Centro Interdisciplinario de Ciencias Marinas

Influence of environmental variability on the distribution of silky sharks (*Carcharhinus falciformis*) caught in the Eastern Pacific Ocean

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Introduction

Eastearn Pacific Ocean
EPO

Bigeye tuna
(*Thunnus obesus*)

Bluefin tuna
(*Thunnus orientalis*)

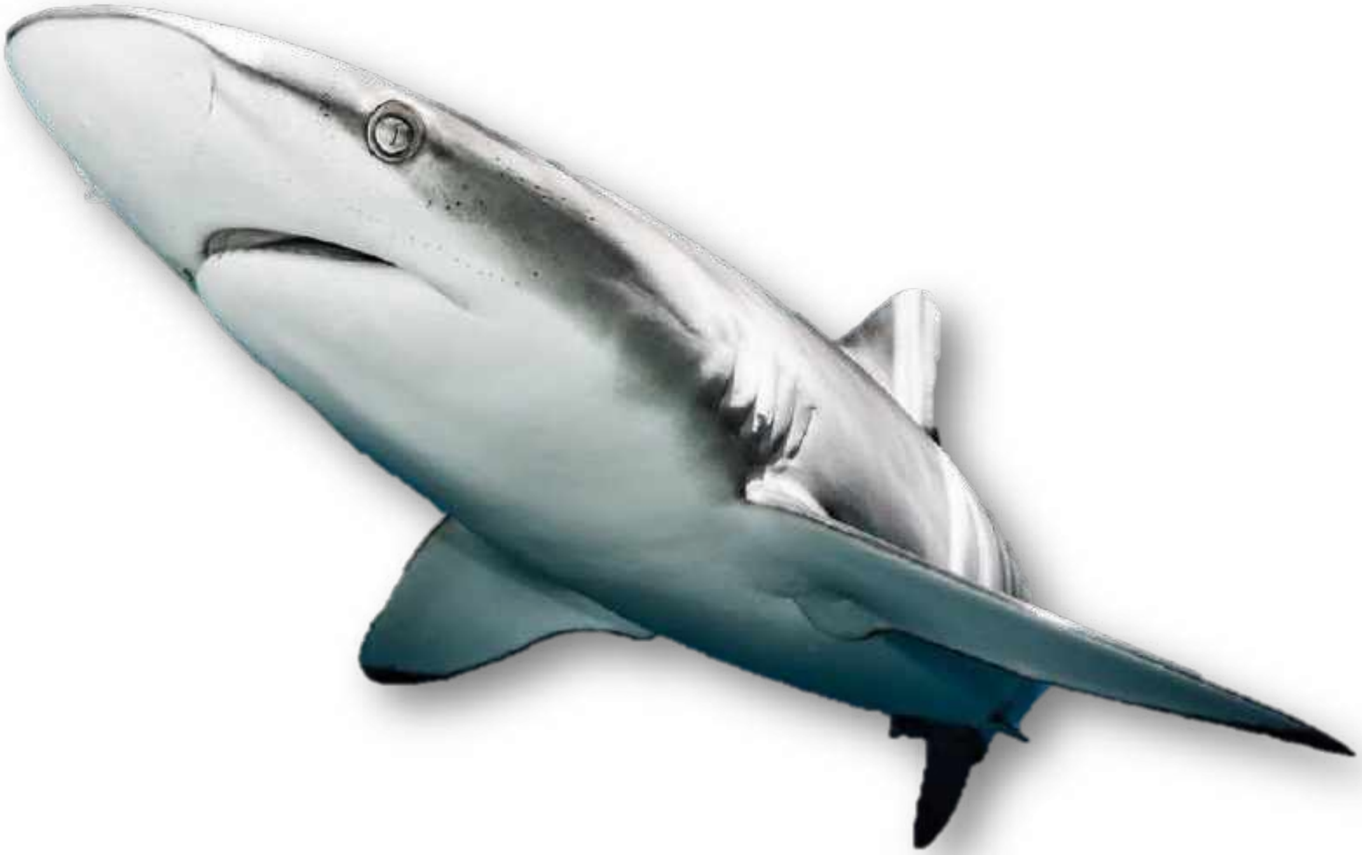
Yellowfin tuna
(*Thunnus albacares*)

Skipjack tuna
(*Katsuwonus pelamis*)

(Amandé *et al.*, 2010; Hall & Roman, 2013; FAO, 2014; Le Manach *et al.*, 2016; Crespo *et al.*, 2018)

Silky shark

Carcharhinus falciformis



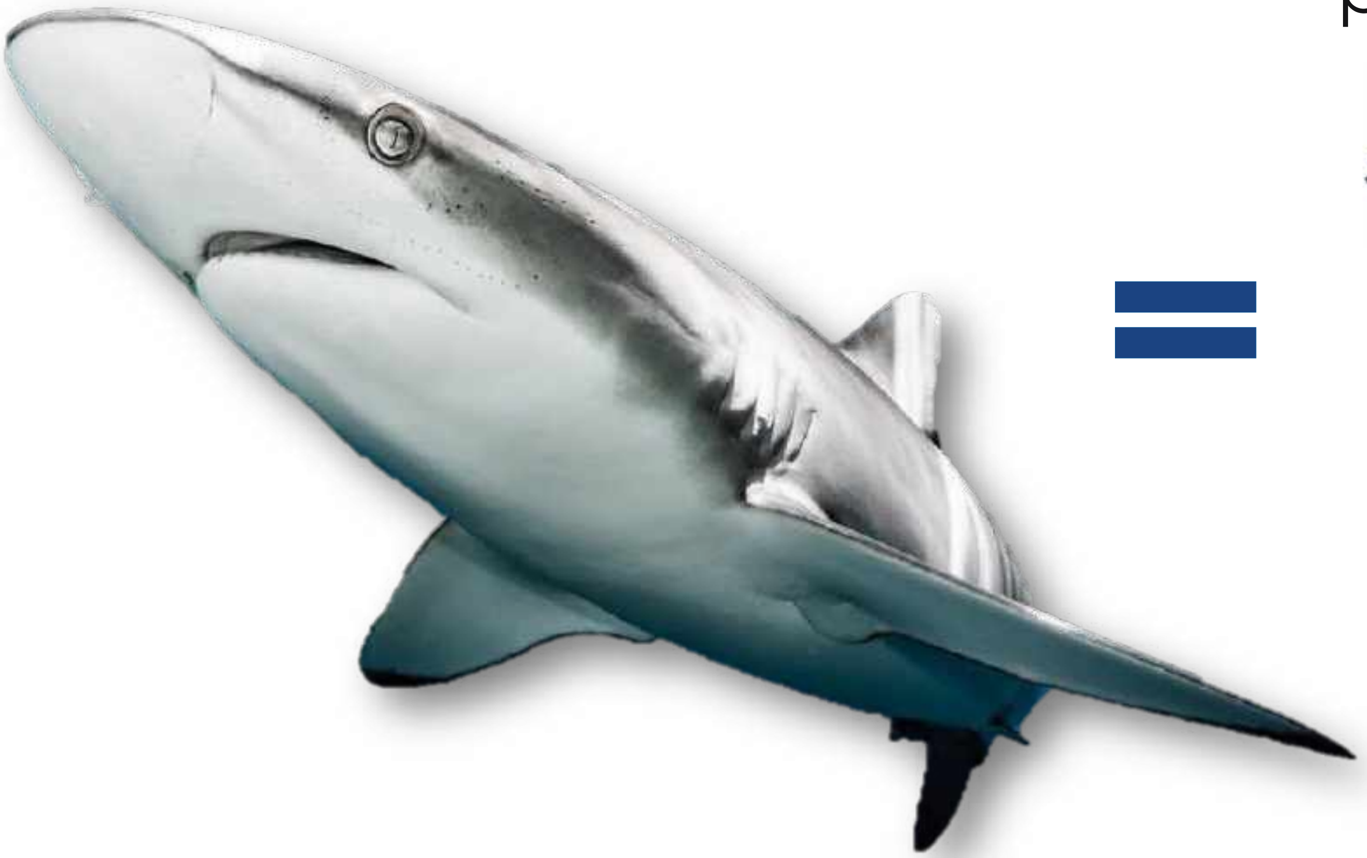
Bycatch species

- Gillnets
- Longline
- Purse-seine

(CONAPESCA, 2004; Amandé *et al.*, 2008; Bonfil, 2008; Cortés *et al.*, 2010; SEMARNAT, 2018; Hutchinson *et al.*, 2019)

Introduction

Silky shark
Carcharhinus falciformis



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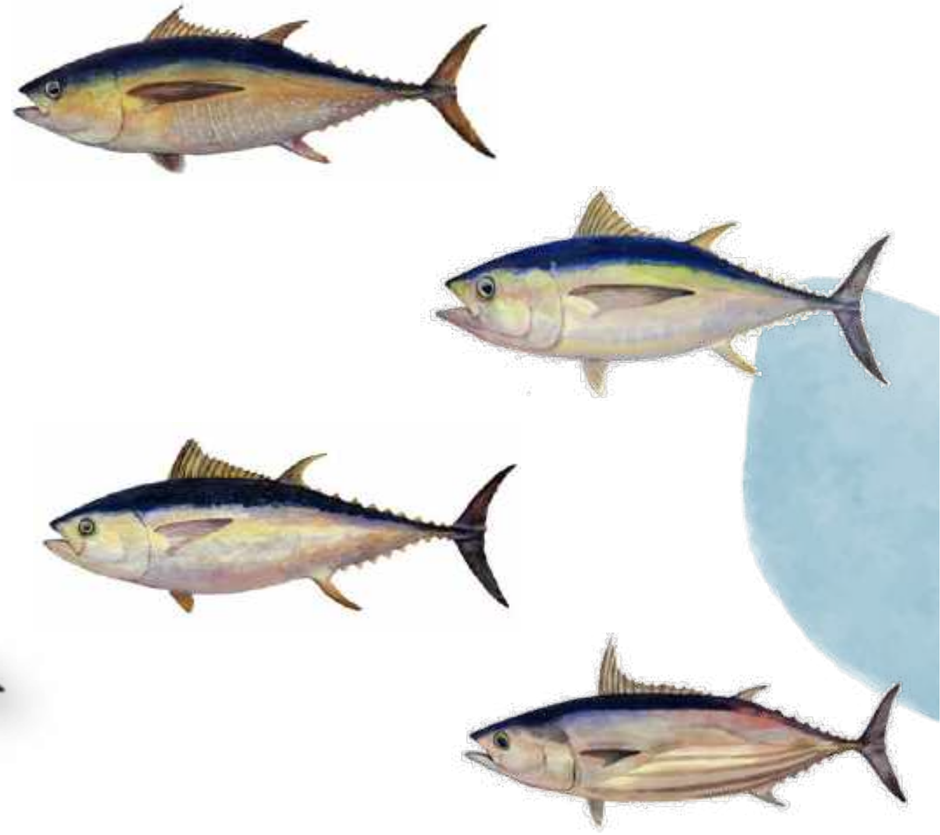
Similar thermal and depth preferences to tuna



