Marine Ecological Modelling Global Climate Change

Principles of Ecological Niche Modelling

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2023, Centre of Marine Sciences, University of Algarve

Ecological Niche Modelling**

Process of using **computer algorithms to estimate and predict** the **relationship between the distribution of biodiversity and the environmental conditions**.

Provides insights about **species environmental tolerances and habitat preferences**, and allows **making spatial predictions** of geographical distributions across space and time.

** also known as environmental niche modelling, species distribution modelling, habitat distribution modelling, …

Main approaches in ENM

Mechanistic modelling

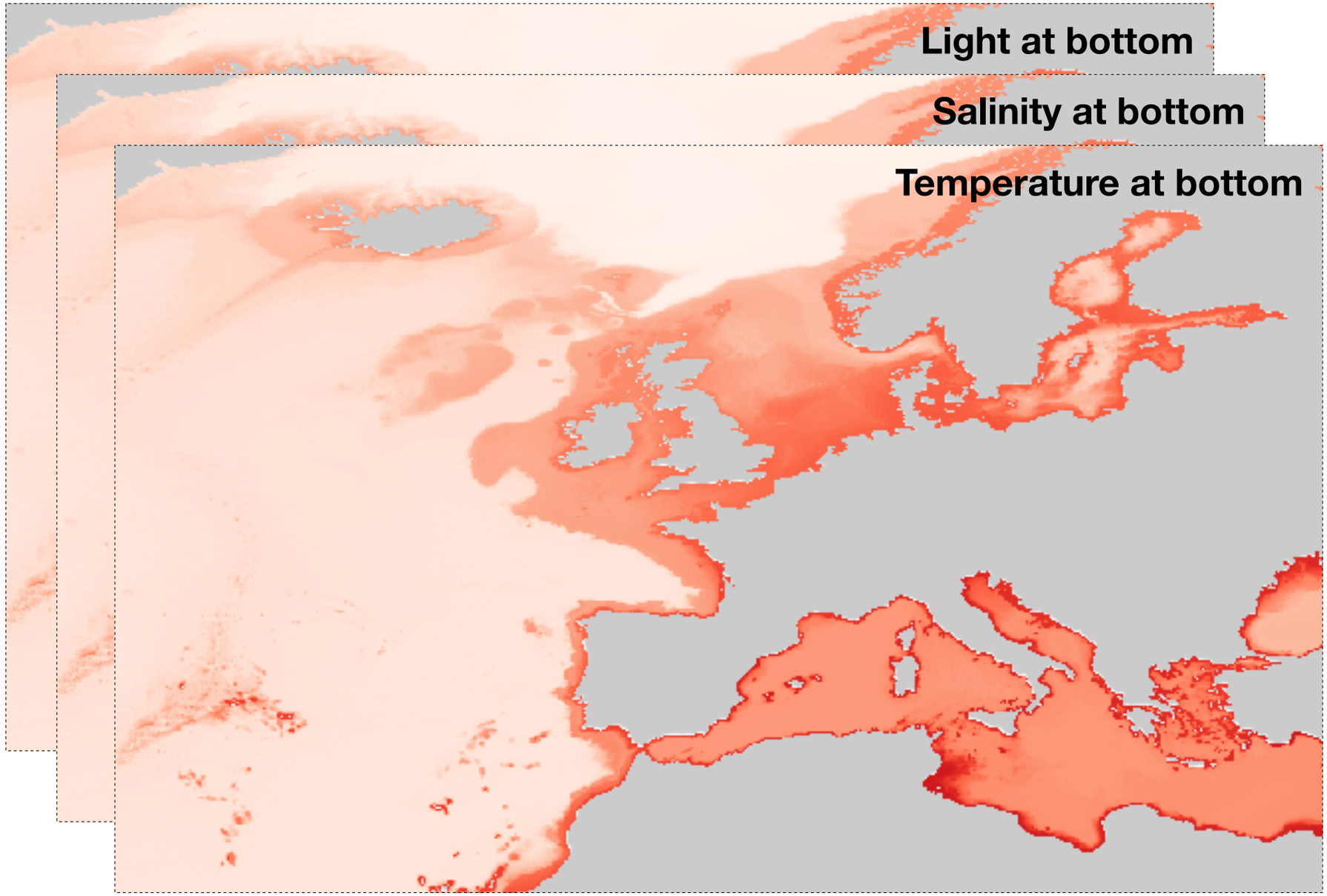
Uses **information about the physiological response of species to environmental conditions.**

(e.g., needs empirical data on the effect of temperature on species survival; not always available).

