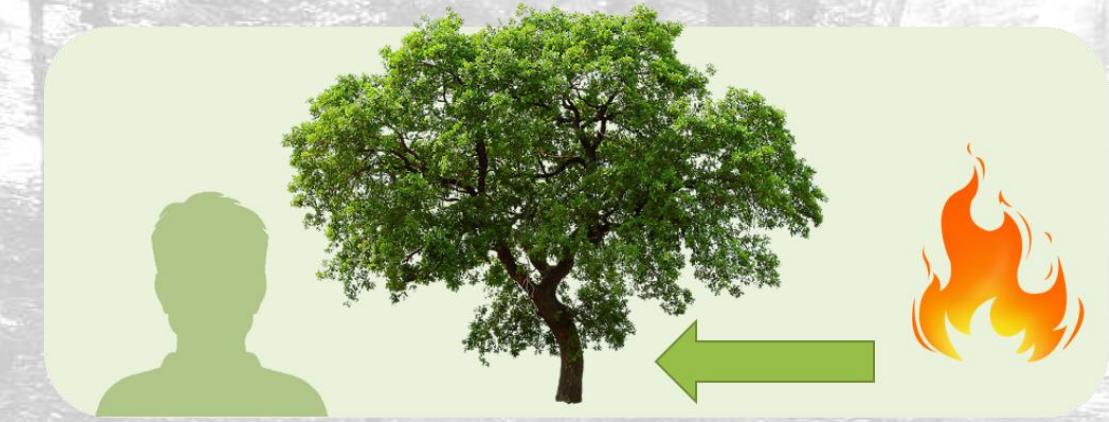
policy

Iterative Scripting vs Manual Approach



Bringing these concepts to an example

Nobody is an expert in everything



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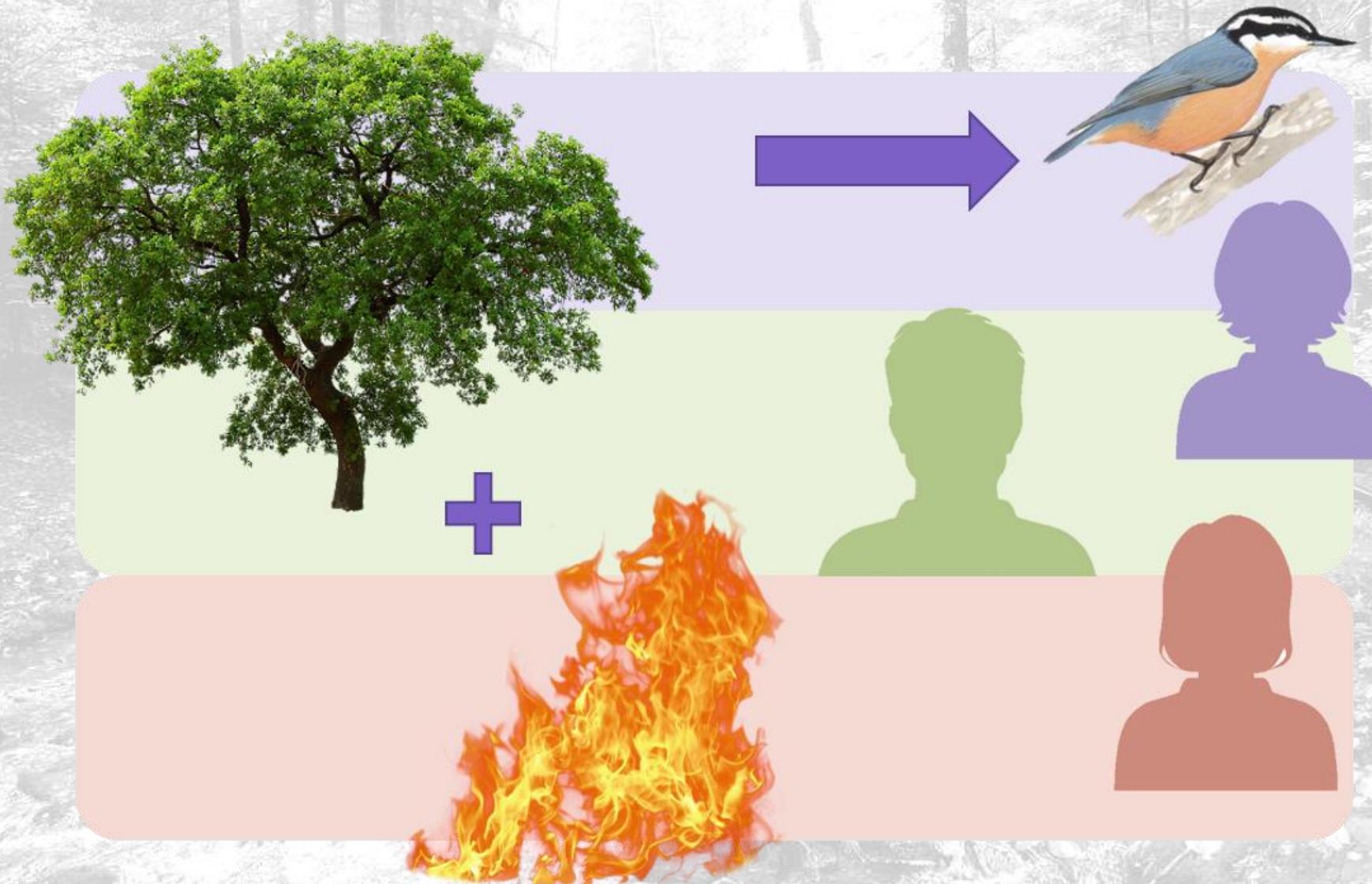
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Bringing these concepts to an example



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Integrating transdisciplinary efforts is key to improve our power of action in changing the world to a better place!



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ANY QUESTIONS?

“It is not the answer that enlightens, but the question.” – Eugene Ionesco

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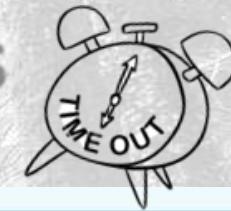
PART IV

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PART IV

Predictive Ecology: a real example

We are running out of time and need to address several aspects of conservation!



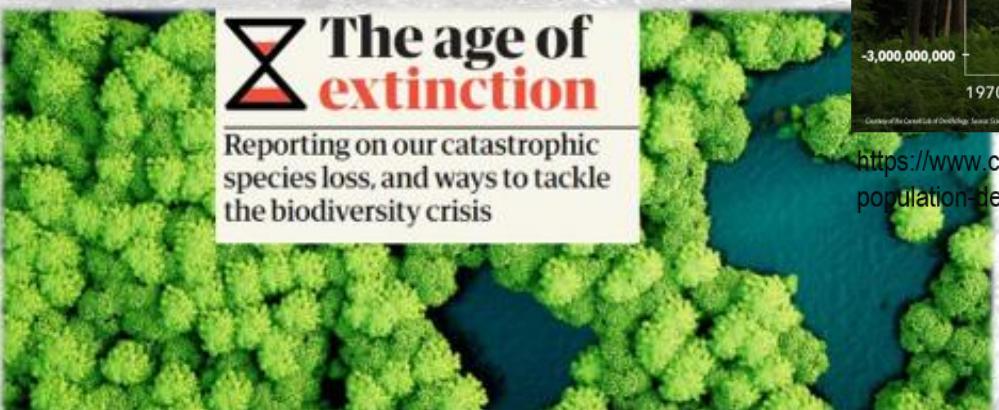
Politics

Woodland caribou continue to decline as provinces fail to meet protection deadline



In the meantime, caribou, and their habitat continue to decline

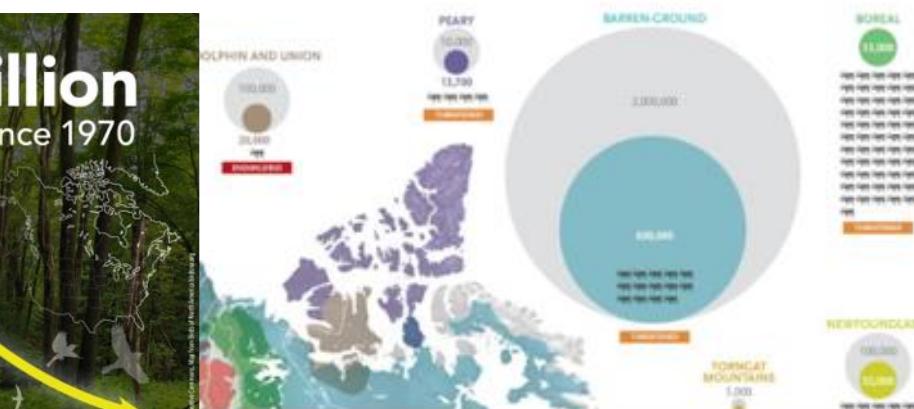
Susan Lunn - CBC News · Posted: Oct 31, 2017 12:01 PM ET | Last Updated: October 31, 2017



Courtesy of the Cornell Lab of Ornithology. Source: Science, 2019
Science
<https://www.cbc.ca/news/technology/bird-population-decline-1.5288454>

Mapping the decline of Canada's caribou

A snapshot of the country's drastically dwindling caribou herds



REPORTS

Cite as: K. V. Rosenberg *et al.*, *Science* 10.1126/science.aaw1313 (2019).

Decline of the North American avifauna

Kenneth V. Rosenberg^{1,2*}, Adriaan M. Dokter¹, Peter J. Blancher³, John R. Sauer⁴, Adam C. Smith⁵, Paul A. Smith³, Jessica C. Stanton⁶, Arvind Panjabi⁷, Laura Helft¹, Michael Parr², Peter P. Marra^{8†}

¹Cornell Laboratory of Ornithology, Cornell University, Ithaca, NY 14850, USA. ²American Bird Conservancy, Washington, DC 20008, USA. ³National Wildlife Research Centre, Environment and Climate Change Canada, Ottawa, ON K1A 0H3, Canada. ⁴Patuxent Wildlife Research Center, United States Geological Survey, Laurel, MD 20708-4017, USA. ⁵Canadian Wildlife Service, Environment and Climate Change Canada, Ottawa, ON K1A 0H3, Canada. ⁶Upper Midwest Environmental Sciences Center, United States Geological Survey, La Crosse, WI, USA. ⁷Bird Conservancy of the Rockies, Fort Collins, CO 80521, USA. ⁸Migratory Bird Center, Smithsonian Conservation Biology Institute, National Zoological Park, PO Box 37012 MRC 5503, Washington, DC 20013-7012, USA.

*Corresponding author. Email: kvr2@cornell.edu

†Present address: Department of Biology and McCourt School of Public Policy, Georgetown University, 37th and O Streets NW, Washington, DC 20057, USA.