(CONAPESCA, 2004; Amandé *et al.*, 2008; Bonfil, 2008; Cortés *et al.*, 2010; SEMARNAT, 2018; Hutchinson *et al.*, 2019)

Introduction

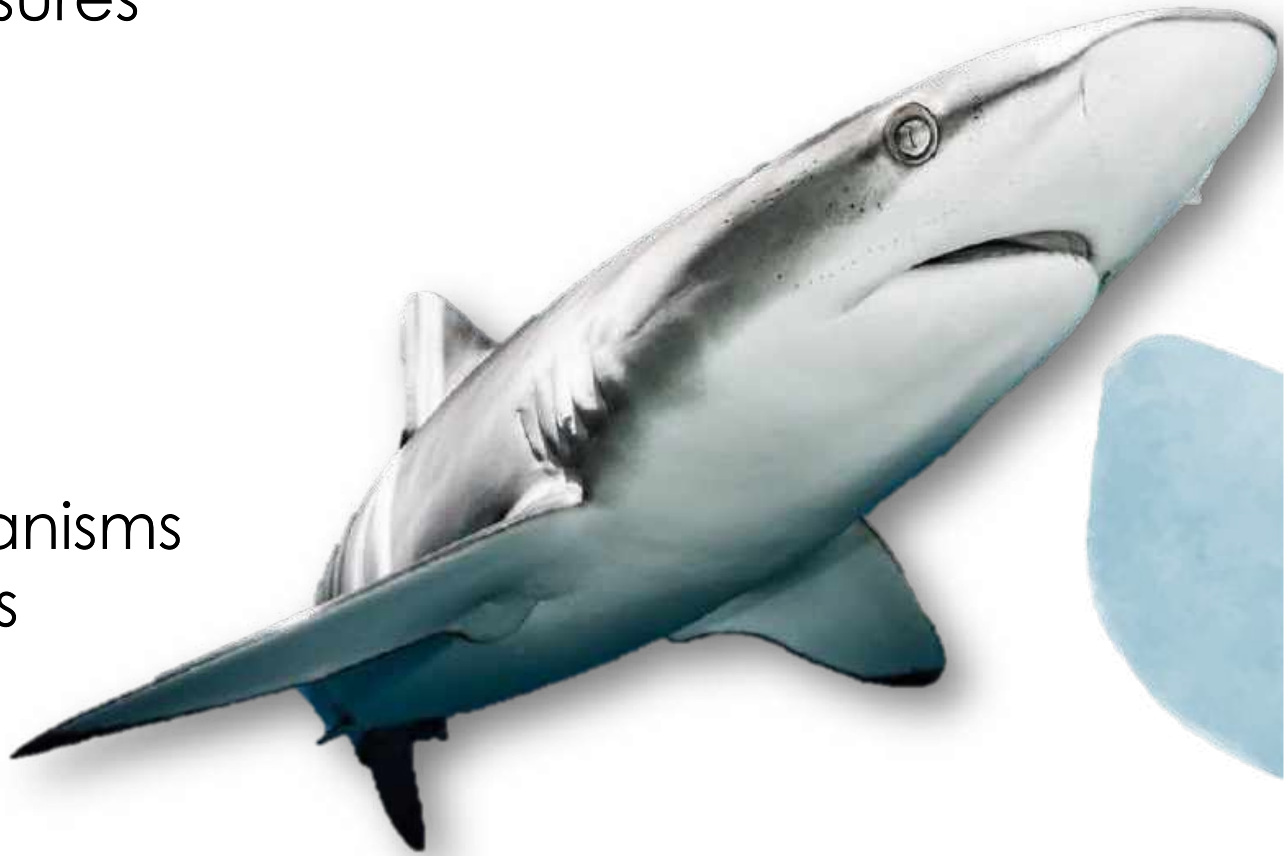
Silky shark
Carcharhinus falciformis

Conservation and mitigation measures

Bycatch species

Predict their distribution

Relationship between pelagic organisms and environmental conditions



Introduction

Environmental variables

Sea Surface Temperature (SST)

Clorophyll *a* (Chl-*a*)

Winds

Primary productivity

Salinity

(Schlaff *et al.*, 2014; Su *et al.*, 2014; Hobday *et al.*, 2011; Lezama-Ochoa *et al.*, 2018)

Introduction

+ Species richnes and diversity

Lezema-Ochoa *et al.* (2018)
SST y salinity

Sharks distribution

López *et al.* (2017)
Upwelling events

Introduction

Western Pacific Ocean

Carcharhinus falciformis

Kindong *et al.* (2022)
SST, primary productivity, and winds

Introduction

Carcharhinus falciformis

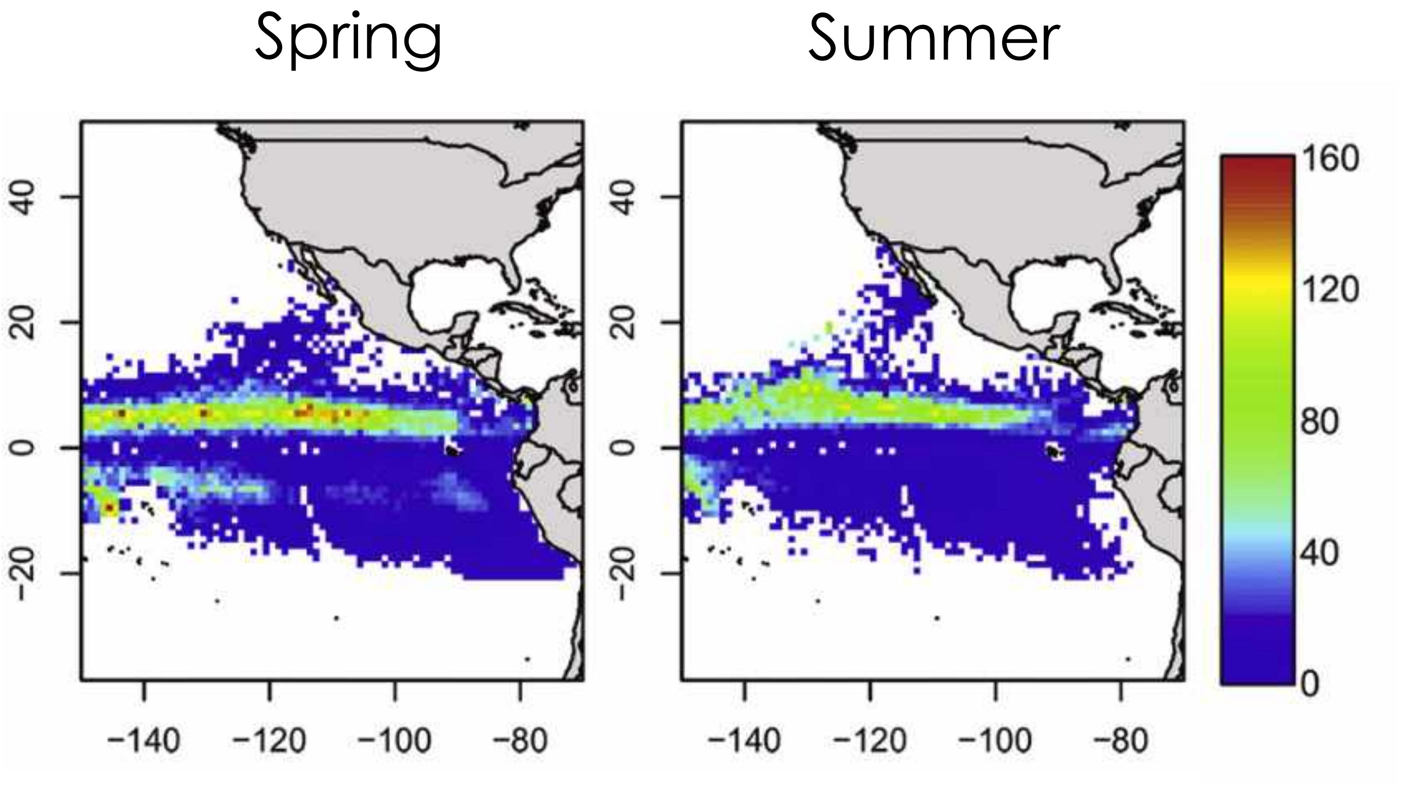
Hutchinson *et al.* (2021)
SST, depth

Brenes *et al.* (2000)
Thermal fronts

Melgar-Martínez *et al.* (2024)
Chl-*a*, Sea Surface Height

Introduction

FAD's



Carcharhinus falciformis

Díaz-Delgado *et al.* (2021)
SST ~ Chl-*a*

Spring and summer

Equatorial tongue
(FAD´s)

Inter-American Tropical Tuna Comission (IATTC)

“Stock condition assessments of the silky shark population in the EPO”

Correlation with environmental variables

Development of improved models

Goal

Identify the environmental conditions that influence silky shark bycatch and **determine the areas of greatest probability of bycatch** by tuna purse seine vessels in the Eastern Pacific Ocean.