Correlative modelling

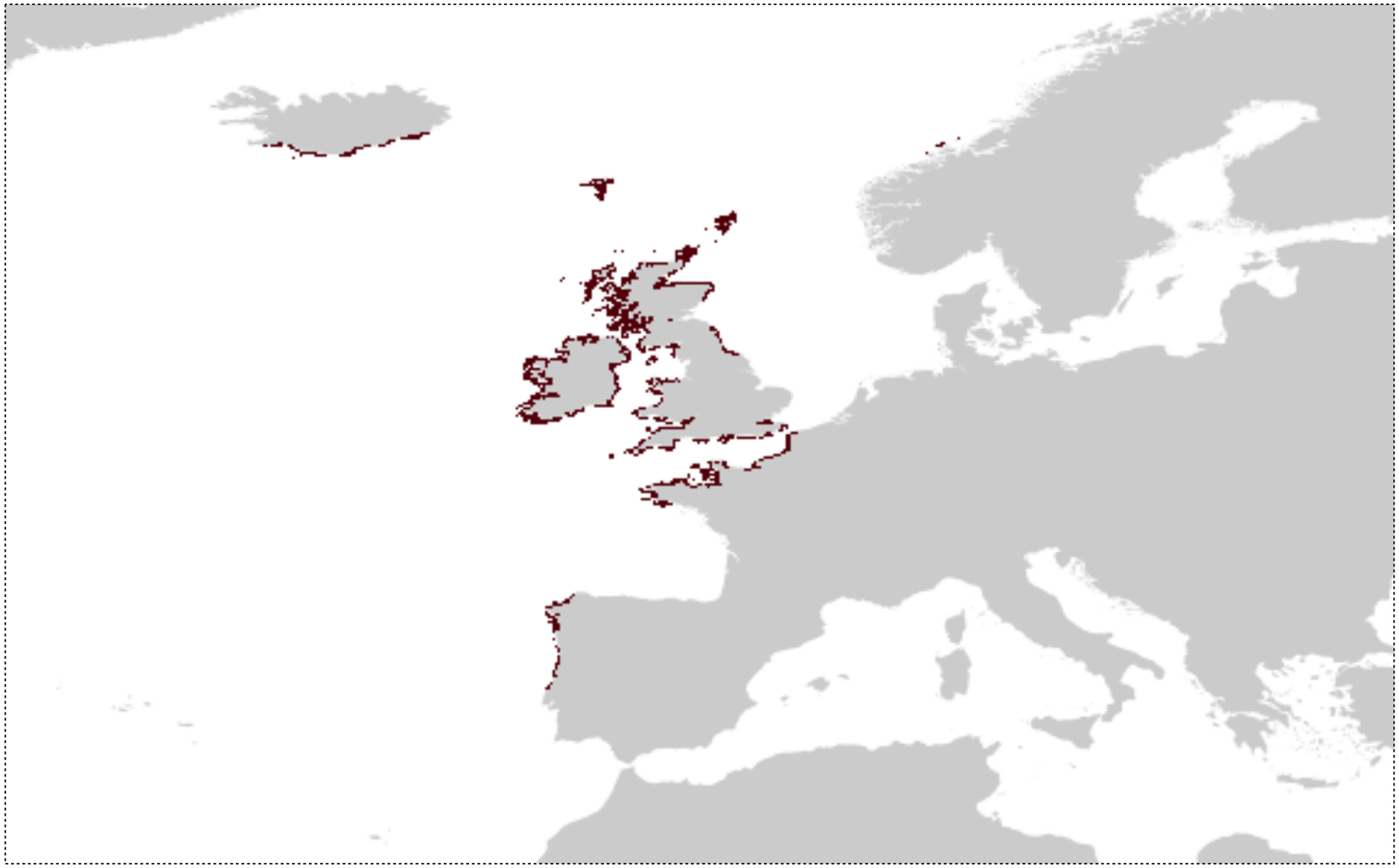
Based on the statistical **correlation between occurrence records and the environment**, under the assumption that the **distribution of a species is an indicator of its environmental requirements.**

(i.e., the fact that a species occurs is a particular place is linked to its tolerance to the conditions of such place).



Mechanistic distribution models

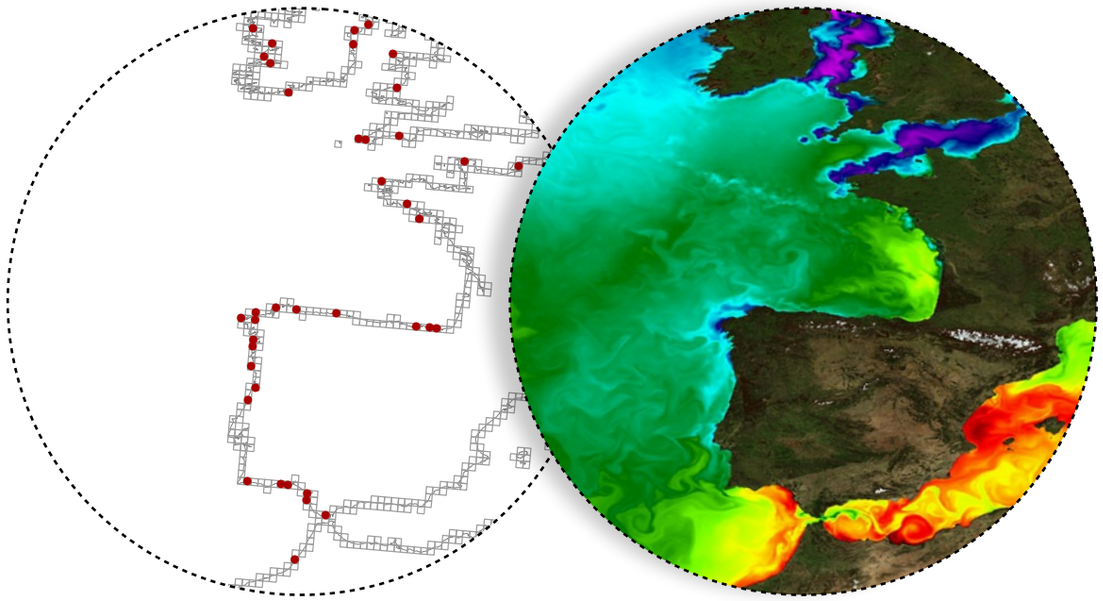
Built by **reclassifying environmental gradients with tolerance limits inferred from physiological experiments**.



Mechanistic distribution models

A straightforward approach to predict the distribution of species.

Presence = [**Light** > 5 E.m^{2}.year^{-1}] ∩ [5°C <= **Temperature** <= 20.5°C]