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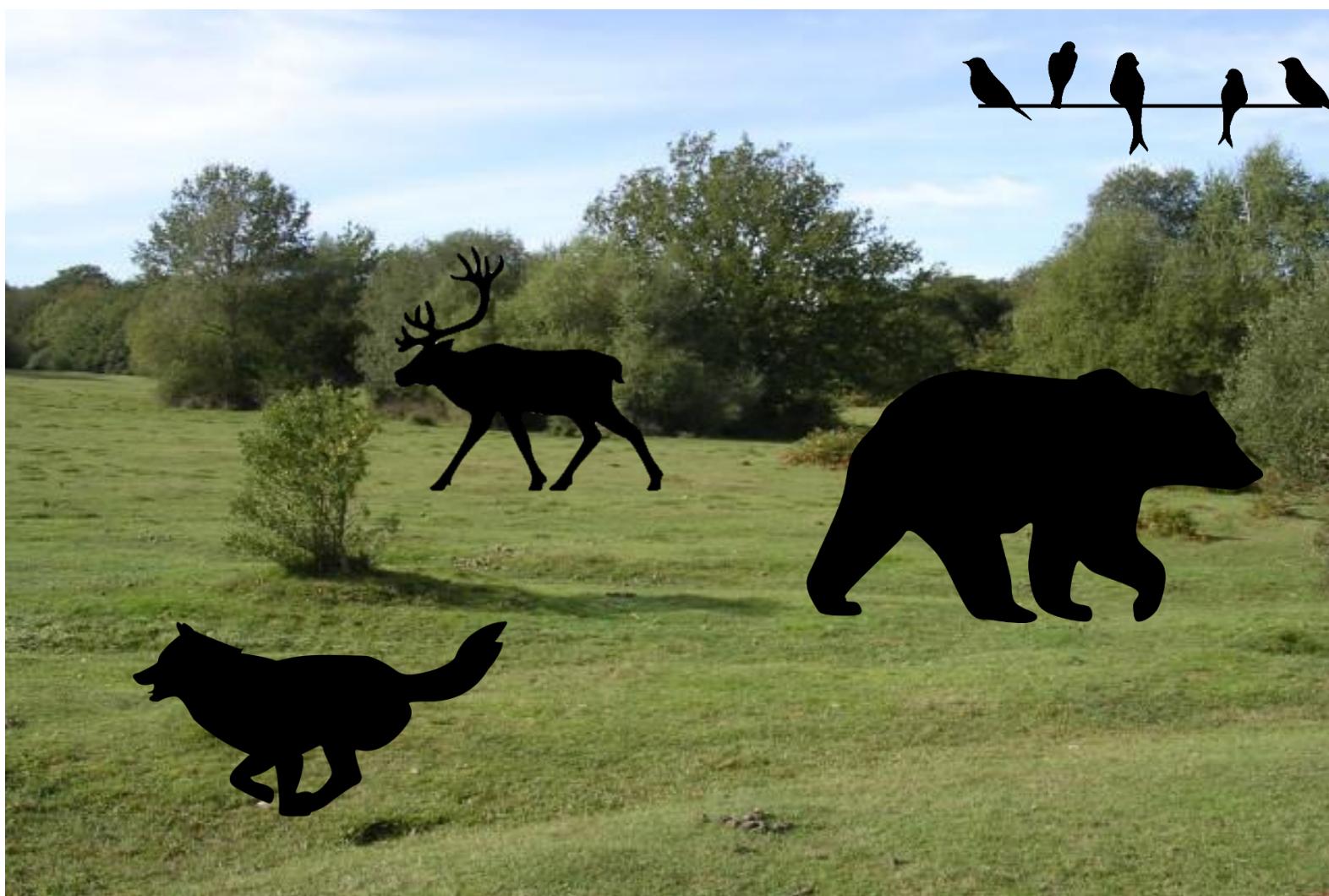
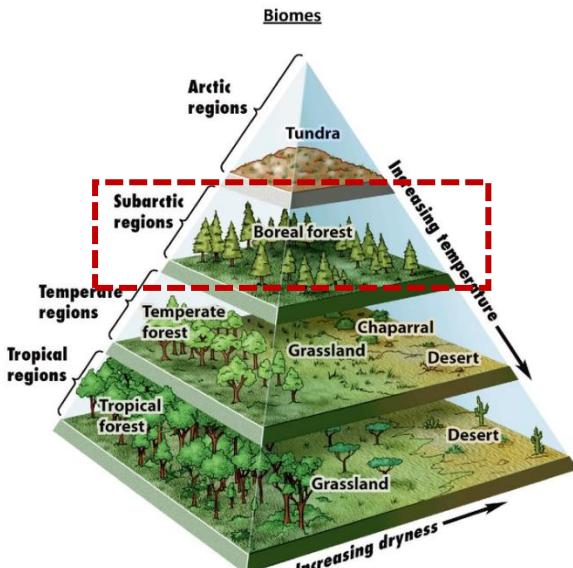
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Northern Boreal Forests are especially sensitive to changes



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The Western Boreal Initiative: From the Northwest Territories to West Canada



Western
Boreal
Initiative



Content

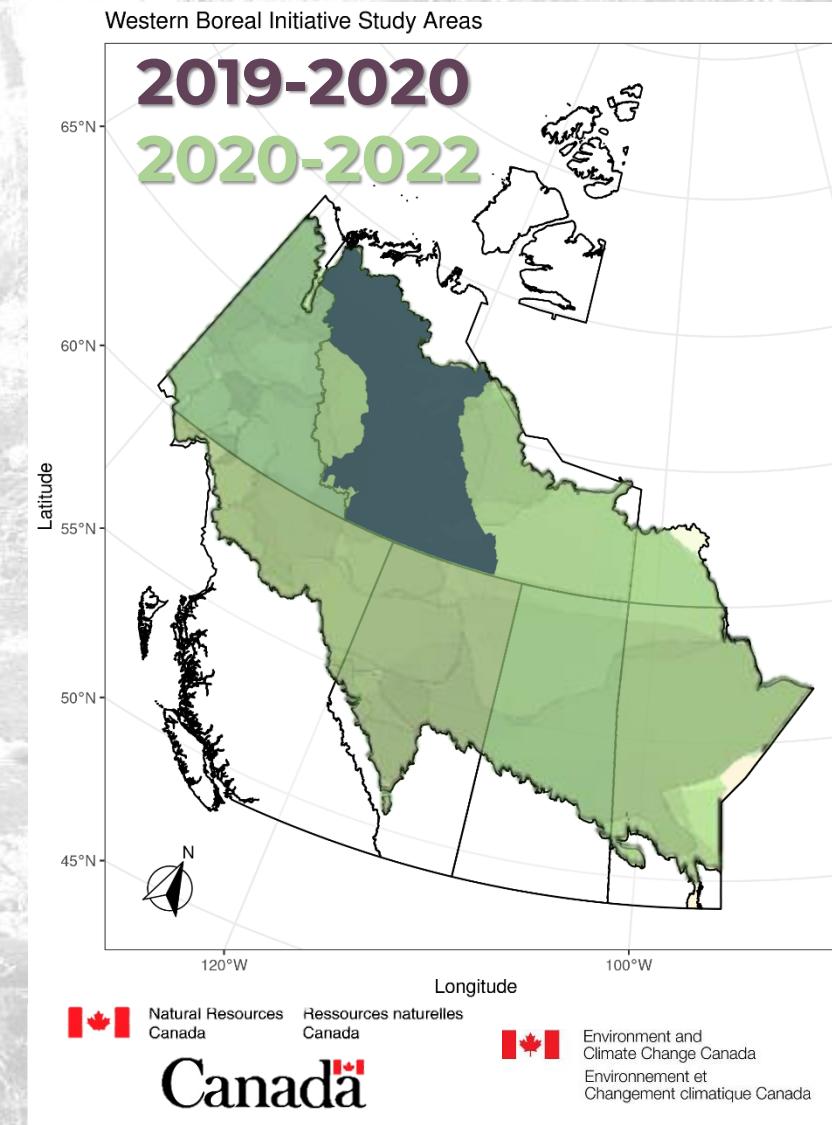
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The Western Boreal Initiative: From the Northwest Territories to West Canada



Western
Boreal
Initiative



Native Land native-land.ca

About Us ▾ Media ▾ How To Contribute ▾ Resources ▾ Support ▾

Territories Languages Treaties

Search your address, or toggle switches above to add shapes. Click around! Think critically about this map

Search (Deg Xitan)

Territories Languages Treaties

Inuit

<https://native-land.ca/>

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Research Team



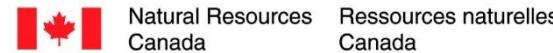
THE UNIVERSITY
OF BRITISH COLUMBIA



tati.silva@ubc.ca



@PredictiveEcol



Canada



Canada

@PredictiveEcol



Eliot McIntire



Western
Boreal
Initiative

Samuel Hache

Dene First Nations

Frances Stewart

Diana Stralberg

Junior Tremblay

Mathieu Leblond

Alex Chubaty

James Hodson

Steve Cumming

Celine Boisvenue

Greg Paradis

Ian Eddy

Ceres Barros

... and many others!



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Other collaborators who jumped right in...



Western
Boreal
Initiative



Yukon



Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development

Manitoba A black silhouette of a bison standing next to the word "Manitoba" in a green, sans-serif font.



Government of
Northwest Territories
Gouvernement des
Territoires du
Nord-Ouest



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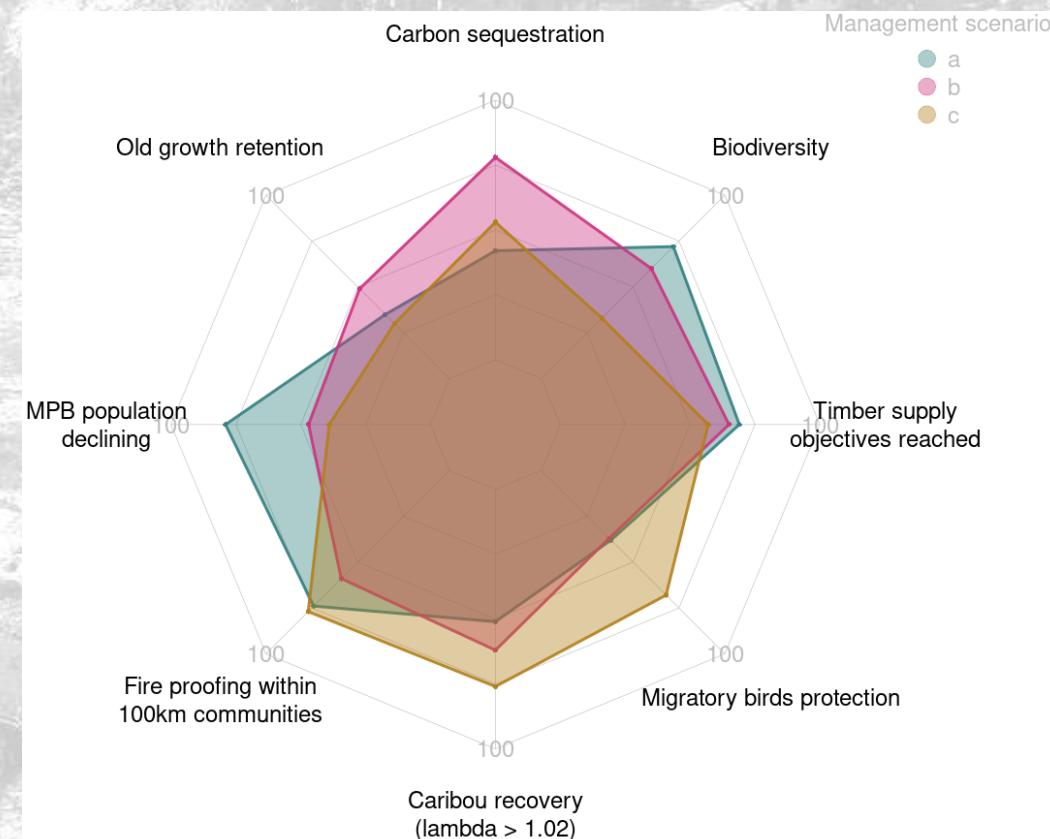
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Main objectives