Specific aims

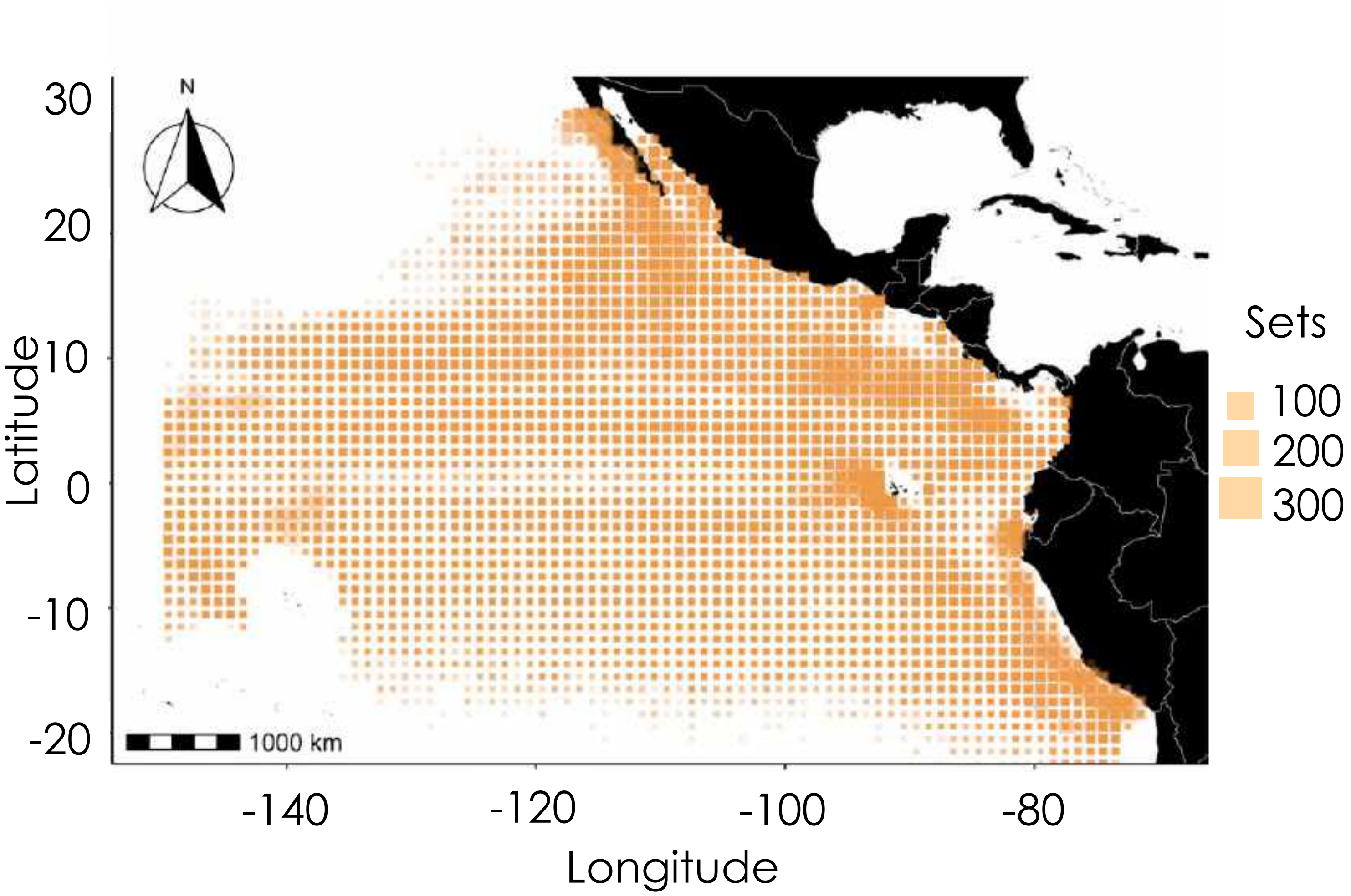
1. **Determine the spatiotemporal distribution** of sharks bycaught by purse-seine in the EPO.
2. **Estimate bycatch per unit effort** (BPUE) as an index of the relative abundance of silky sharks.
3. **Model the presence** of silky shark bycatch by purse seiners with oceanographic variables.

Bycatch data in the EPO

IATTC

2009-2019

Purse seine (1° x 1°)



Methods

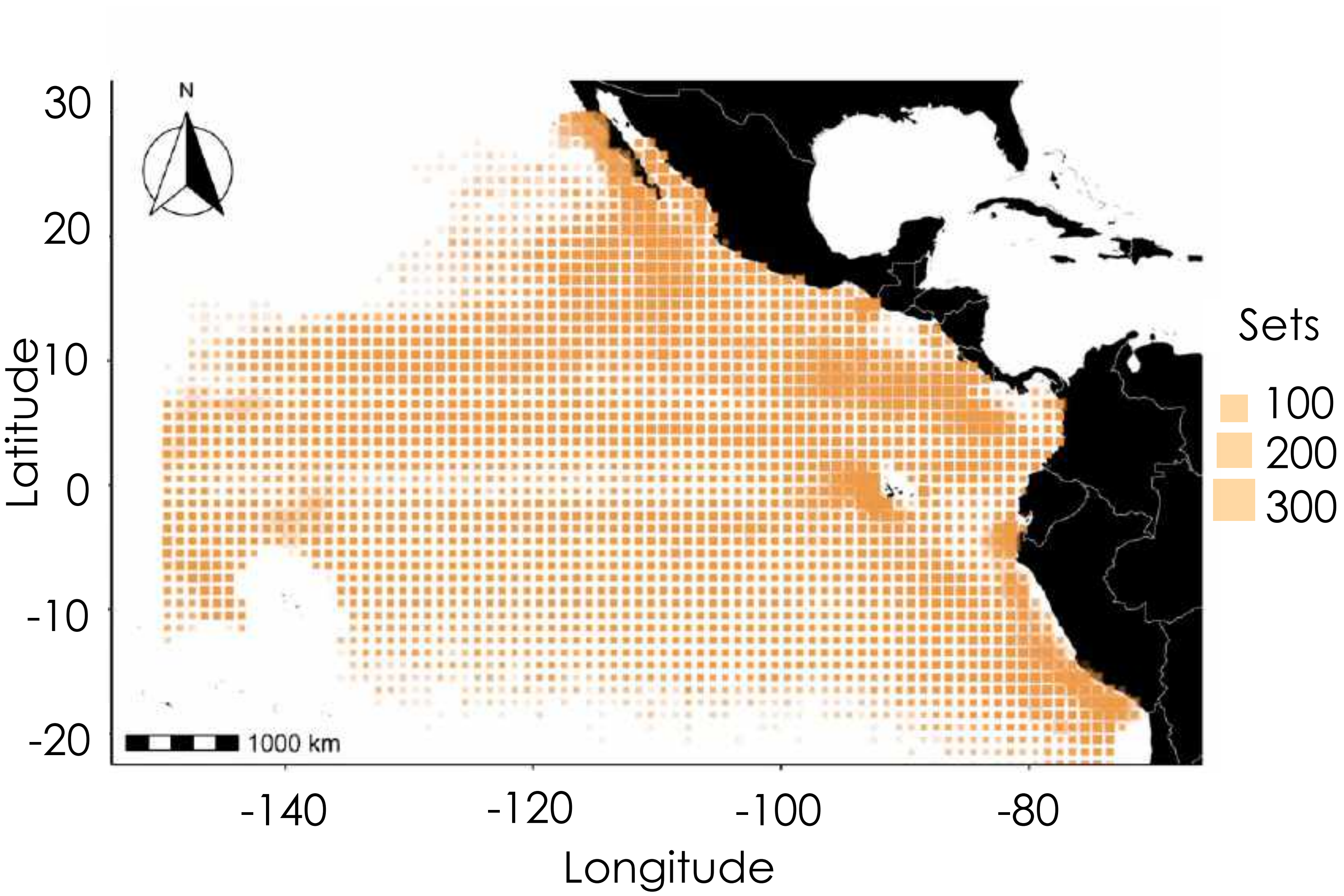
Bycatch data in the EPO

IATTC

2009-2019

Purse seine (1° x 1°)

OBJ: associated with floating objects
NOA: unassociated schools of tunas
DEL: associated with dolphins



Year, month, geoghaphic position, type of fishing, number of organisms bycaught, number of sets