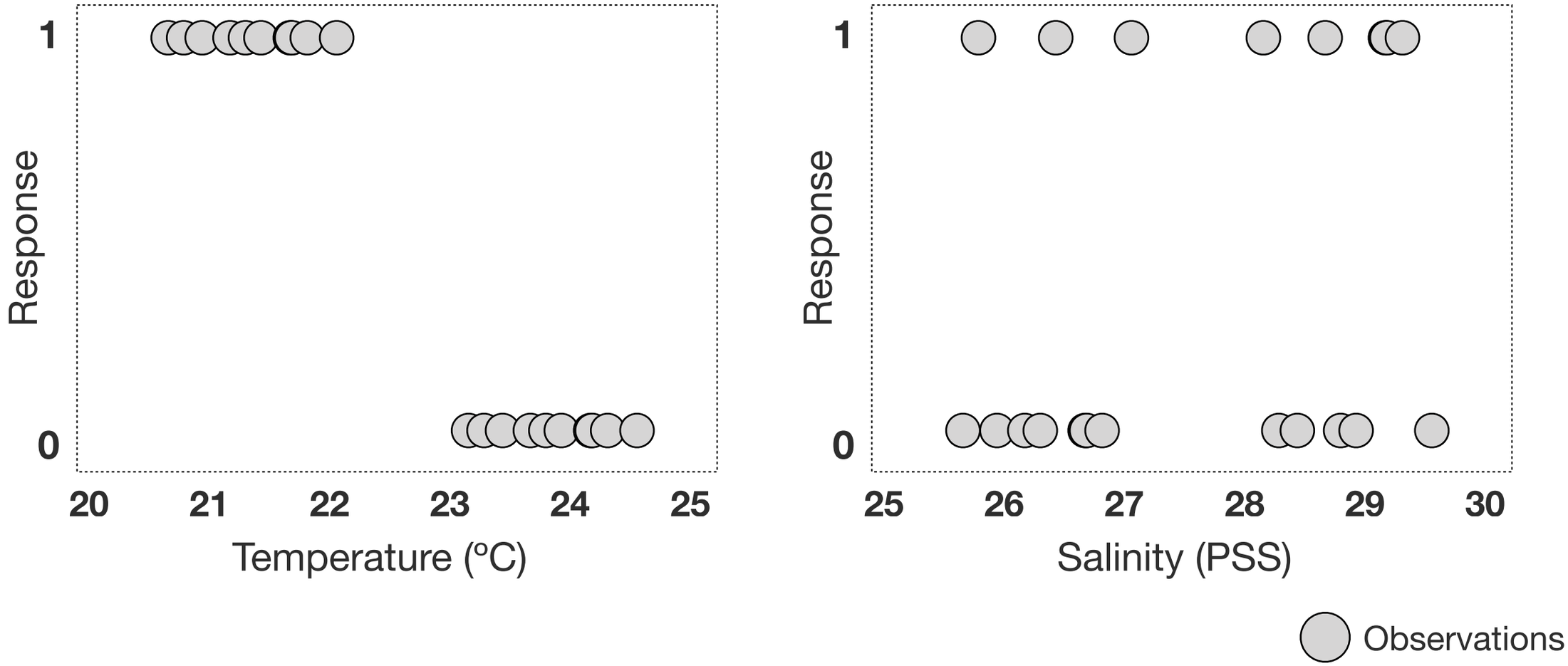
Occurrence **Environment**

Resp	TempMax	Nitrate	Salinity
1	21	3	27
1	22	2	28
1	21	3	30
1	20	3	26
1	21	2	26
1	22	2	26
0	23	1	27
0	24	0	30
0	23	0	28
0	25	1	27
0	23	0	26
0	23	0	26

Data for modelling

Correlative distribution models

Describe the **statistical relationship between distribution records and environmental conditions at those sites.** The **models should be evaluated for “ecological realism” - consistency with ecological knowledge of limiting factors** and species response curves.



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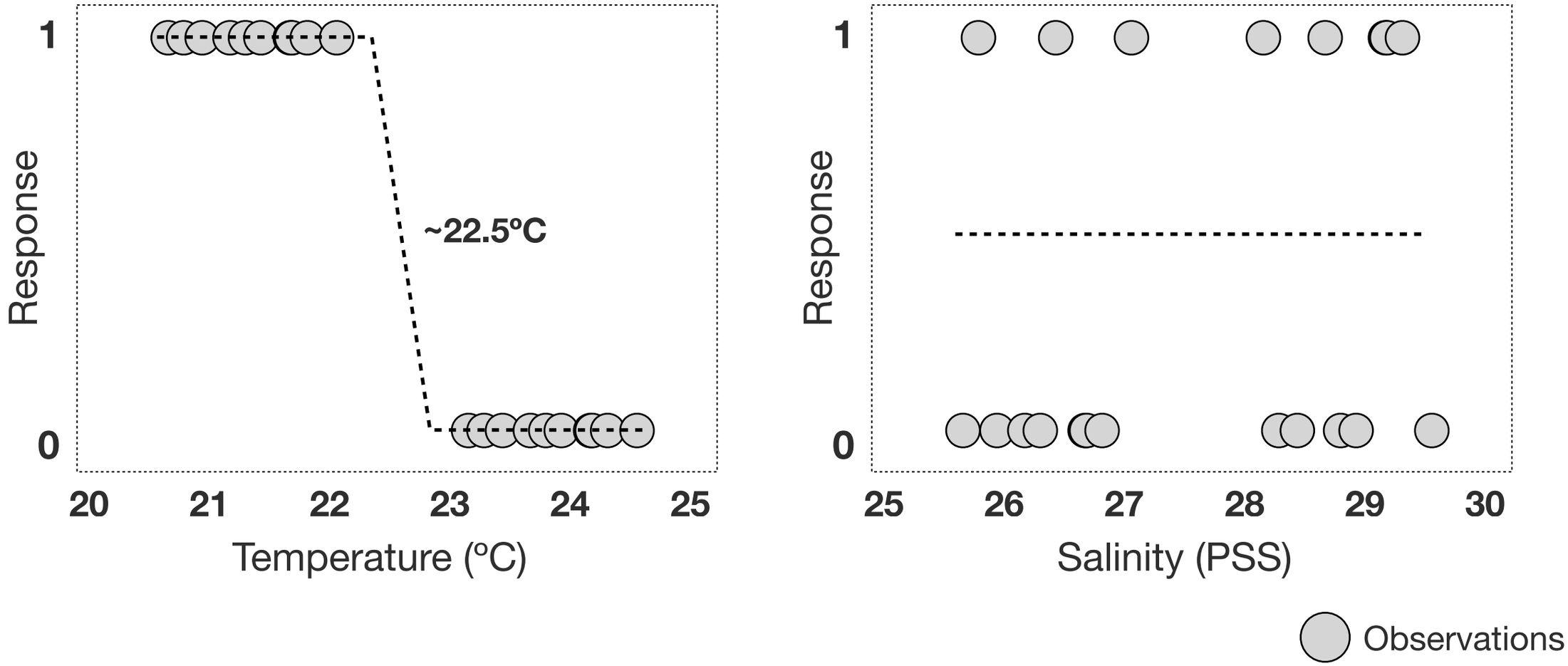