- **Assess the cumulative effects of natural and anthropogenic disturbances under climate change in Western Canada**
- ***Identify trade-offs among long-term conservation of priority species and places, carbon sequestration, and land management***



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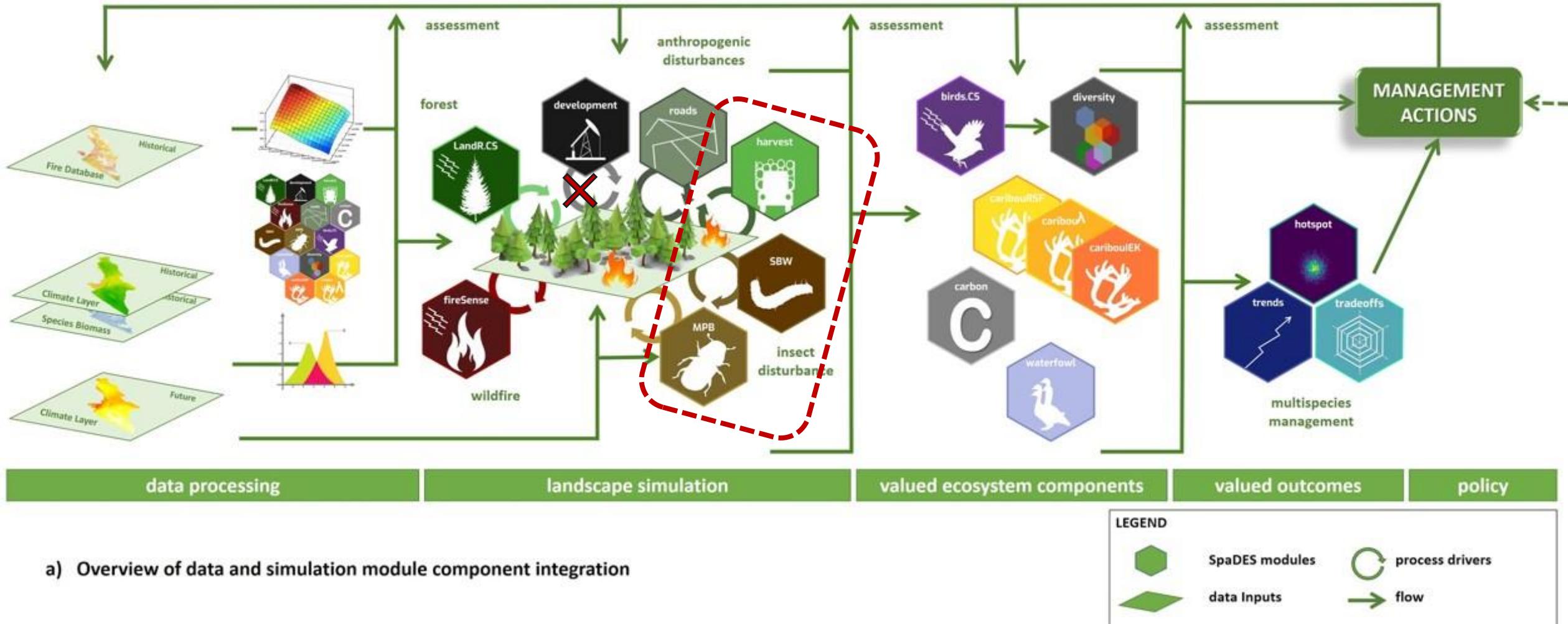
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Current Framework



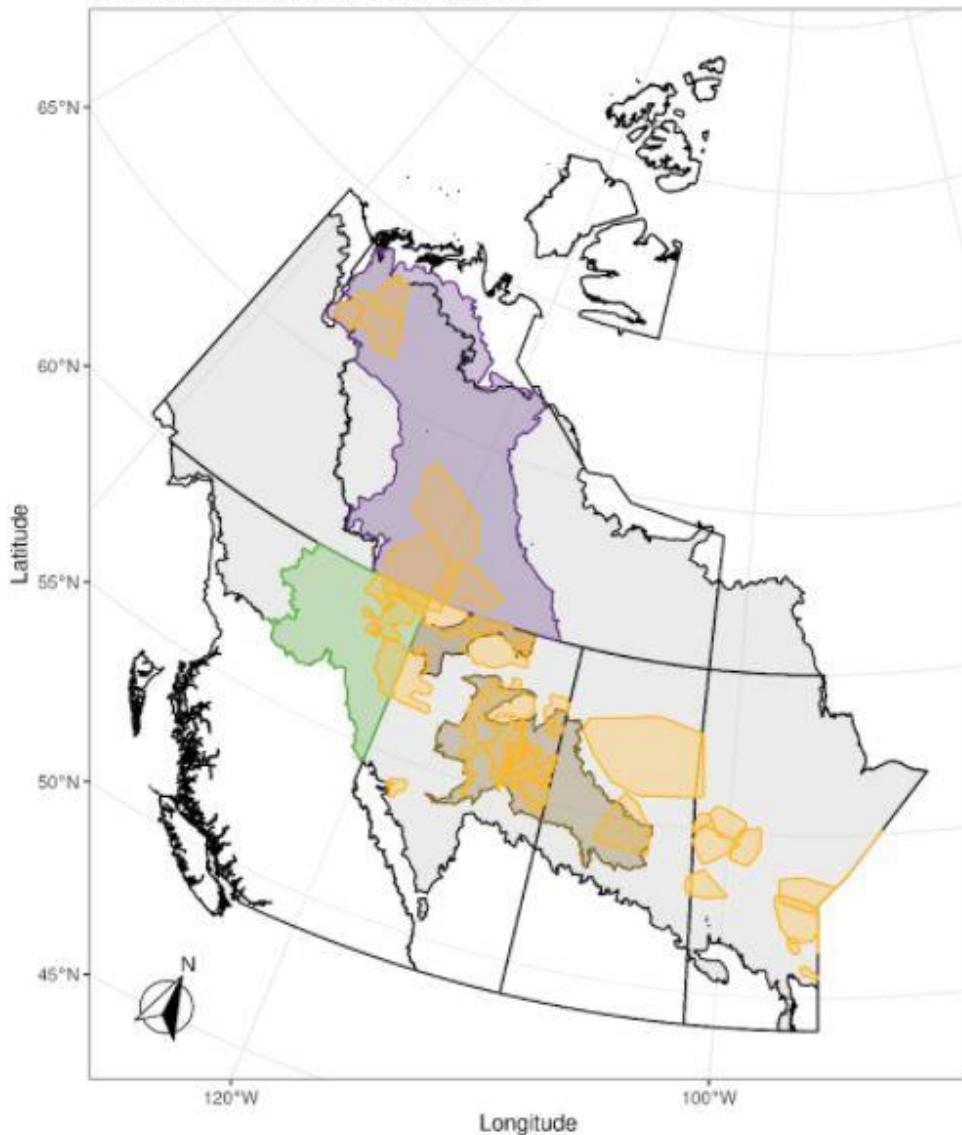
Western
Boreal
Initiative





Study Area of each component

Western Boreal Initiative Study Areas



- Harvesting, Carbon Budget Model, Carbon LandR
- Caribou Resource Selection (Caribou IEK*)
- Caribou Population Growth, Anthropogenic disturbance
- Spruce Budworm
- Mountain Pine Beetle
- Landbirds, Waterfowl, Forest Dynamics, Wildfire, Priority Places**

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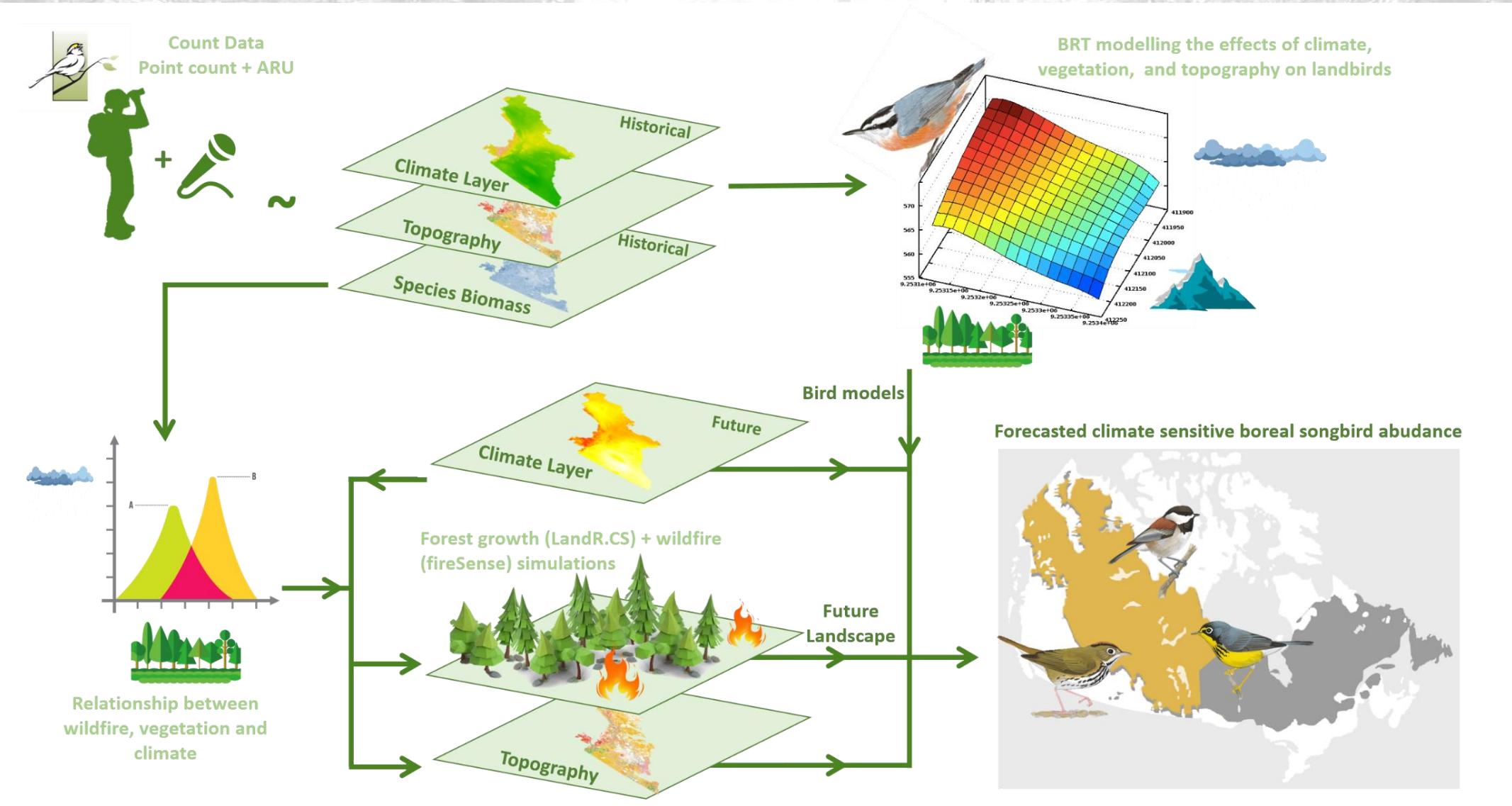
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Current Framework in more detail: birds example