Methods

Bycatch data in the EPO

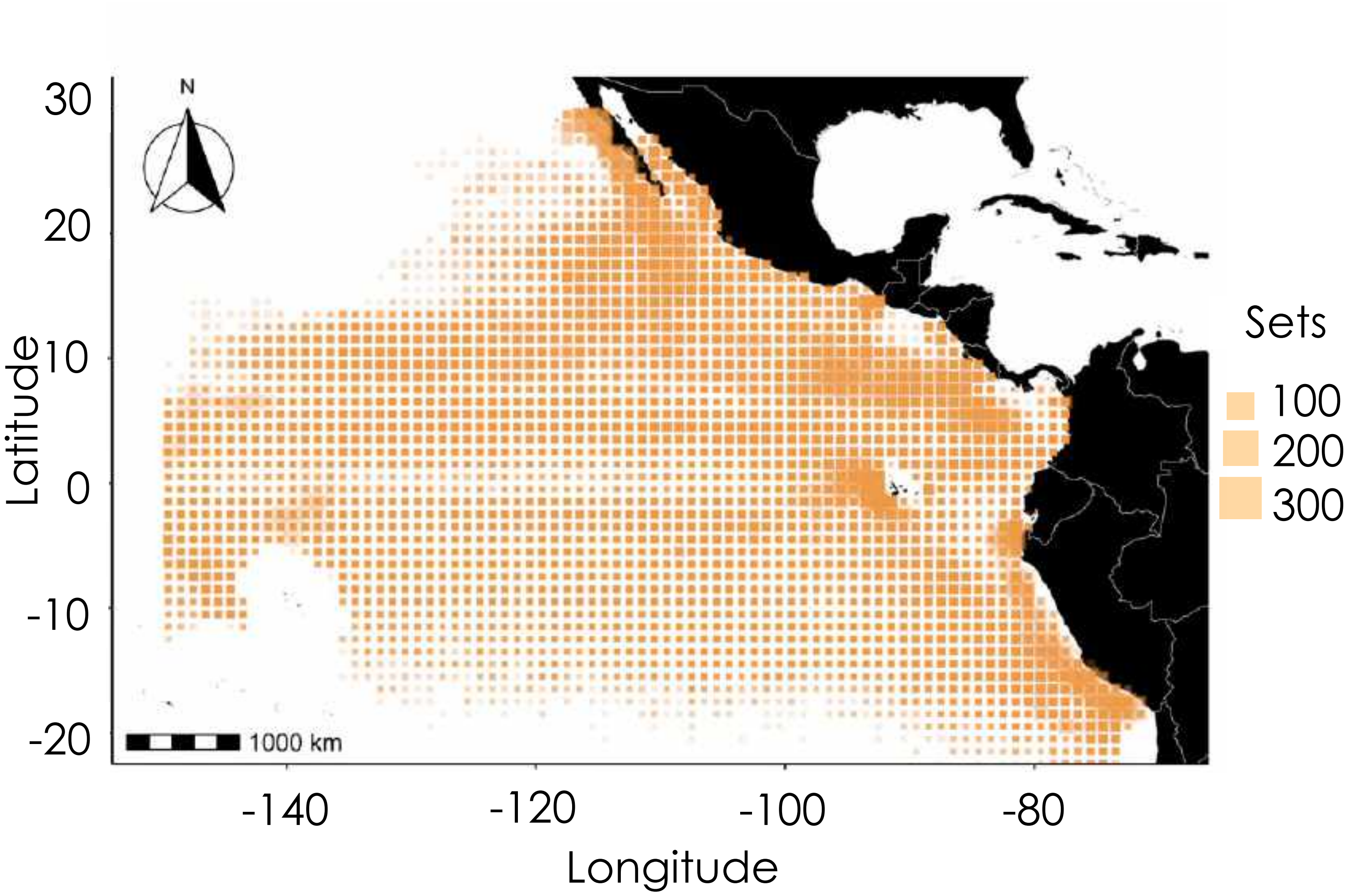
IATTC

2009-2019

Purse seine (1° x 1°)

OBJ: associated with floating objects
NOA: unassociated schools of tunas
DEL: associated with dolphins

$$BPUE = \frac{No.organisms}{Set}$$



Year, month, geoghaphic position, type of fishing, number of organisms bycaught, number of sets

Environmental variables

✓ Sea Surface Temperature (°C)	**SST**
✓ Clorophyll-*a* concentration (mg*m3)	**Chl-*a***
✓ Sea Surface Height (m)	**SSH**
✓ Mixed Layer Depth (m)	**MLD**
✓ Dissolved Oxygen Molar Concentration (mmol*m3)	**DO**

Monthly, resolution 0.083°, 0.25°

Copernicus Marine Service

Methods

Bayesian Additive Regression Trees (BART)

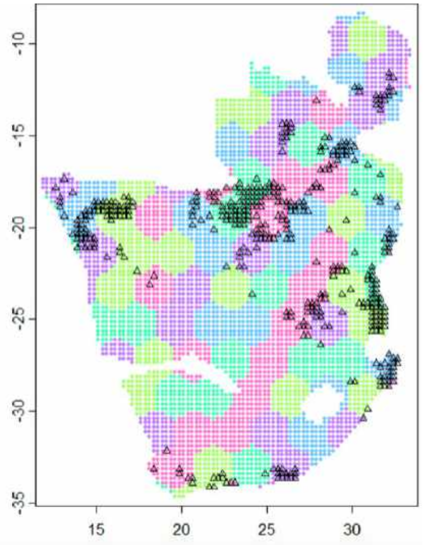
Presence ~ environmental variables (SST, SSH, MLD, DO, Chl-*a*)

Evaluation:

Discrimination and Calibration

	Range
Sensibility	0 - 1
Specificity	0 - 1
Precision	-1 – 1
TSS	-1 – 1
Miller calibration	~ 1

Cross-validation

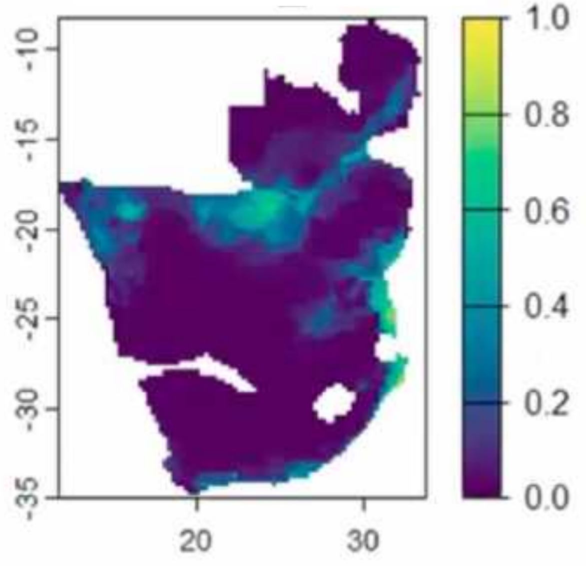


(AUC, TSS, Miller)

- embarcadero
- ModEvA
- BlockCv
- crossval

Bayesian Additive Regression Trees (BART)

Predictions



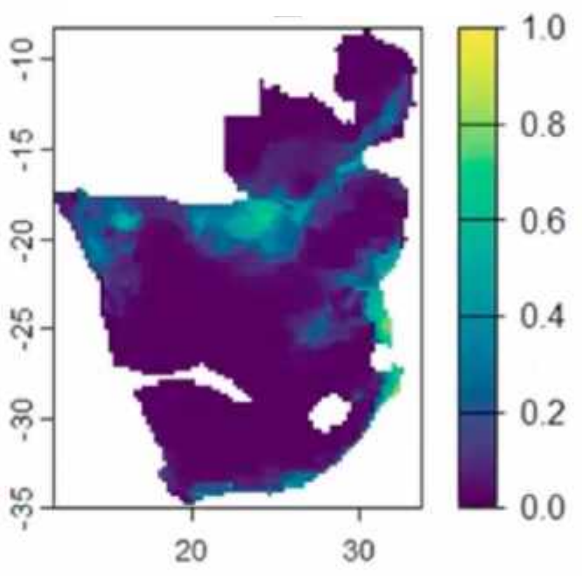
Values between 0 – 1

- fuzzySim
- embarcadero

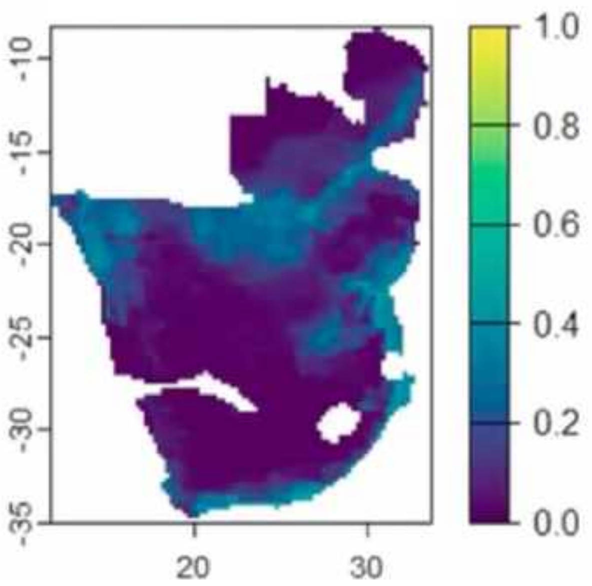
Methods

Bayesian Additive Regression Trees (BART)

Predictions



Uncertainty
(Confidence interval)

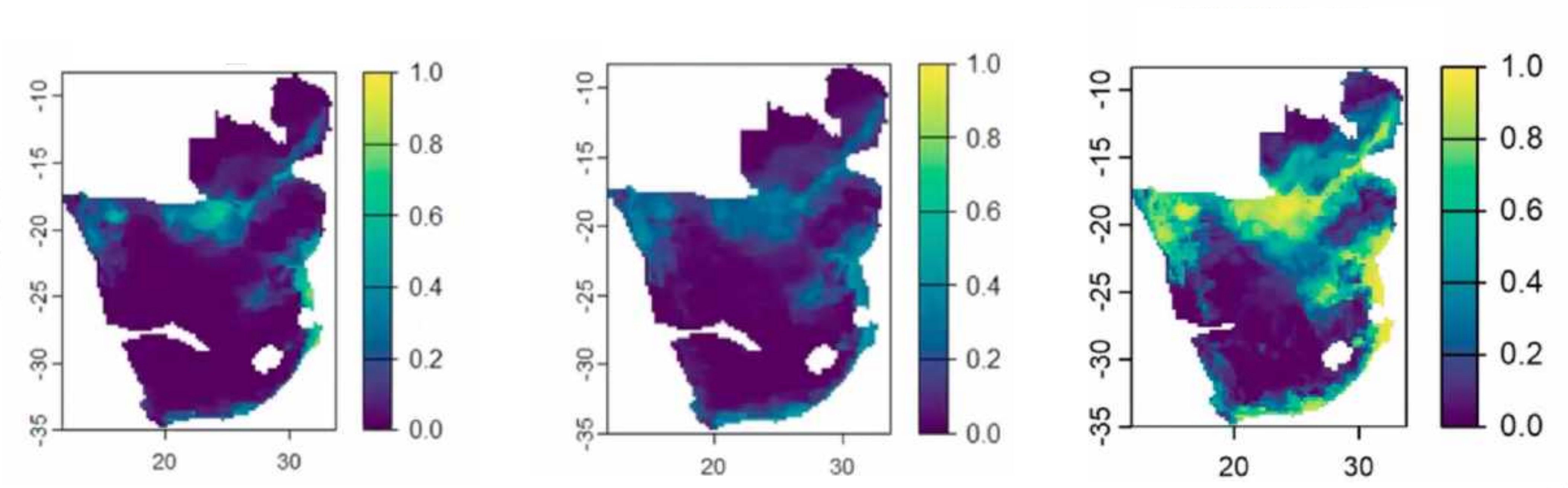


Values between 0 – 1

- fuzzySim
- embarcadero

Bayesian Additive Regression Trees (BART)