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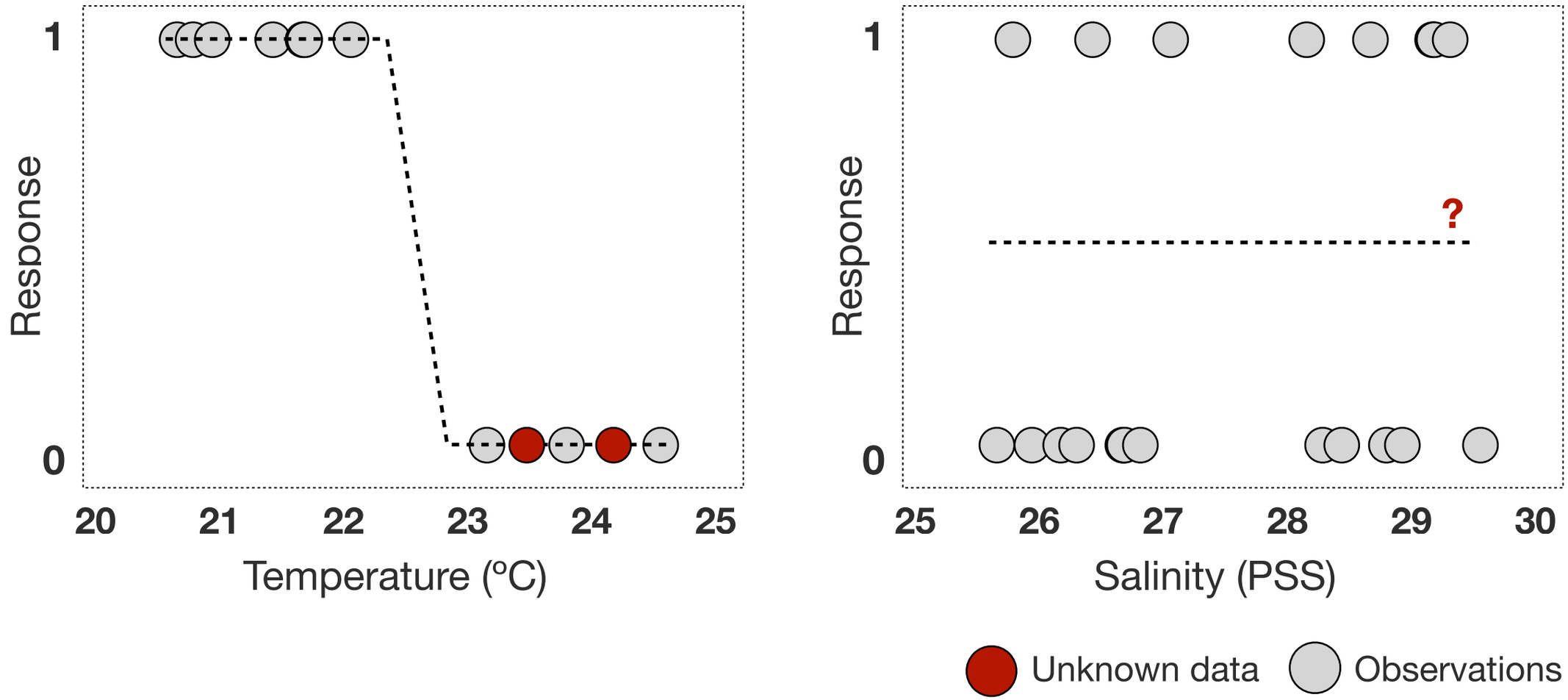
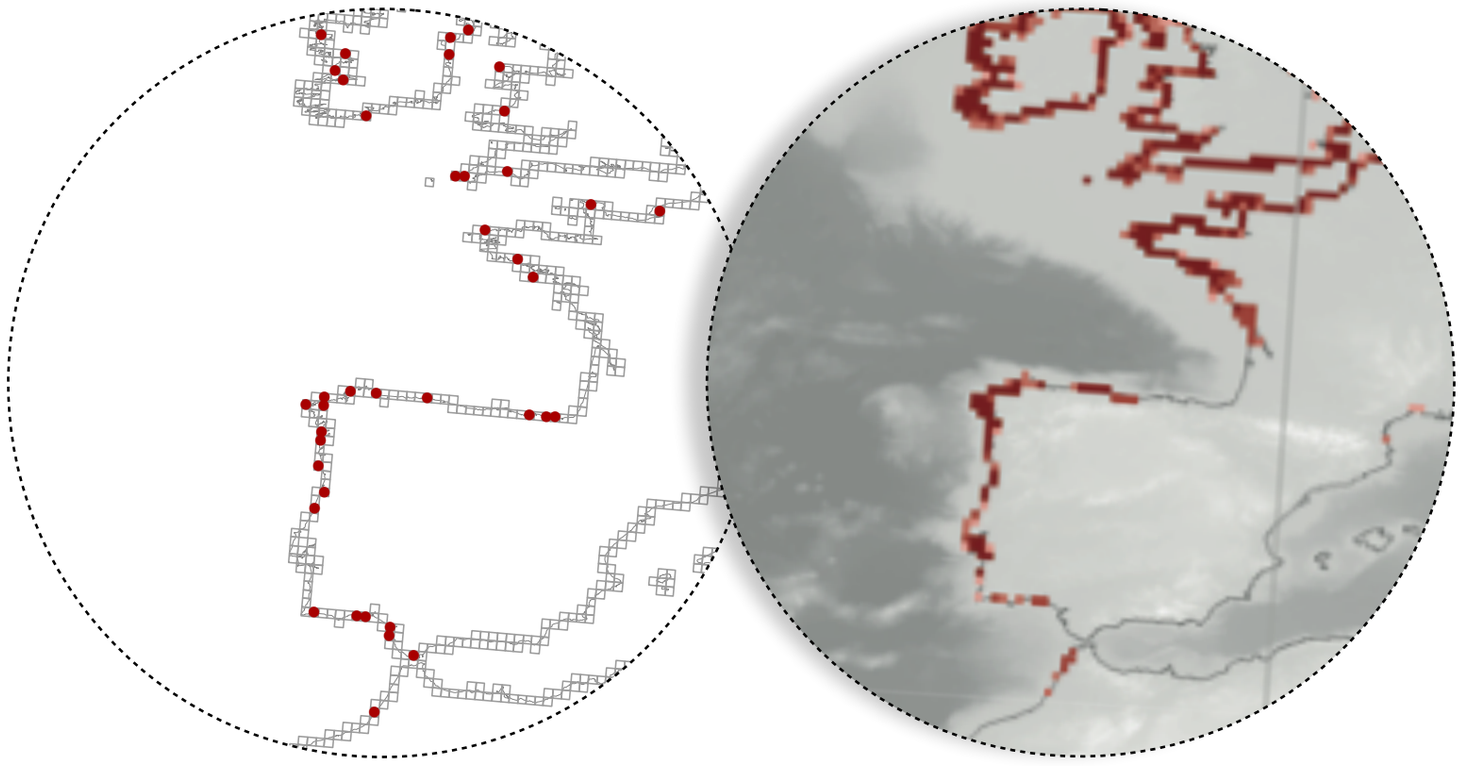