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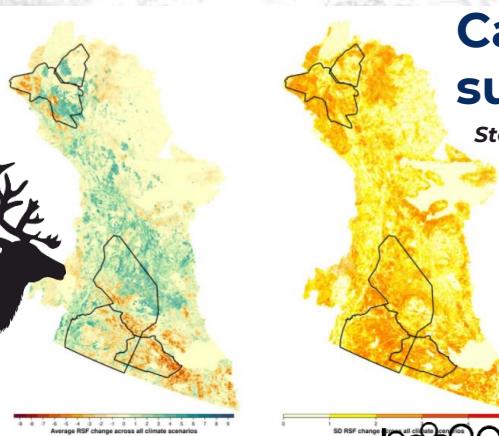
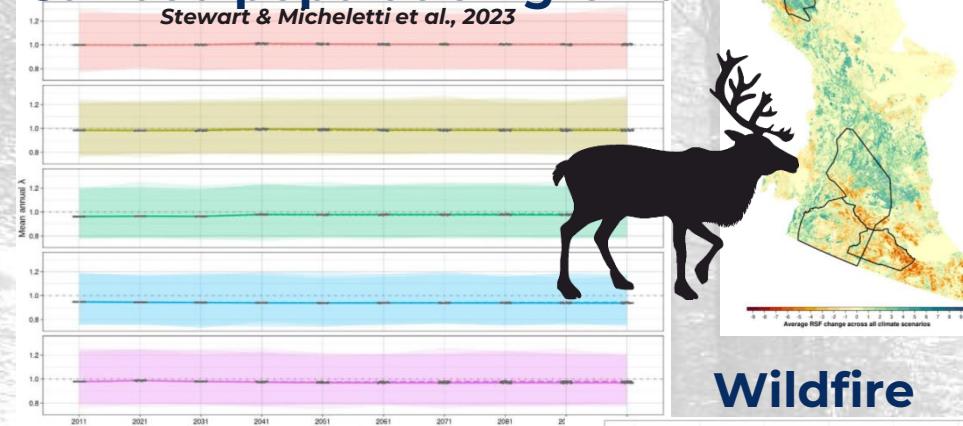
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Some results

Caribou population growth

Stewart & Micheletti et al., 2023

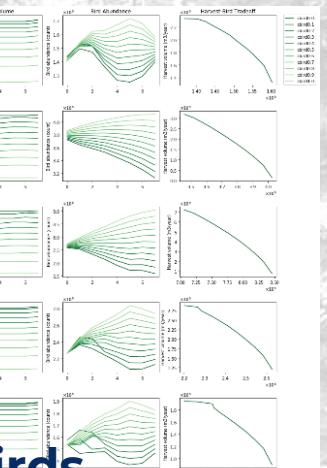


Caribou habitat suitability

Stewart & Micheletti et al., 2023

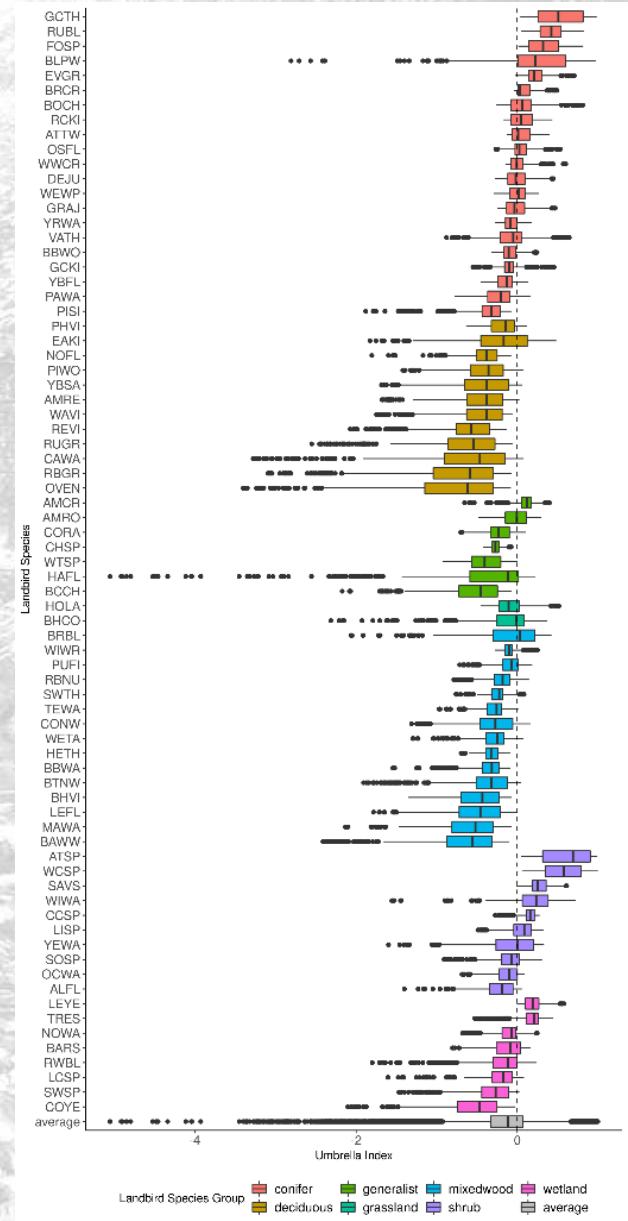
Forestry and birds

Paradis et al., in prep



Caribou umbrella function for birds

Micheletti et al., 2023



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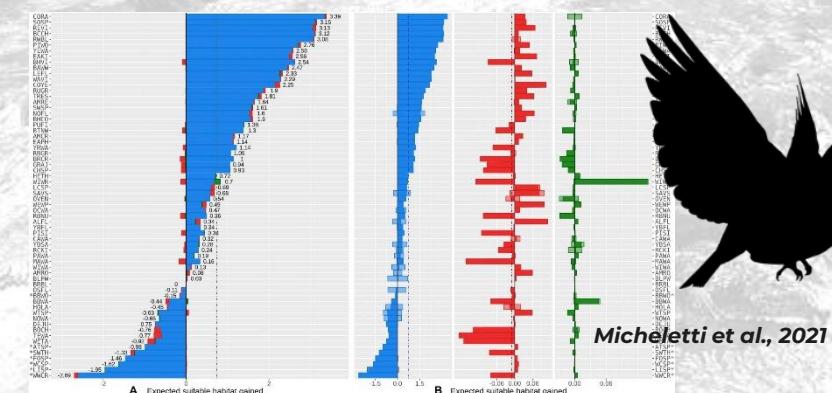
Hands-on

Vegetation

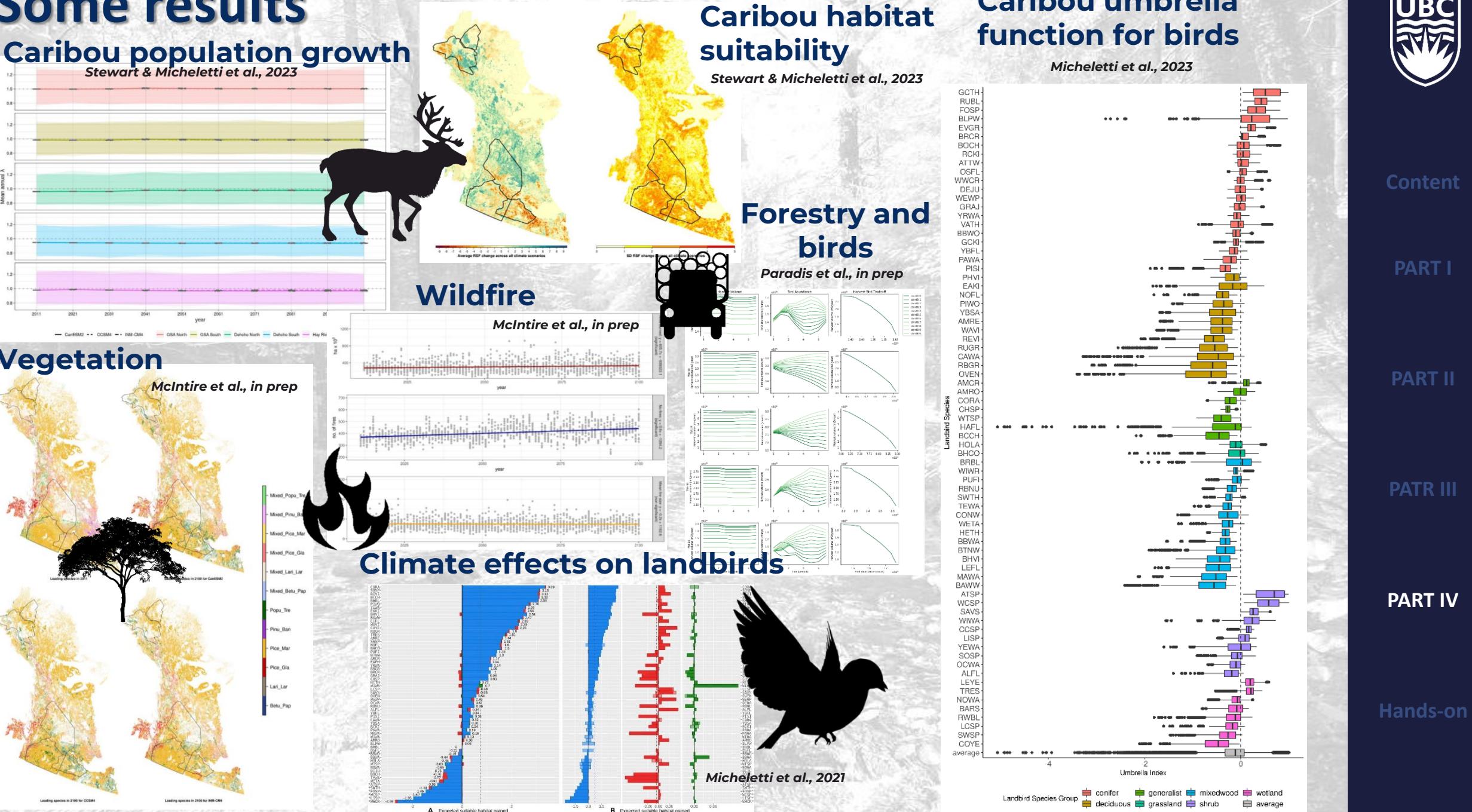
McIntire et al., in prep



Climate effects on landbirds



Micheletti et al., 2021





OPEN ACCESS

Edited by:

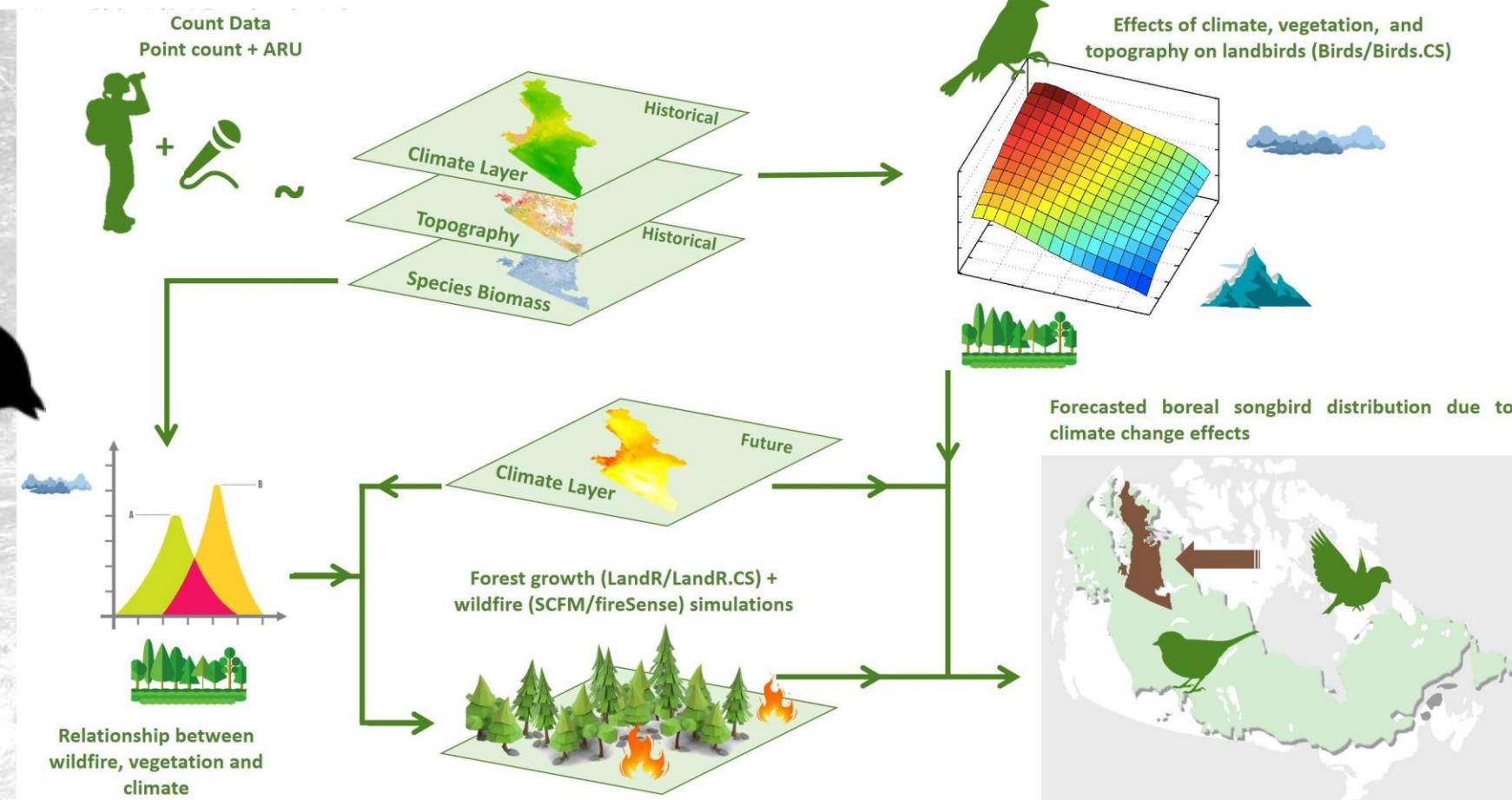
Daniel de Paiva Silva,
Goiânia Federal Institute (IFGOIANO),
Brazil

Reviewed by:

Miguel Ángelo Marini,
University of Brasília, Brazil
Alejandra Morán-Ordóñez,
Ecological and Forestry Applications
Research Center (CREAF), Spain*Correspondence:
Tatiane Micheletti
tati.micheletti@gmail.com

Assessing Pathways of Climate Change Effects in SpaDES: An Application to Boreal Landbirds of Northwest Territories Canada

Tatiane Micheletti^{1*†}, Frances E. C. Stewart^{2,3†}, Steven G. Cumming^{4†}, Samuel Haché^{5†}, Diana Stralberg^{6,7†}, Junior A. Tremblay^{4,8†}, Ceres Barros^{1†}, Ian M. S. Eddy^{2†}, Alex M. Chubaty^{9†}, Mathieu Leblond^{10†}, Rhiannon F. Pankratz^{5†}, C. L. Mahon^{11,12†}, Steven L. Van Wilgenburg^{13†}, Erin M. Bayne^{12†}, Fiona Schmiegelow^{6,14†} and Eliot J. B. McIntire^{1,2†}



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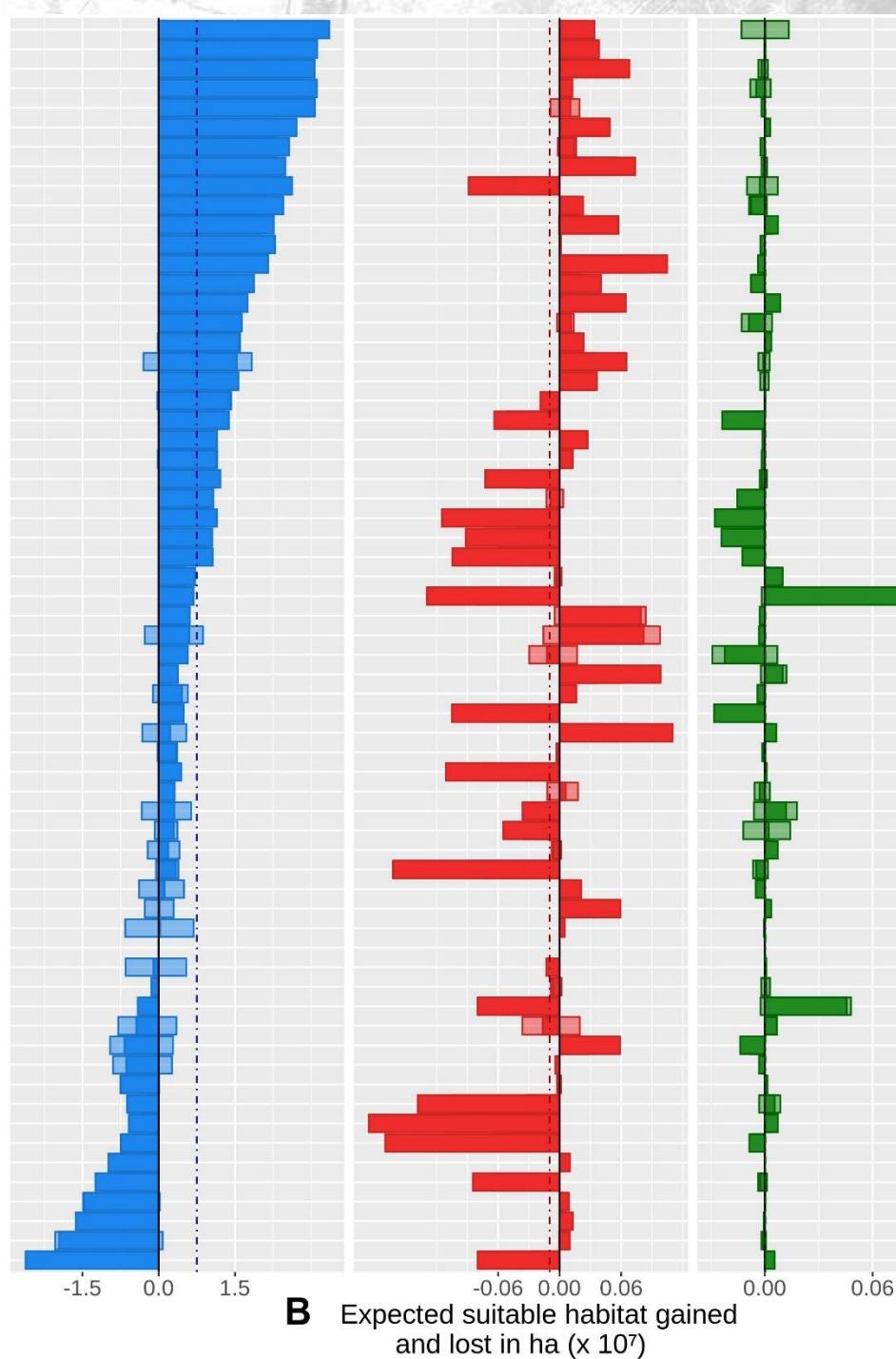
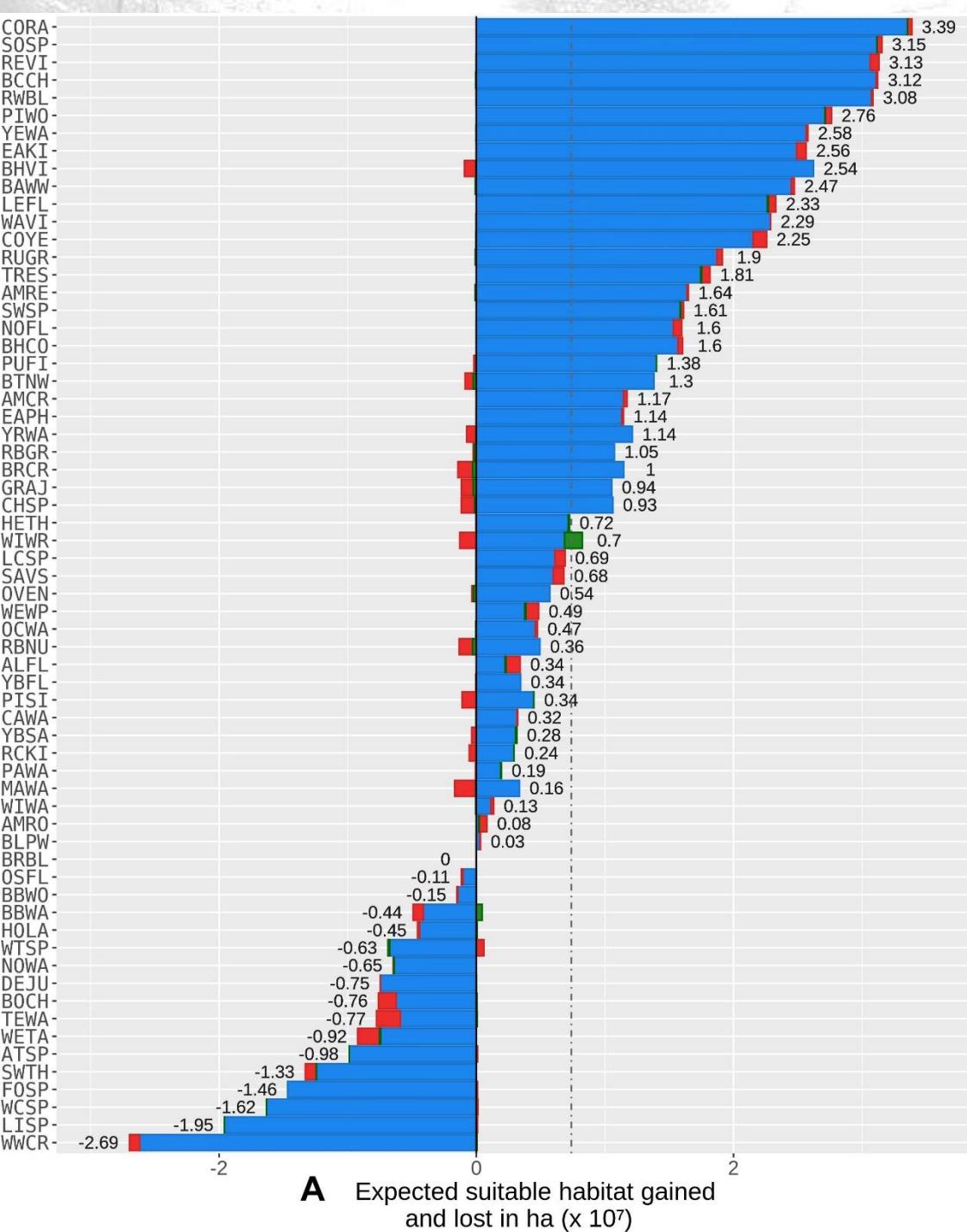
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CORA
SOSP
REVI
BCCH
RWBL
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EAKI
BHVI
BAWW
LEFL
WAVI
COYE
RUGR
TRES
AMRE
SWSP
NOFL
BHCO
PUFI
BTNW
AMCR
EAPH
YRWA
RBGR
BRCR
GRAJ
CHSP
HETH
WIWR
LCSP
SAVS
OVEN
WEWP
OCWA
RBNU
ALFL
YBFL
PISI
CAWA
YBSA
RCKI
PAWA
MAWA
WIWA
AMRO
BLPW
BRBL
OSFL
BBWO
BBWA
HOLA
WTSP
NOWA
DEJU
BOCH
TEWA
WETA
ATSP
SWTH
FOSP
WCSP
LISP
WWCR*