Predictions | **Uncertainty** (Confidence interval) | **Favourability**



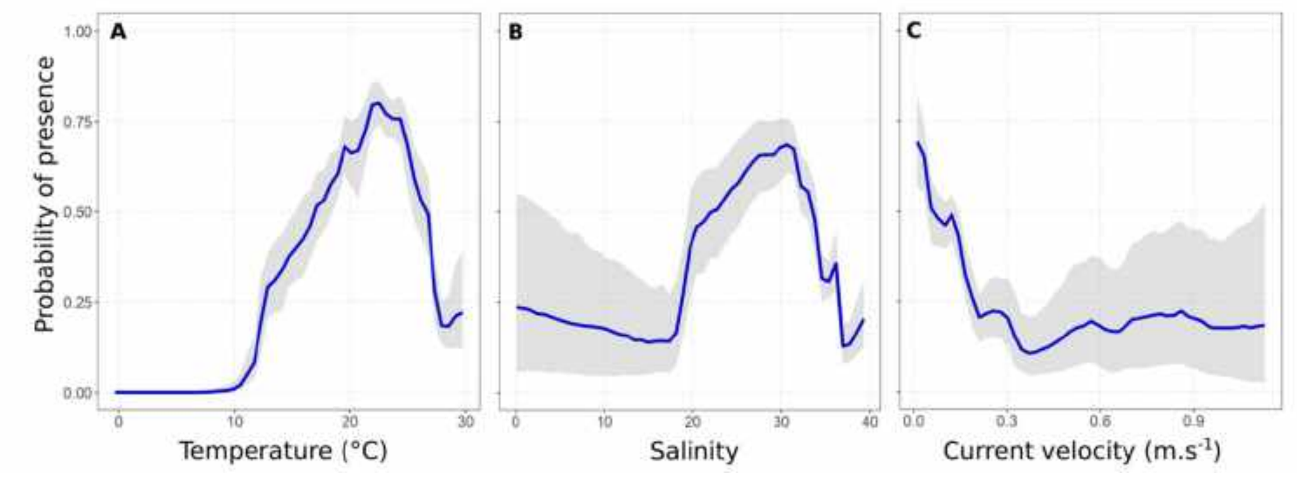
Values between 0 – 1

- fuzzySim
- embarcadero

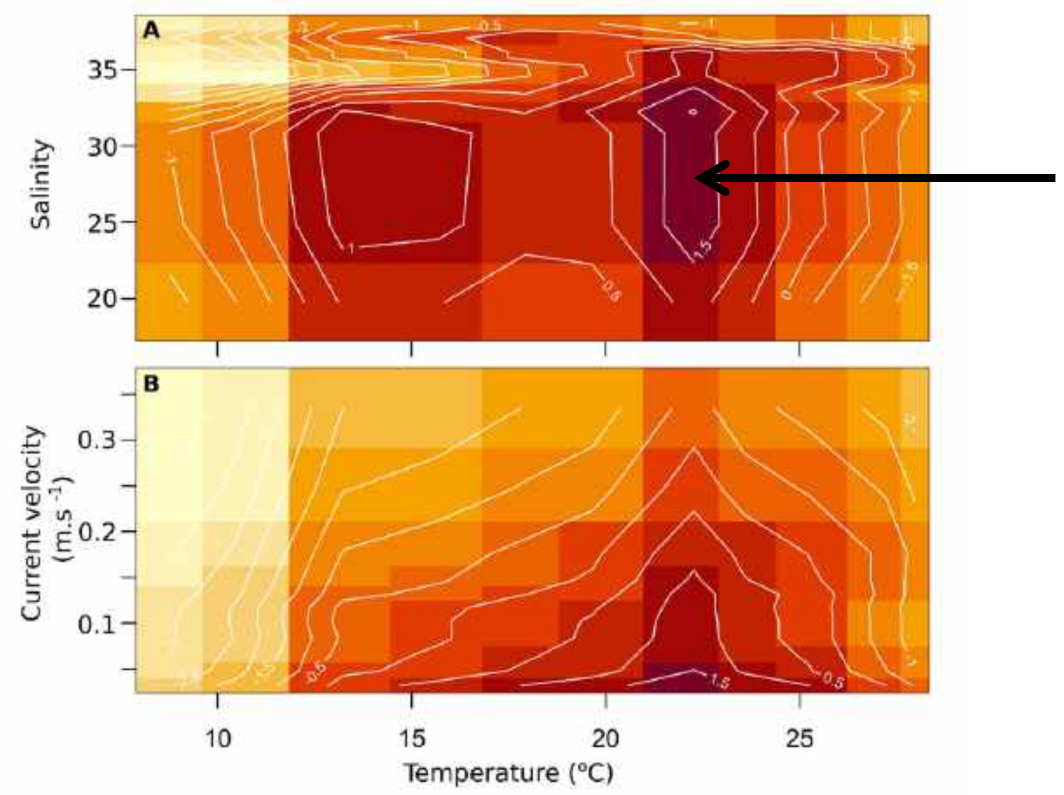
Methods

Bayesian Additive Regression Trees (BART)