If a model can explain the relationship between distribution records and environmental variables, we can **make predictions to unknown samples (regions not surveilled)**.

e.g., Temp. = 23.5ºC or 24.5ºC, response is 0 (i.e., absence).

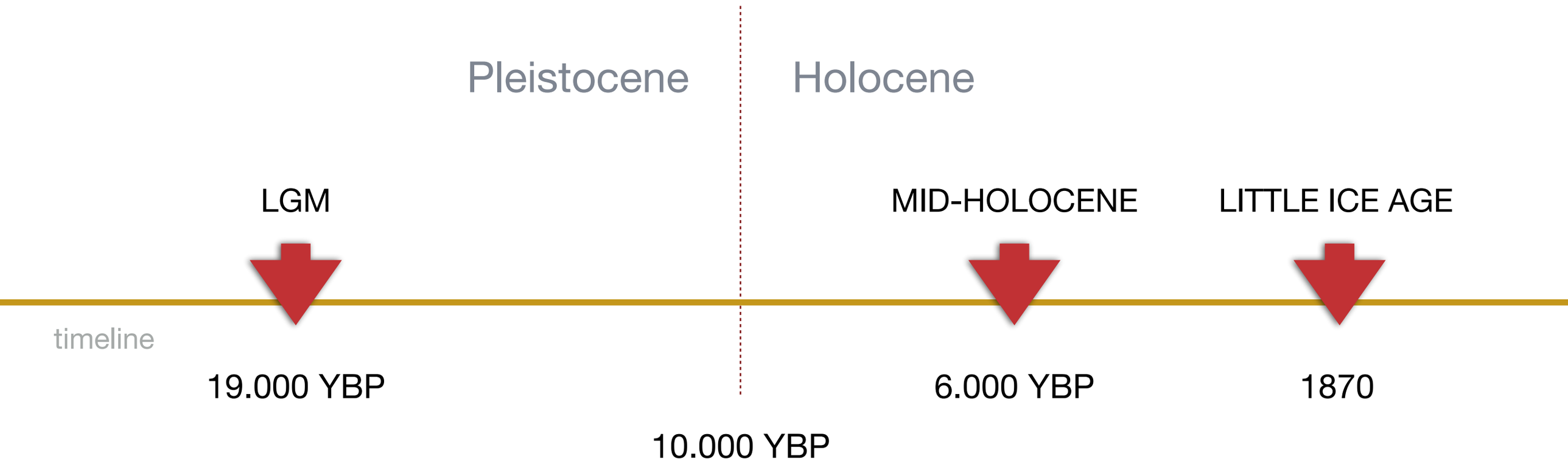


Predictive model-based interpolation

Made to **new sites within the range of values of environmental conditions sampled in the training data (data that fitted the model)**.

From **scattered records in space to continuous distribution surfaces**.