Conclusions

- ♠ Direct climate effects were approximately two orders of magnitude more important in explaining predicted changes in landbird occupancy than the indirect pathways.
 - actions directed at indirect pathways such as wildfire suppression or forest management may not be enough to effectively mitigate landbird species distributional changes under climate change.
- ♠ Effects of climate will not necessarily impose important range contractions to most species we studied, as previously proposed.

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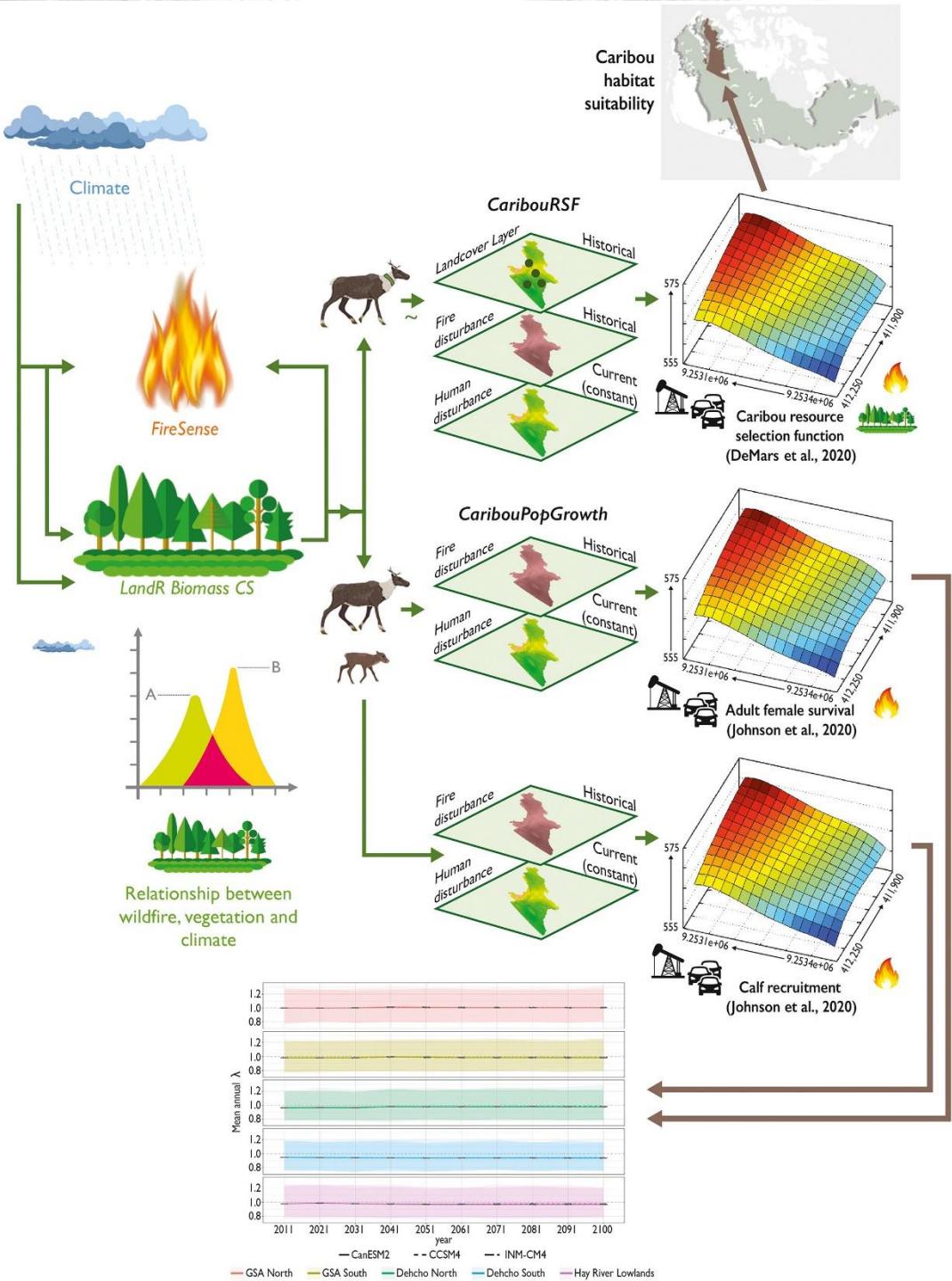
Climate-informed forecasts reveal dramatic local habitat shifts and population uncertainty for northern boreal caribou

Frances E. C. Stewart Tatiane Micheletti, Steven G. Cumming, Ceres Barros, Alex M. Chubaty, Amanda L. Dookie, Isabelle Duclos, Ian Eddy, Samuel Haché, James Hodson ... See all authors

First published: 08 February 2023 | <https://doi.org/10.1002/eap.2816>

Handling Editor: Karen E. Hodges

Frances E. C. Stewart and Tatiane Micheletti share first authorship.