Partial effects

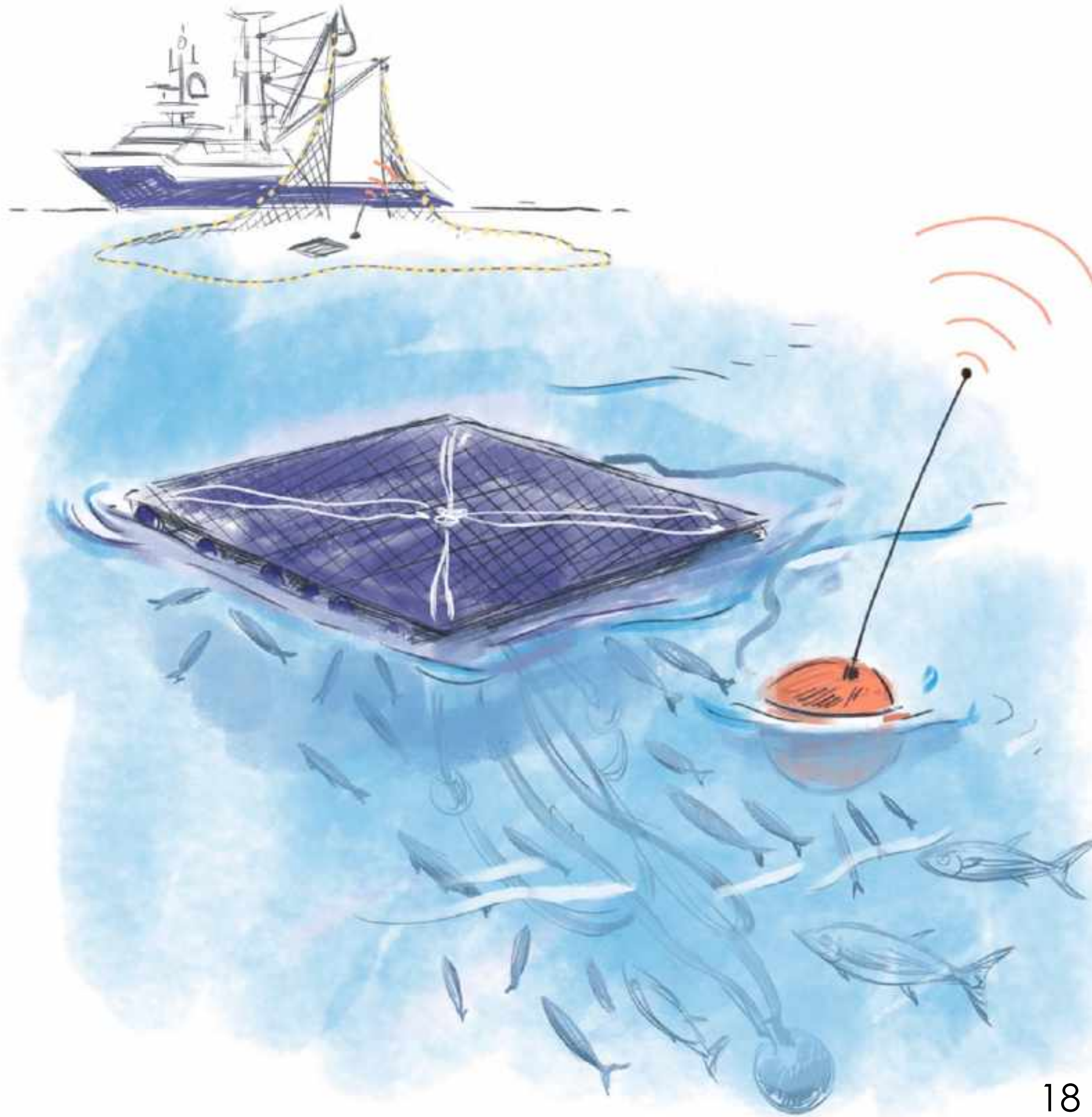


Bidimensional partial dependence plots



- dbarts
- embarcadero

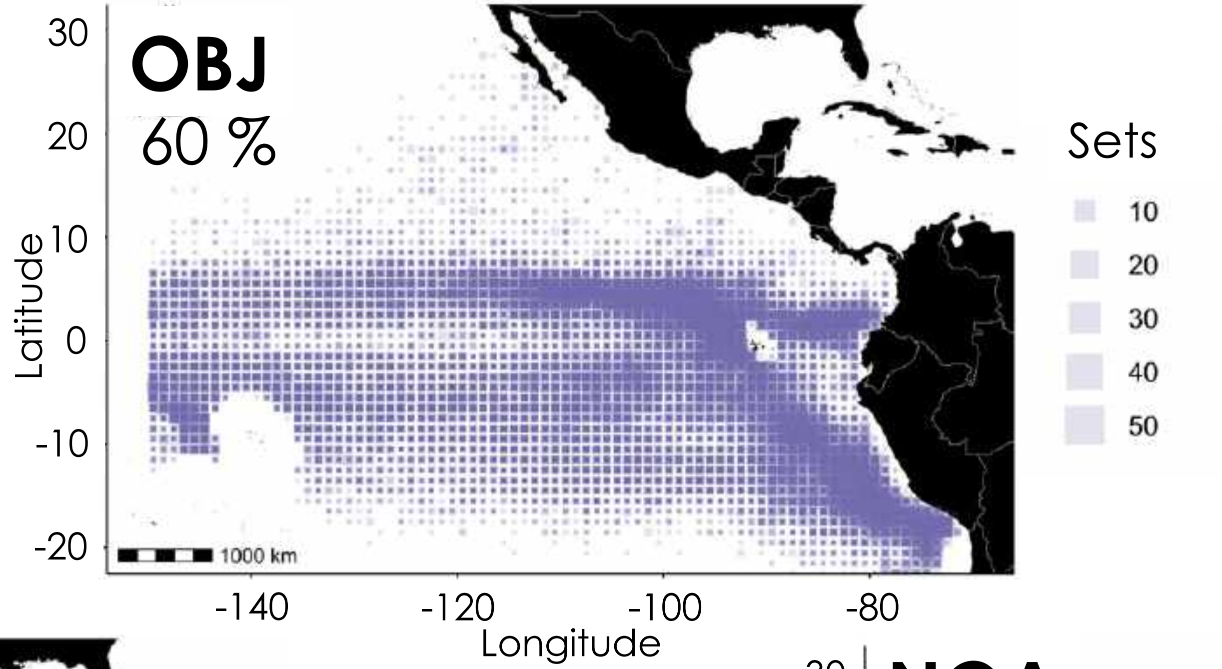
Results

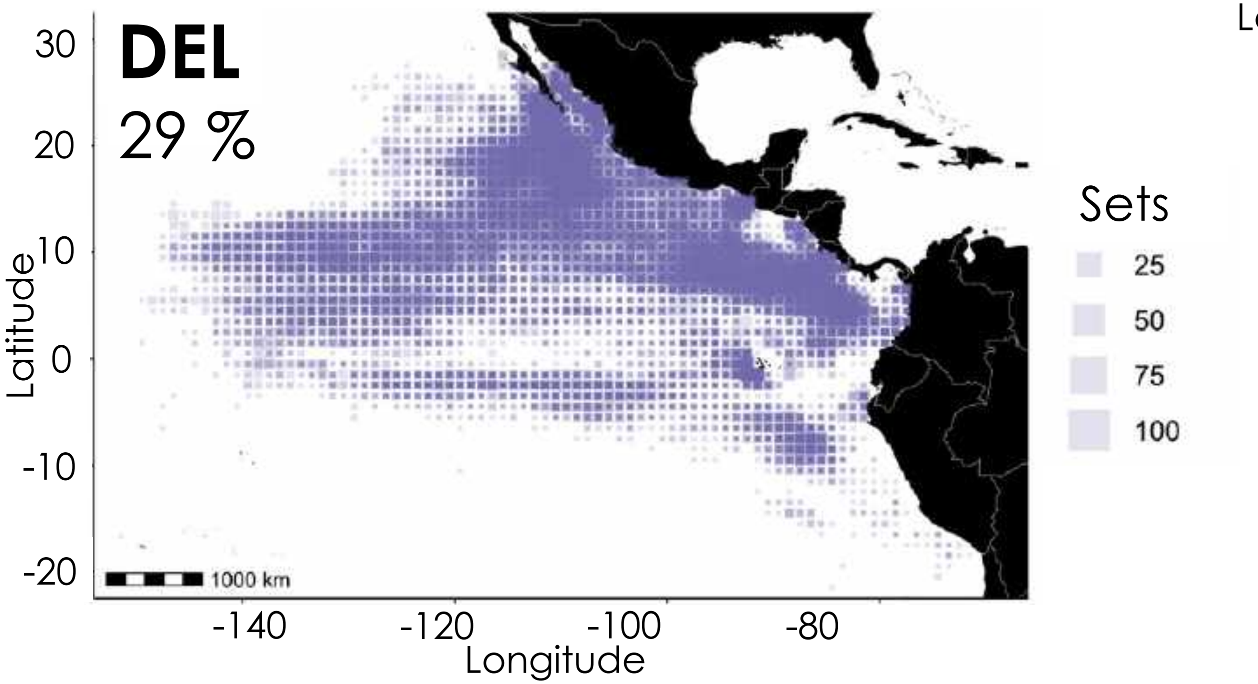


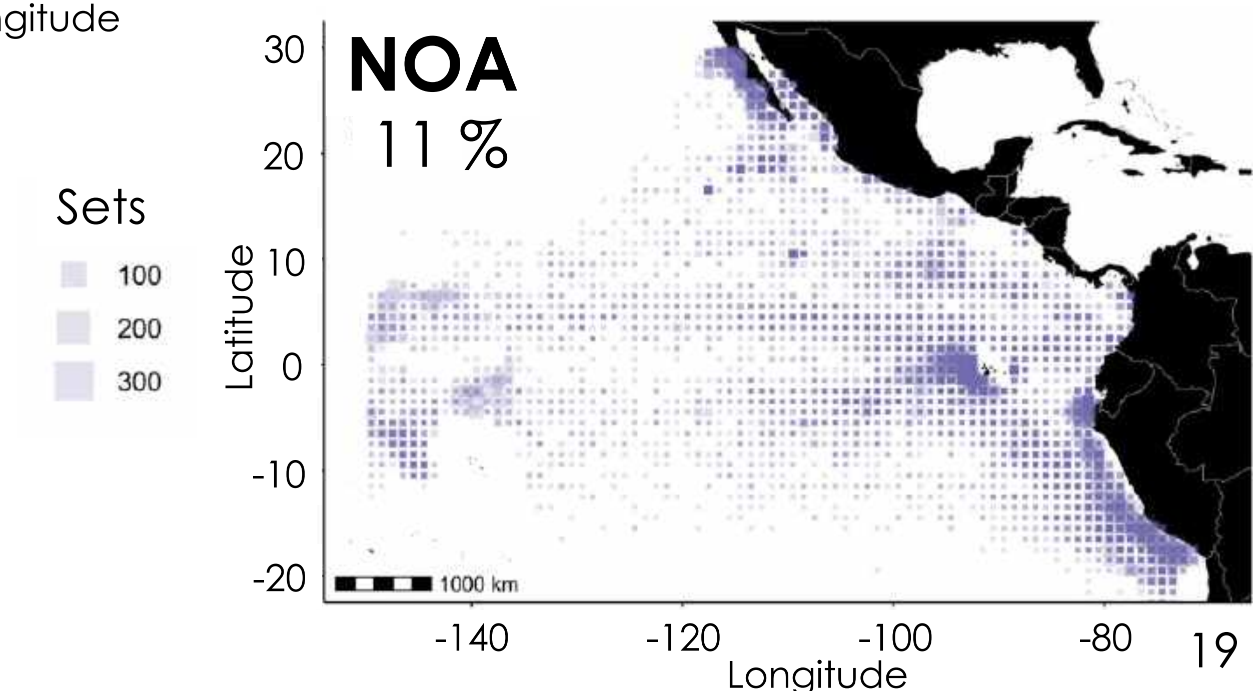
PURSE-SEINE