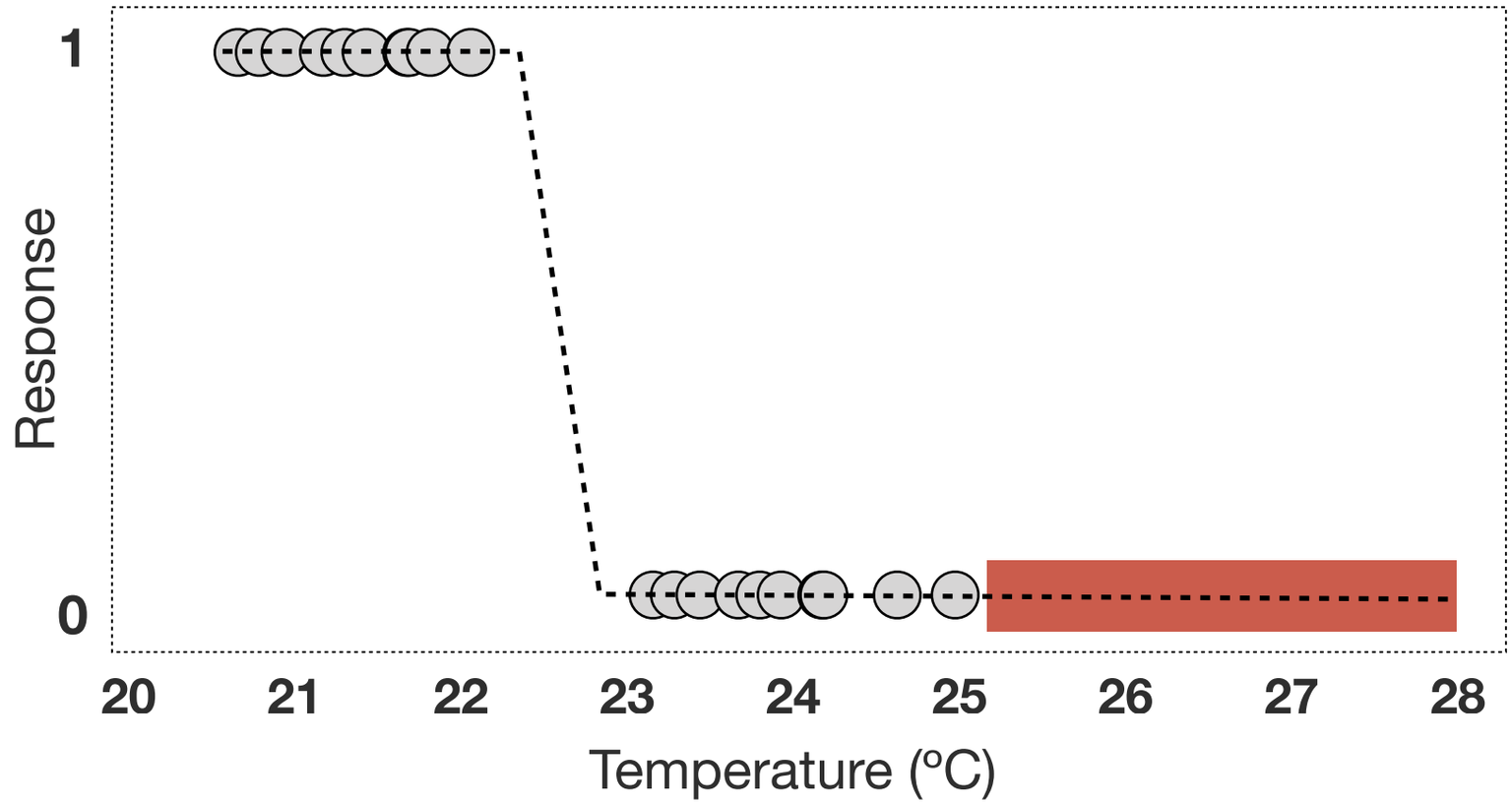
Typical **applications** include **mapping species' present distributions, important tools for ecology and conservation planning**.



Predictive model-based transferability

Made to **unsurveilled geographic or temporal domains**.

No information on the similarity between the environment of training data and the predictions (e.g., present-day vs future conditions), thus **can lead to extrapolation**.



Extrapolation refers to **predictions for environmental values** that are **outside the range of environmental values used to fit the model**.

e.g.,

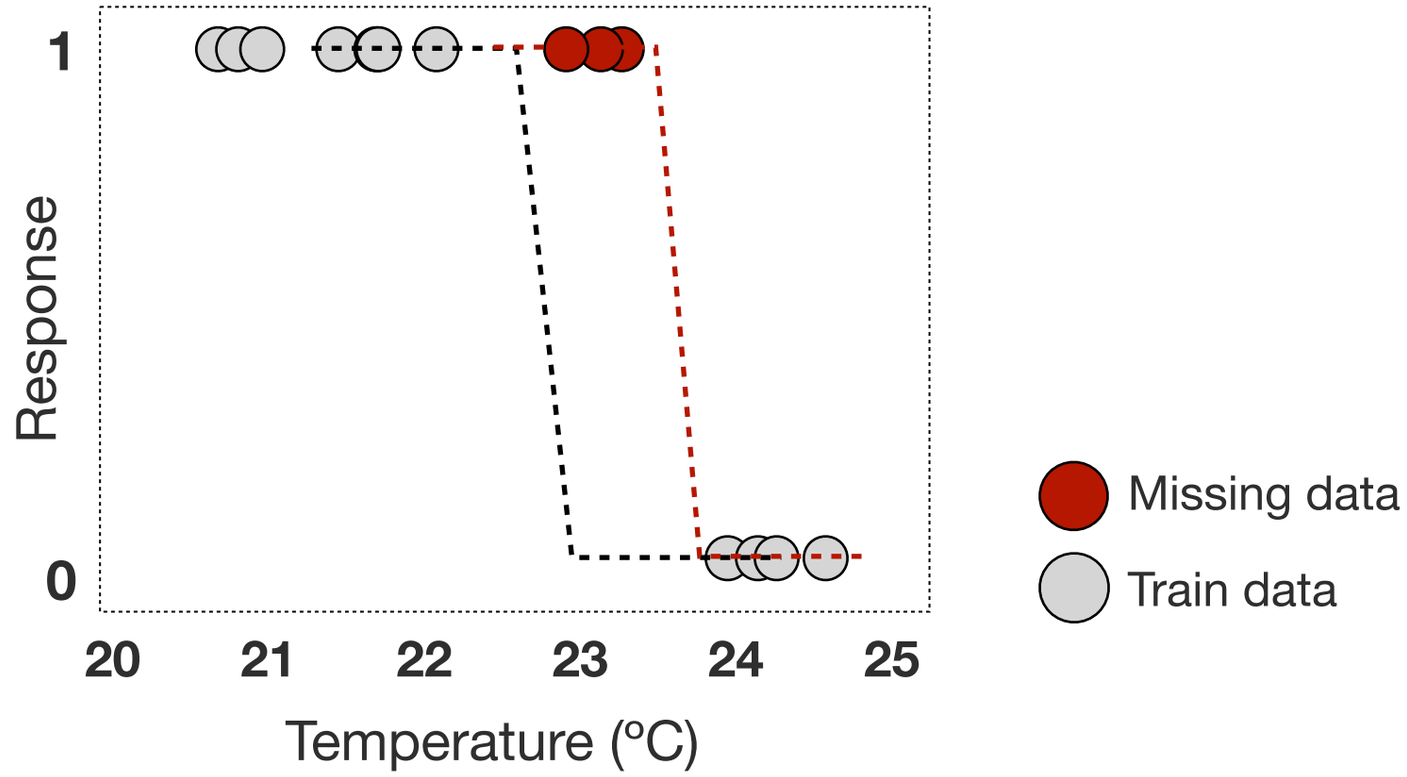
A **model used records with temperatures between 20-25ºC**.