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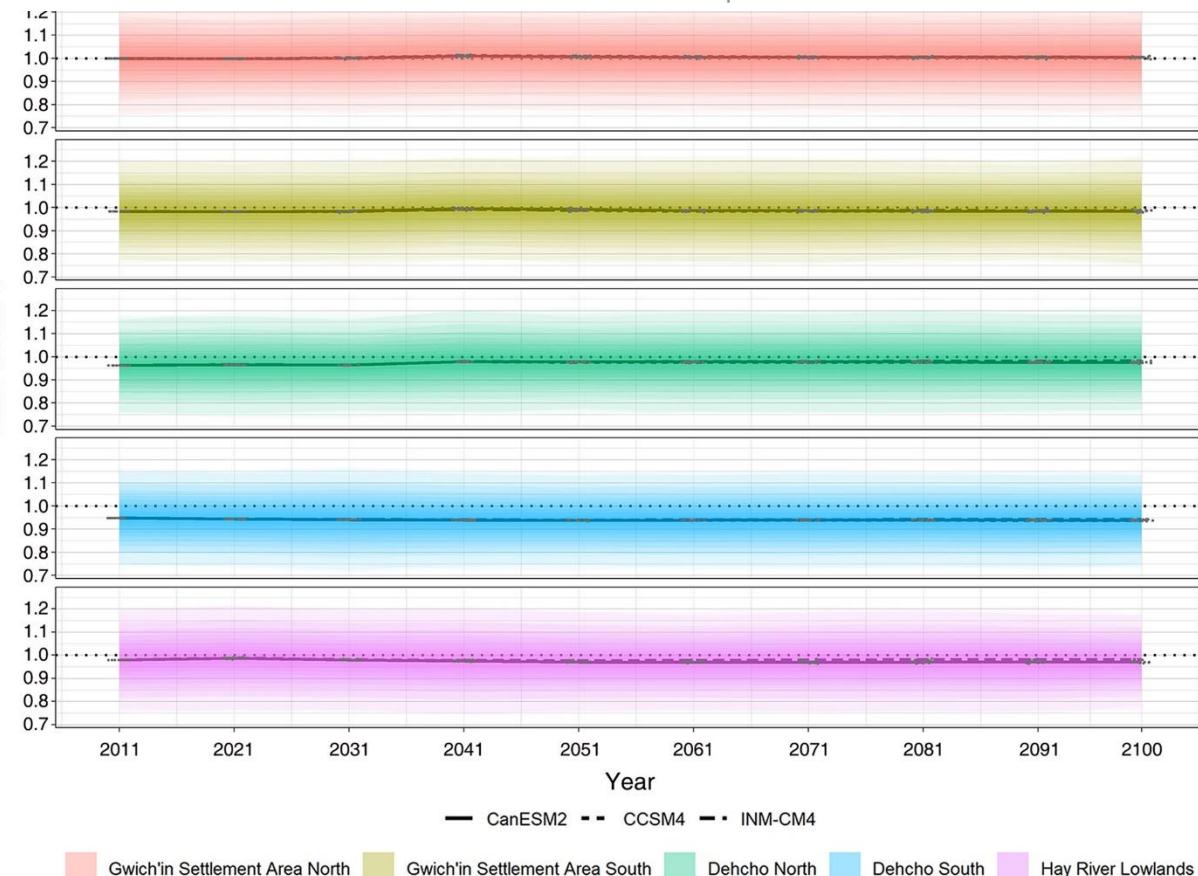
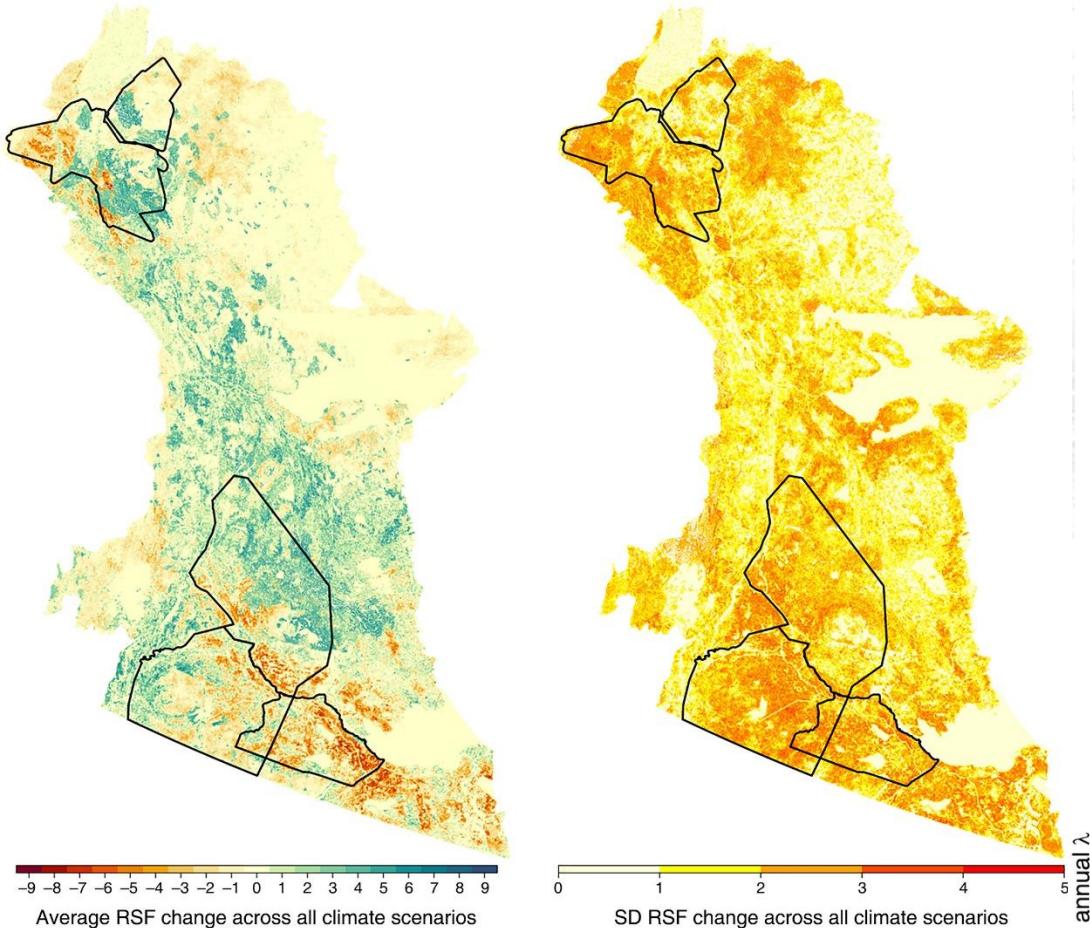
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WHERE WILL NORTHERN BOREAL CARIBOU LIVE AS THE CLIMATE CHANGES?

Stewart, Micheletti, et al. 2023. doi: <https://doi.org/10.1002/eap.2816> Contact: fstewart@wlu.ca



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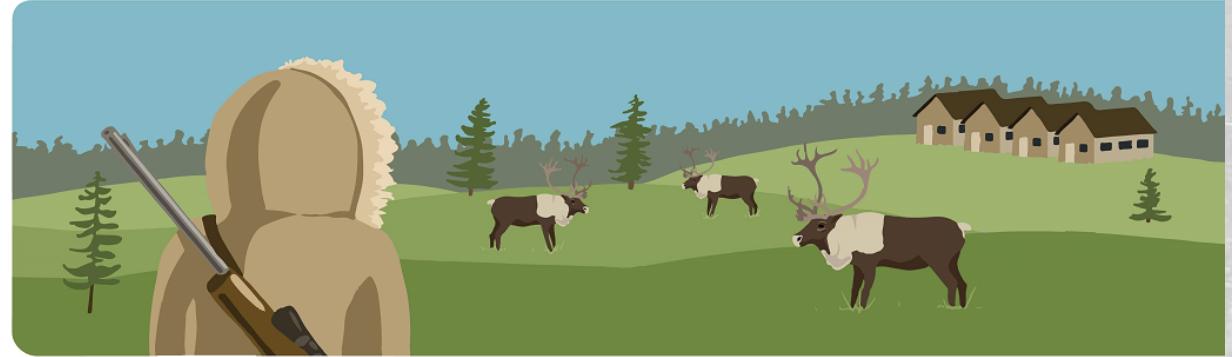
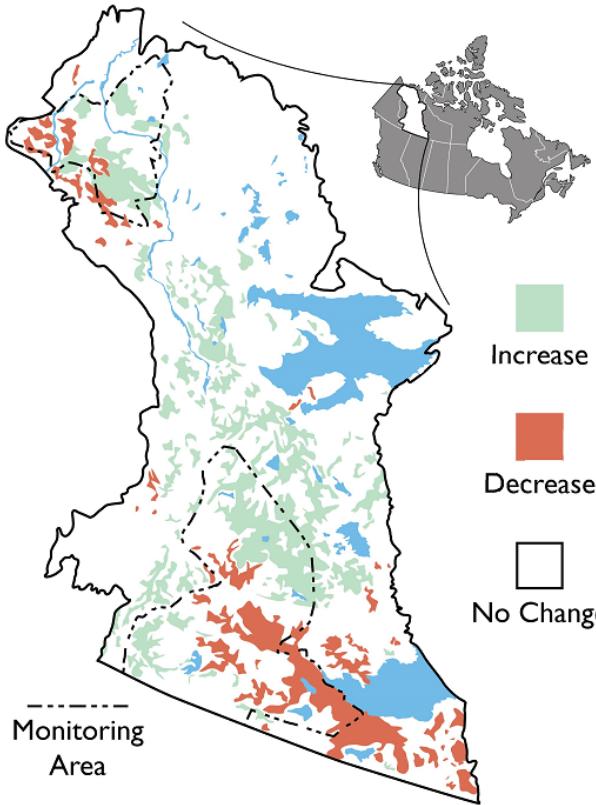
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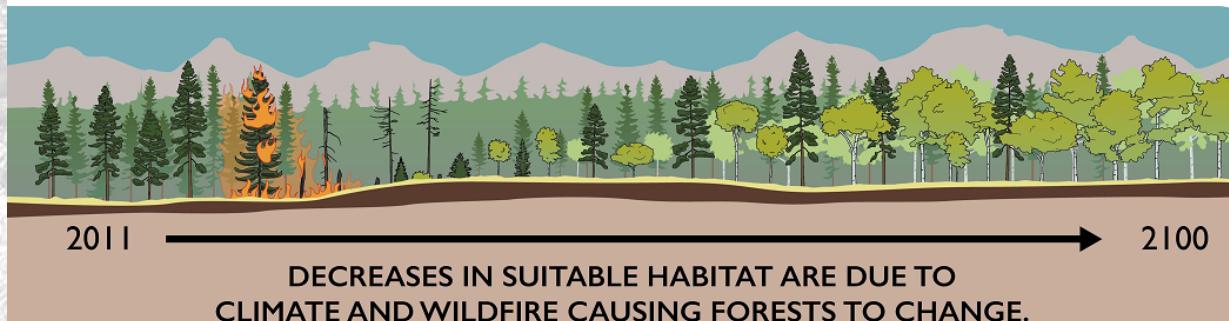
Hands-on

PREDICTED CHANGE IN SUITABLE HABITAT



WE FOUND

- Boreal caribou habitat will shift north, but there are areas in the southwest NWT that will become more suitable.
- Caribou populations will continue on their current trajectories - some will remain stable, and some will continue to decline.
- Protecting and restoring northern boreal caribou habitat despite climate uncertainty is important for many regions and people.



DECREASES IN SUITABLE HABITAT ARE DUE TO
CLIMATE AND WILDFIRE CAUSING FORESTS TO CHANGE.