Number of sets per set type during 2009 - 2019

93,820 sets





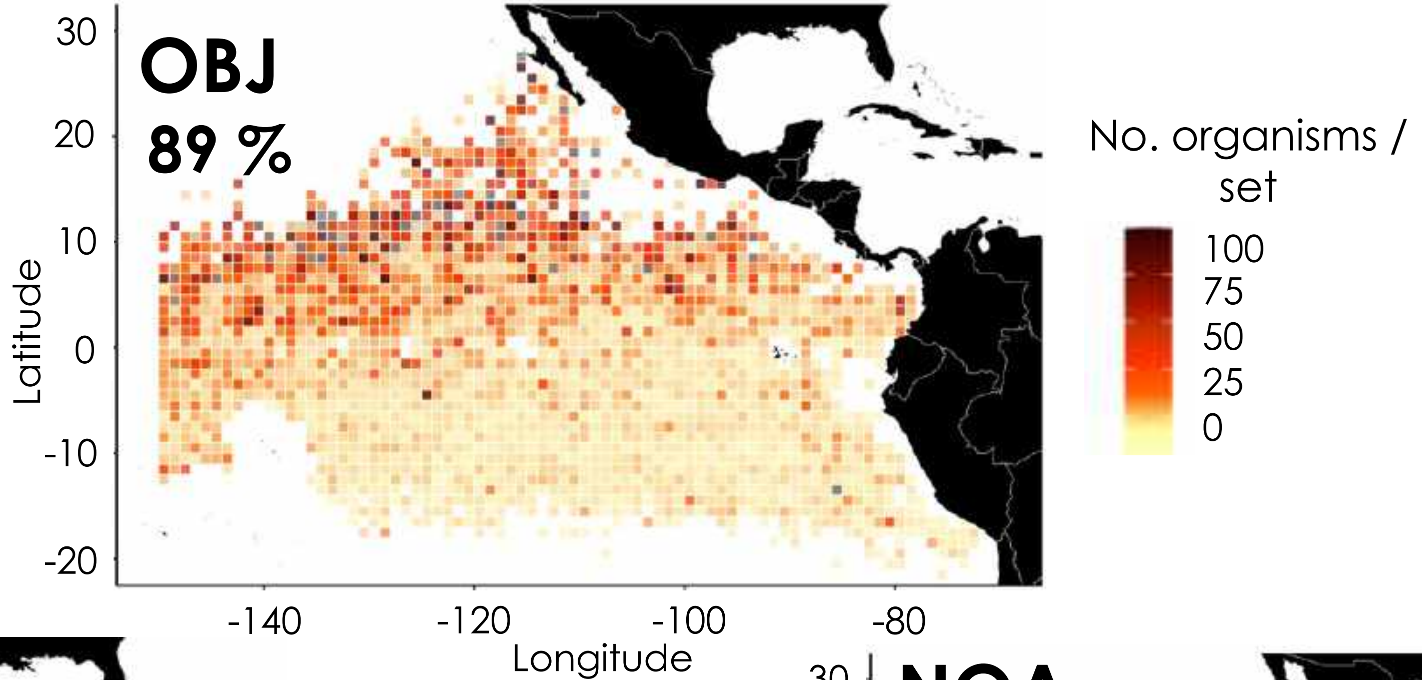


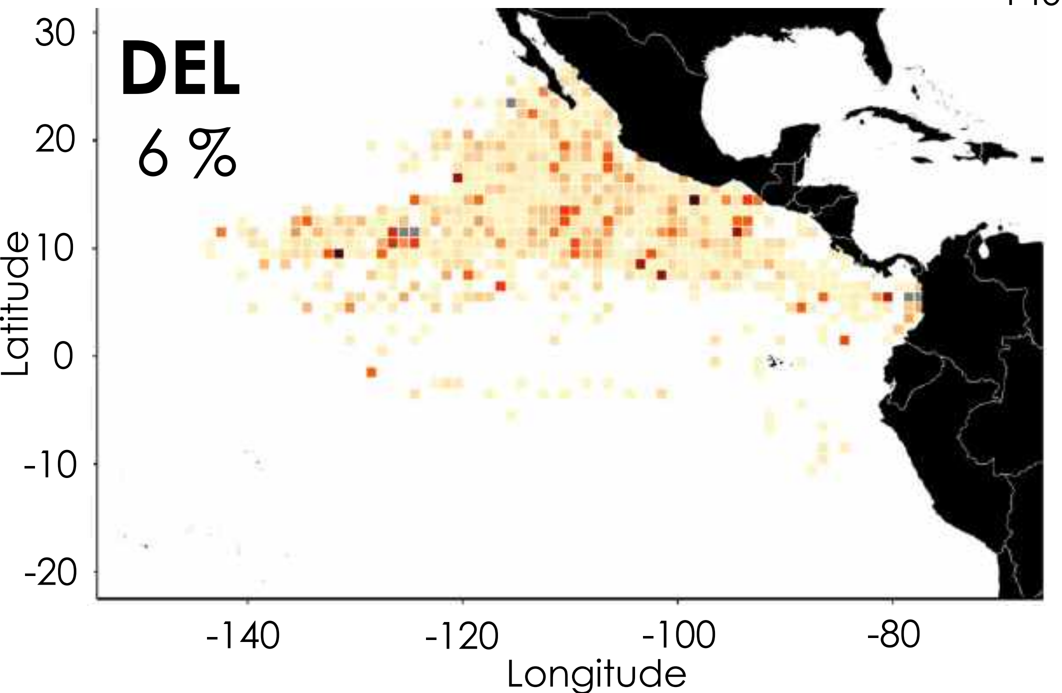
PURSE-SEINE

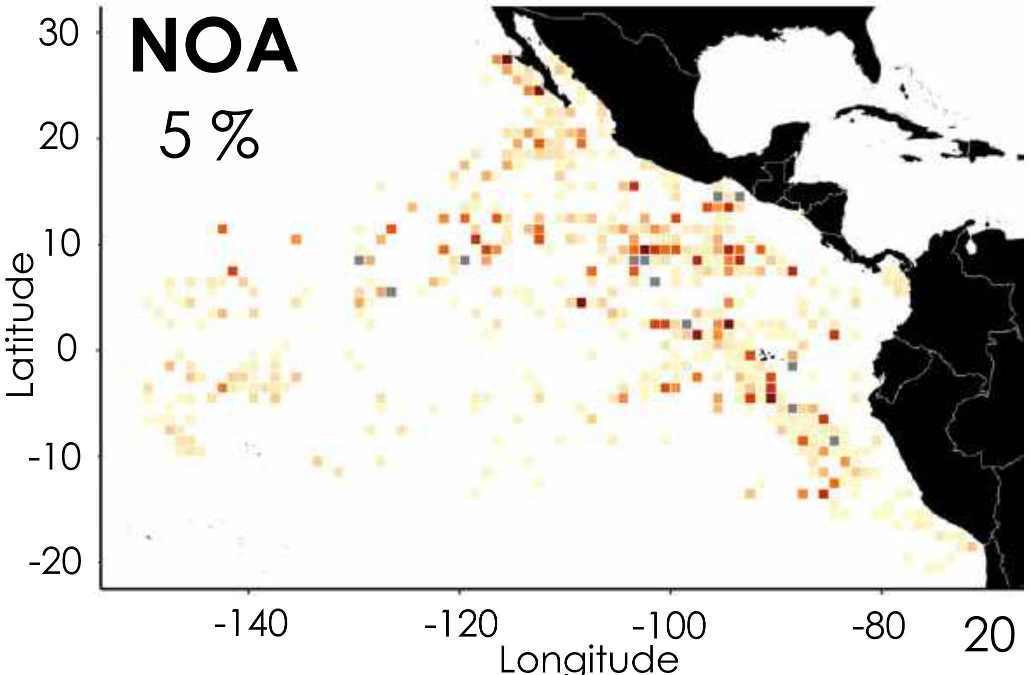
No. of bycaught organisms per set type during 2009 - 2019