If **predictions** are **made for temperatures > 25ºC**, then the model will extrapolate. No information exists on the probability of occurrence at > 25ºC, so the **predictions will be uncertain**.

Corrective models can identify the **niche of a species only if the records used to fit the models cover the distribution of the species**.

When mapped, it represents the **potential distribution or the habitat suitability**.

If records are insufficient, the models do not identify the fundamental niche; **the model fits only to the portion of the niche that is represented by the observed records** (truncated niche).



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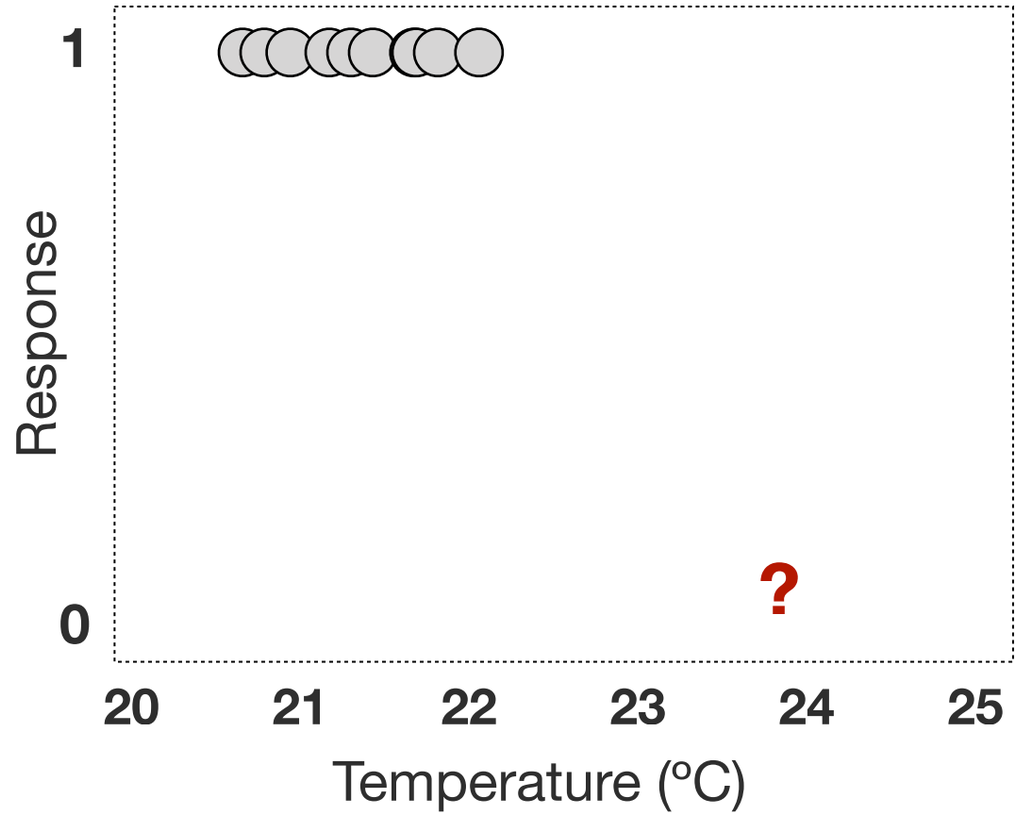
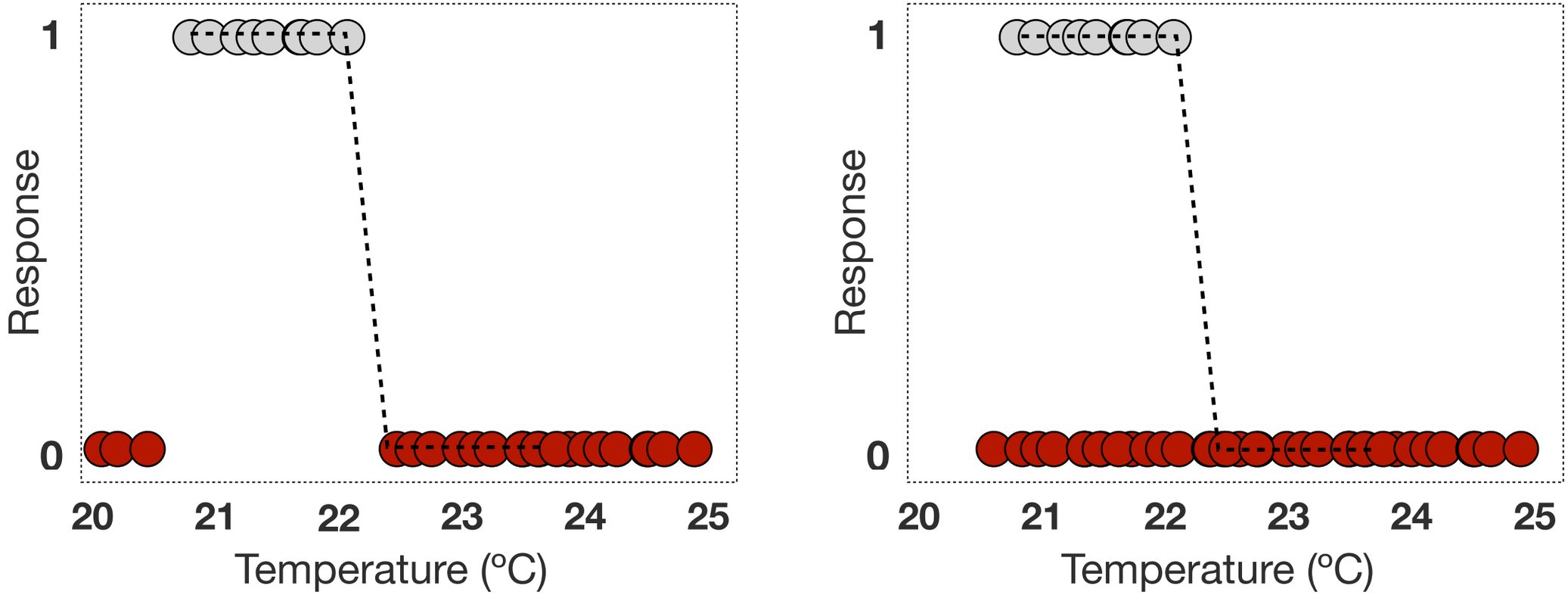


Correlative models infer the **relationship between the occurrence of biodiversity and the environment**, but **absence records are often unavailable** or unknown, leading to **presence-only datasets** and to the need of developing **presence-only models**.