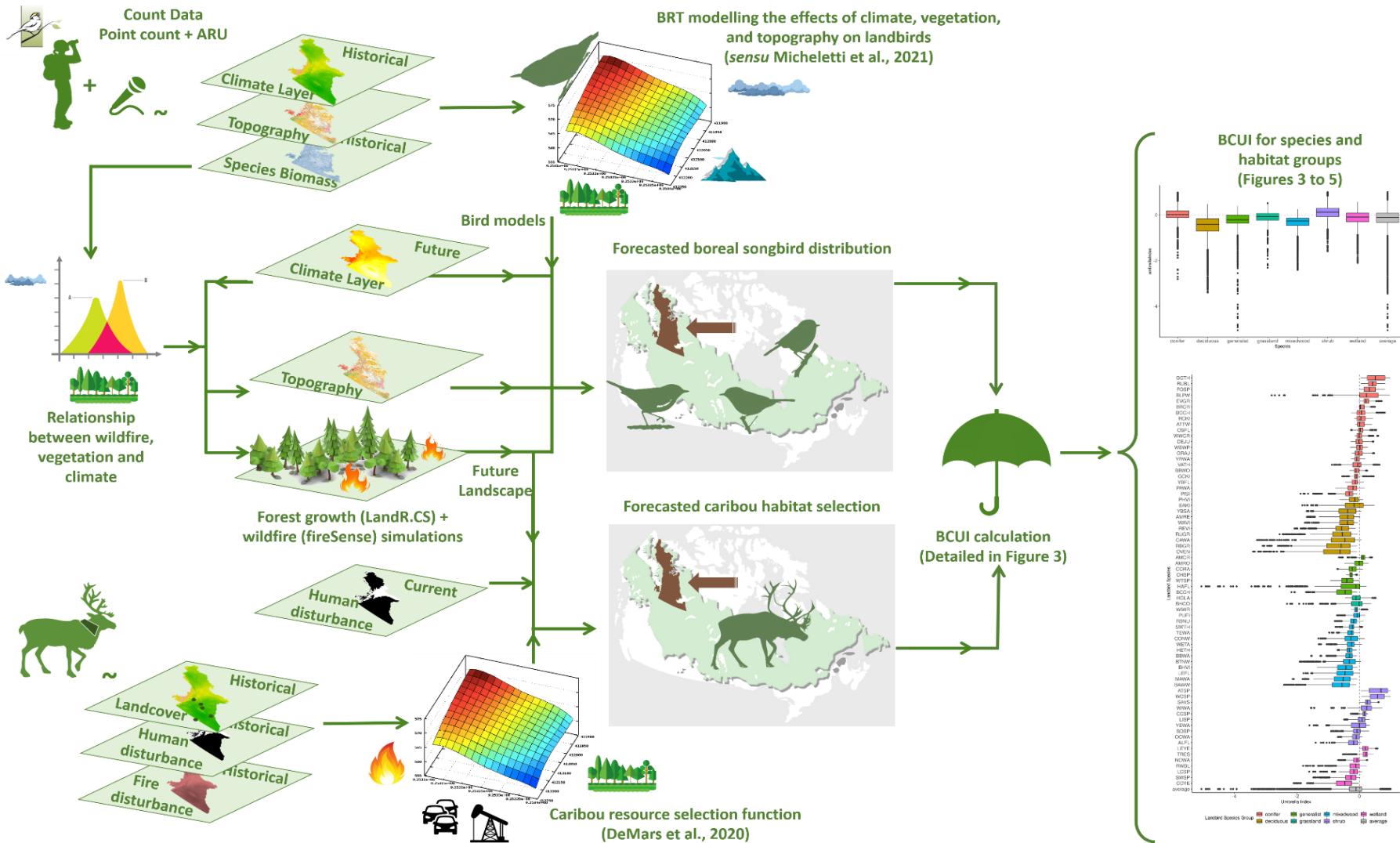
- We combined models to forecast where and when caribou habitat and populations will change in the Northwest Territories.
- We quantified how certain these changes are with climate change.

CONTRIBUTED PAPER | Open Access | CC BY

Will this umbrella leak? A caribou umbrella index for boreal landbird conservation

Tatiane Micheletti Samuel Haché, Diana Stralberg, Frances E. C. Stewart, Alex M. Chubaty, Ceres Barros, Erin M. Bayne, Steven G. Cumming, Teegan D. S. Docherty ... See all authors

First published: 10 March 2023 | <https://doi.org/10.1111/csp2.12908> | Citations: 1



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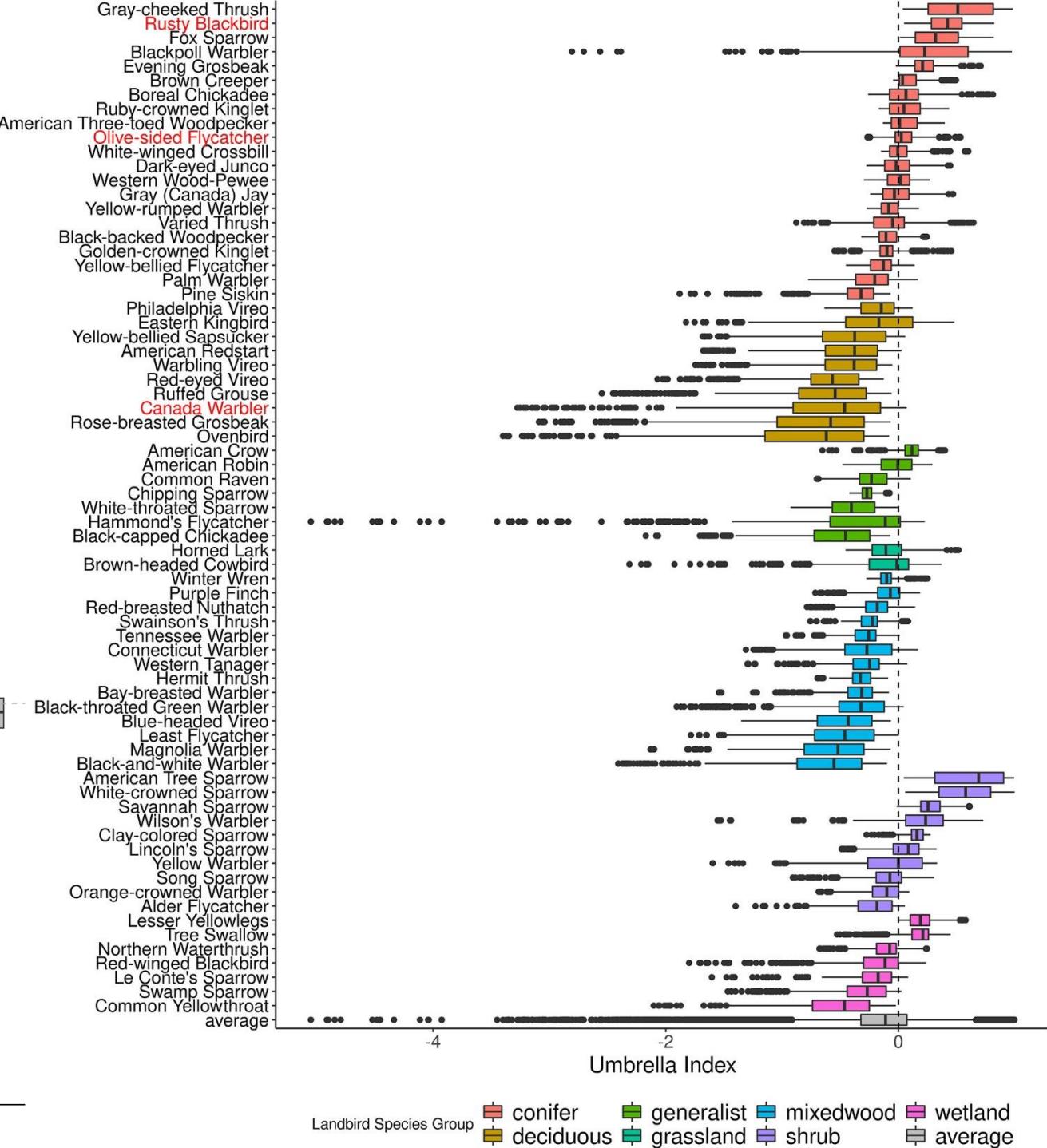
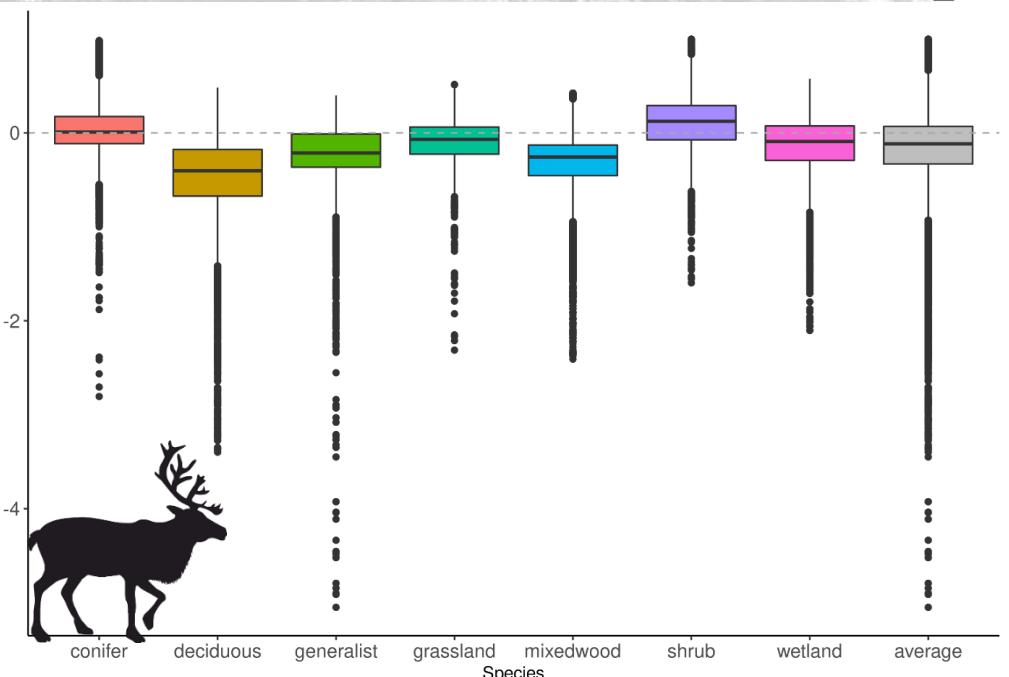
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Will this umbrella leak? A caribou umbrella index for boreal landbird conservation

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First published: 10 March 2023 | <https://doi.org/10.1111/csp2.12908> | Citations: 1



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BOREAL CARIBOU: A LEAKY UMBRELLA SPECIES FOR FOREST BIRD CONSERVATION

Adapted from Micheletti et al 2023, *Conservation Science & Practice*. <https://doi.org/10.1111/csp.2.12908>

- A species that is wide ranging and the focus of conservation is often considered an “umbrella” species, covering the habitat needs of many others.
- We tested how effective an umbrella Boreal caribou are for 71 songbird species in the Northwest Territories.
- The caribou umbrella would be somewhat effective at covering only 20% of the bird species, leaving 80% poorly covered (no better than random protection).
- Shrub-associated bird species would be the only highly protected group.
- Boreal Caribou leaves many species out in the rain when used as an umbrella species for songbird management.



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Hands-on

Are birds a good umbrella for turtles in a changing world?

Are birds a good umbrella for turtles in a changing world?



- 1. Form your groups:** You should already have divided yourselves in 3 groups: **TREE**, **BIRDS** and **TURTLE**.
- 2. Get your computers (ONLY ONE PER GROUP!):** You should already have installed the software needed: Excel, R and RStudio, and also the libraries requested in advance.
- 3. Exercise folder:** You should also already have downloaded the exercise folder (named PredictiveEcologyInAction)
- 4. Open RStudio and the project files from the exercise folder:** The name of the file is predictiveEcologyInAction.Rproj
- 5. Open the .Rmd file that belongs to your group:** For example, landscapeSimulation.Rmd, birdSimulation.Rmd or turtleSimulation.Rmd
- 6. Read the Instructions:** I will come to each group and make sure you understand the game
- 7. Duration:** We will have about 1 to 2 hours to finish the game so we can integrate all the work from the three groups.

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