Models based on ‘pseudo-absences’, generated from the **study area where occurrences do not exist**. Any regression or machine learning algorithm can be implemented (e.g., GLM and BRT).

Models based on ‘background’, generated from the entire study area. Focus on **how the environment where the species occurs relates to the environment across** the rest of **the study area** (e.g., MaxEnt).

How many absence records?

Linear models, additive models and maximum entropy models

A large number of pseudo-absences / background (e.g., 10,000);

Boosted Regression Trees models

The same number of pseudo-absences as presences records (but never less than 1,000).

Barbet-Massin et al., 2012

Which environmental predictors for modelling?

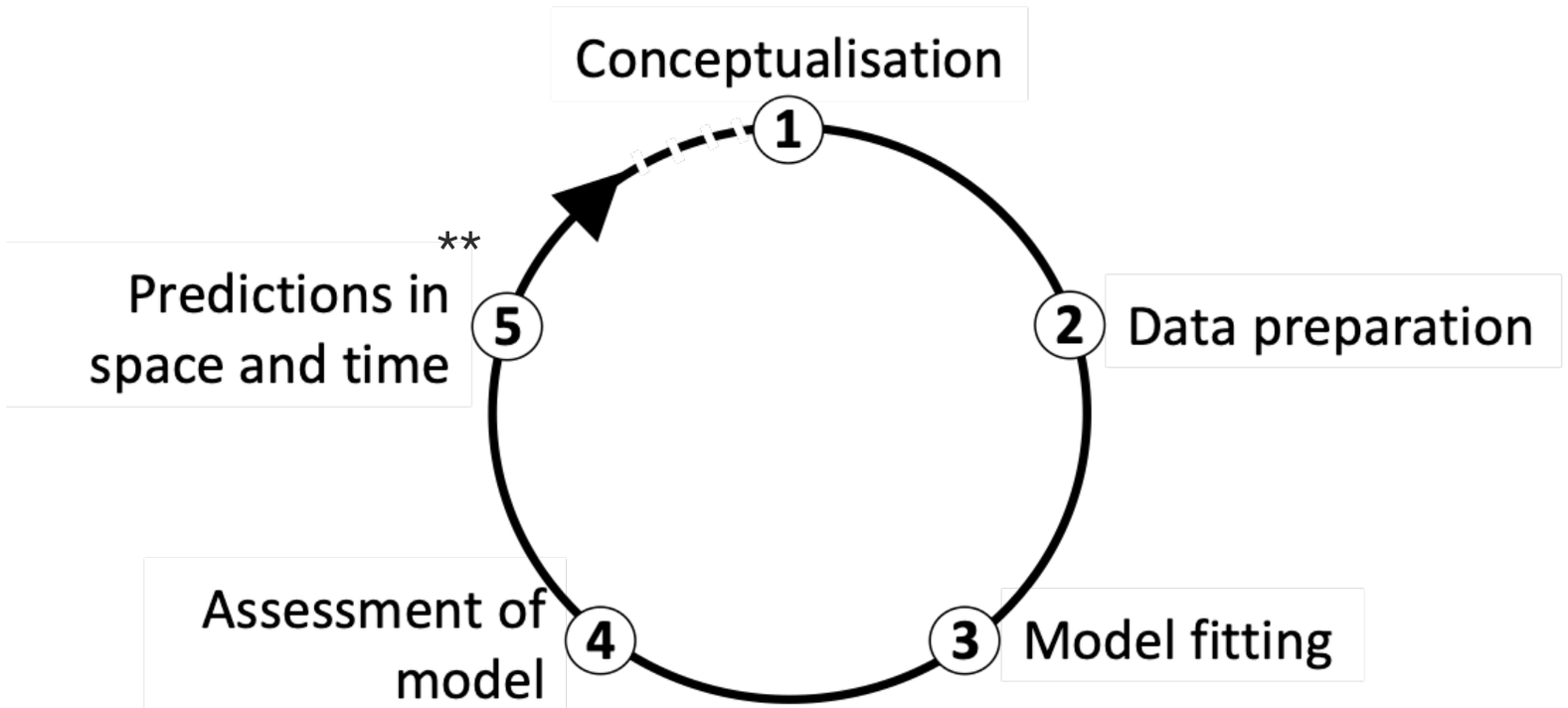
Avoid **large datasets**, an approach with stronger criticism.

Prefer **pre-selected datasets**, linked to known physiological rules**.

** the choice of predictors should be **guided by the objectives and the hypotheses raised** about the species-environment relationship.

Bouchet et al., 2019

Steps for model building



Model building is an iterative process and there is much to learn on the way (a loop rather than a straightforward approach).

You may want to revisit and improve certain steps (e.g., improve biodiversity data collection or remove surplus environmental layers).

** not always part of ENM studies; depends on the model objective.

Assumptions of ENM

Observed distributions are indicative of environmental tolerances and resource requirements of species - species occur in all suitable areas and are absent from all unsuitable areas (niche theory).

Niche space assumption : The study contains the full range of conditions that the species can inhabit.

Dispersal / demographic assumption : Factors related to dispersal, establishment, and persistence do not drive the species not to occupy an environmentally suitable area.

Biotic assumption : Biotic interactions do not drive the species not to occupy an environmentally suitable area.