281,621 organisms

2 org/set

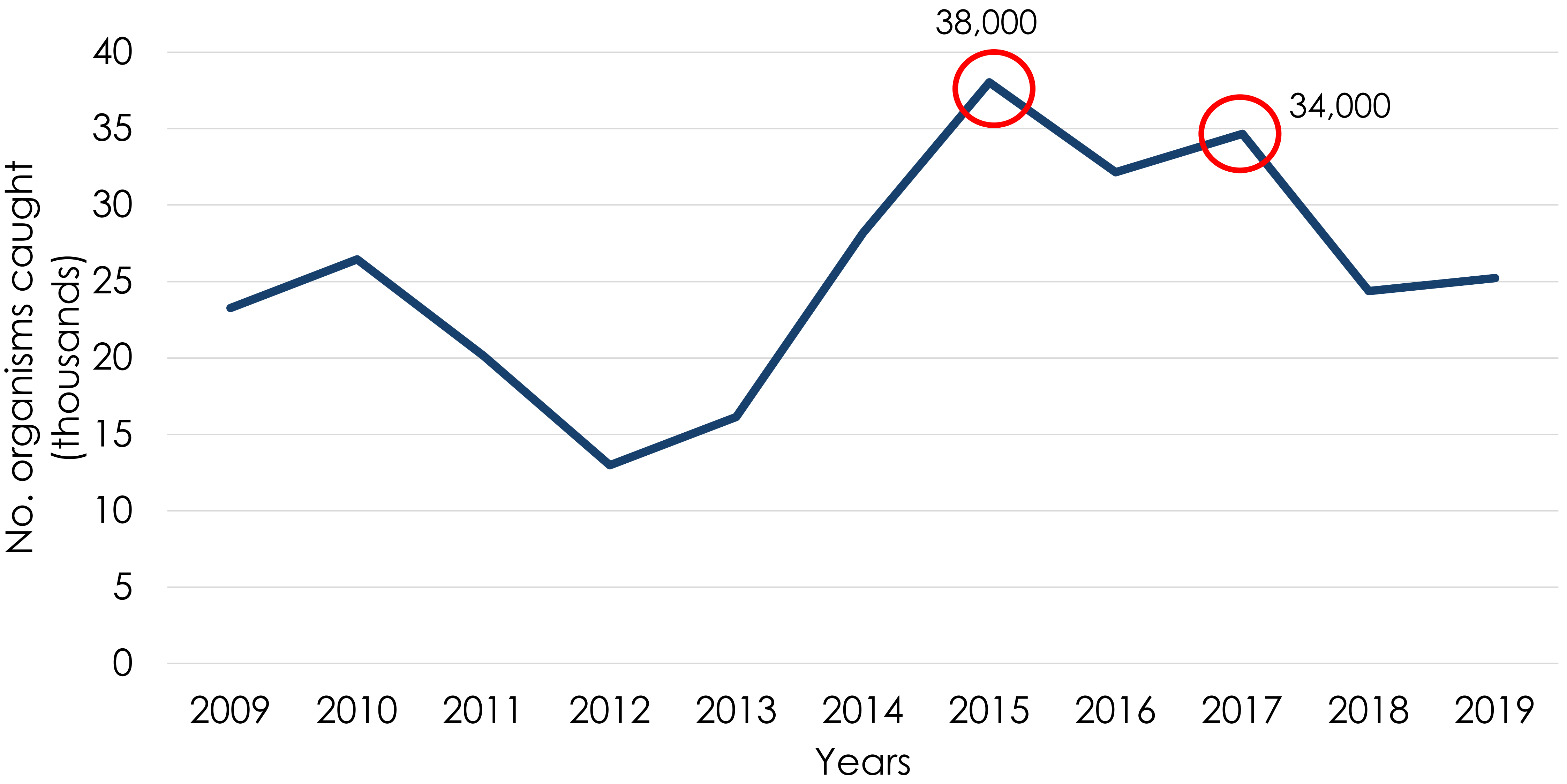






PURSE-SEINE

Interannual variability

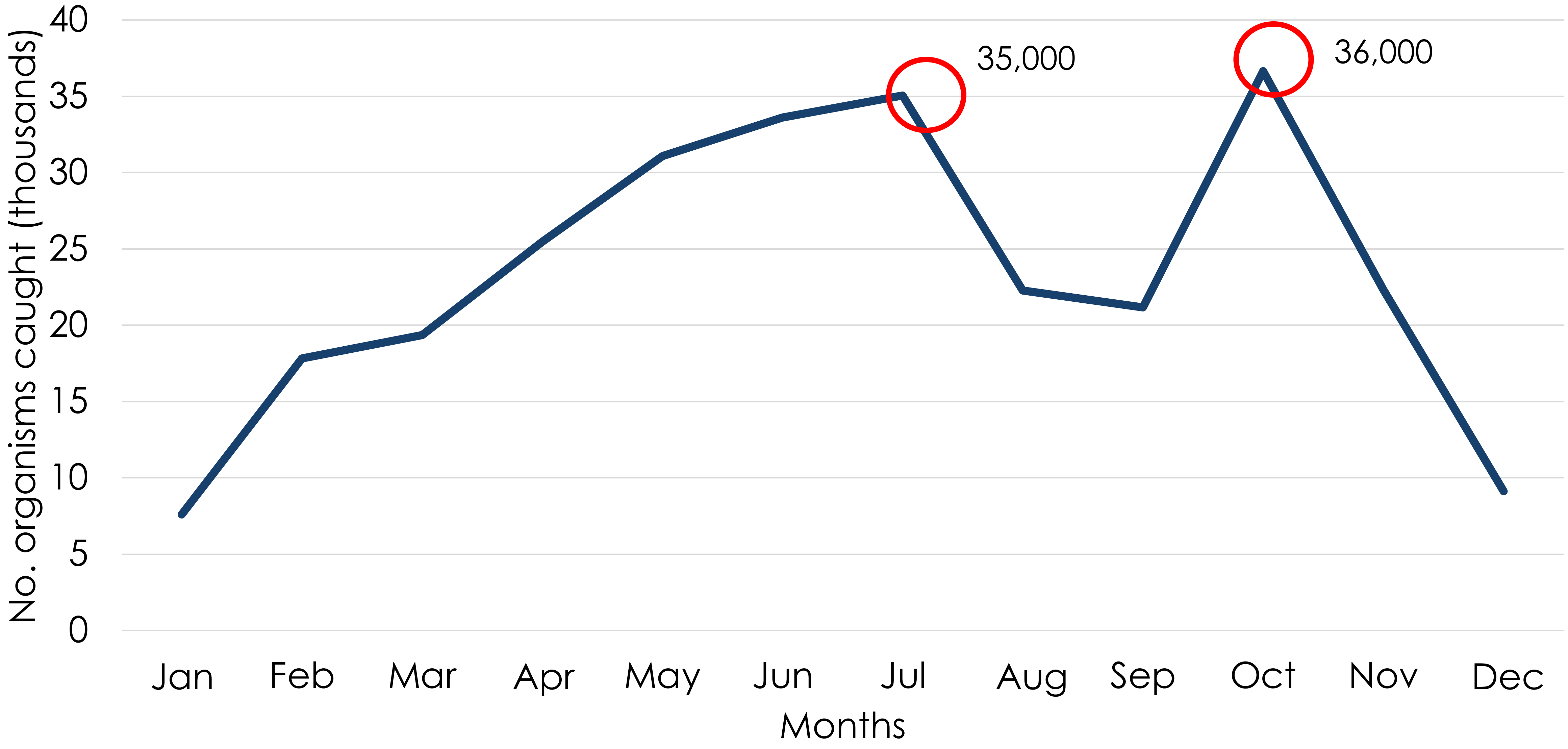


Annual mean: 25,598

H= 768.37, p = <2.2e-16

PURSE-SEINE

Intra-annual variability



H= 638.17, p = <2.2e-16

Model: Presence **~** MXL, Chl-*a*, SSH

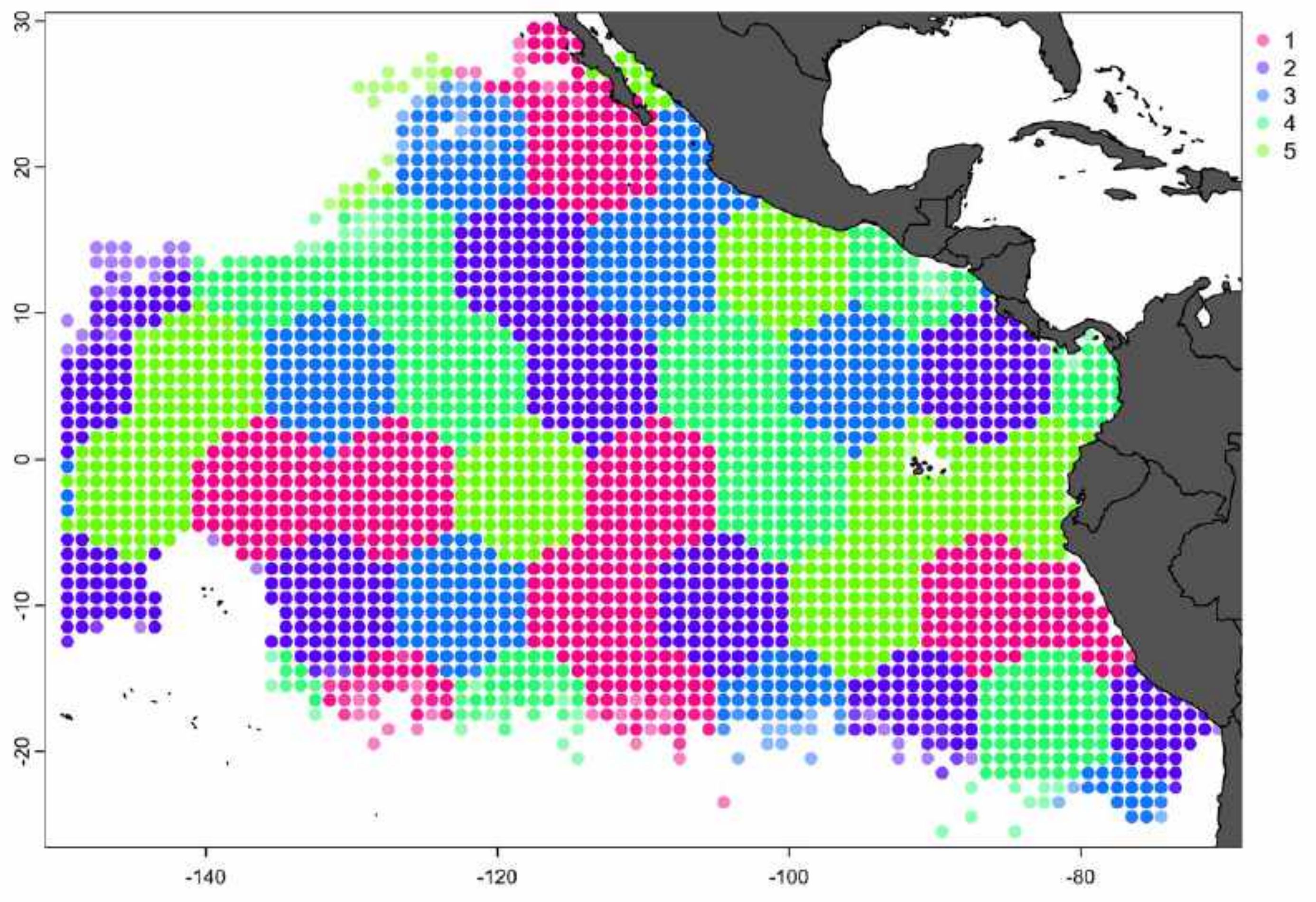
Variable	Importance
MLD	**0.338**
Chl-*a*	0.332
SSH	0.3289

+ 95 %

	Value	Range
Sensibility	**0.70**	0 - 1
Specificity	**0.60**	0 - 1
Precision	**0.38**	-1 – 1
TSS	**0.65**	-1 – 1
Miller calibration	**1.03**	~1

PURSE-SEINE

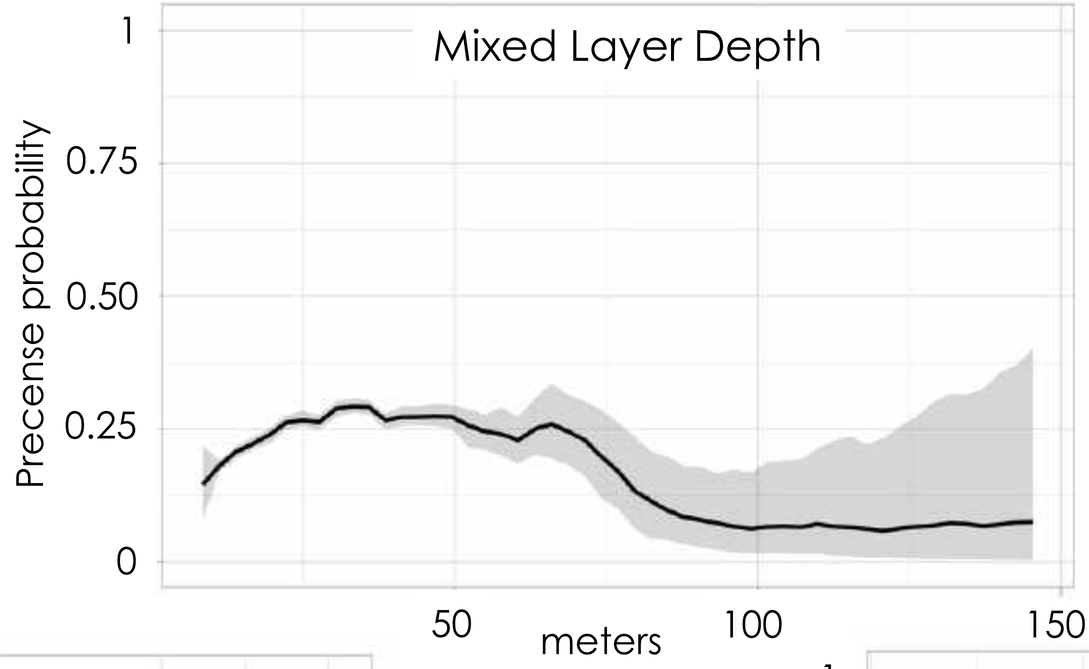
BART: cross validation

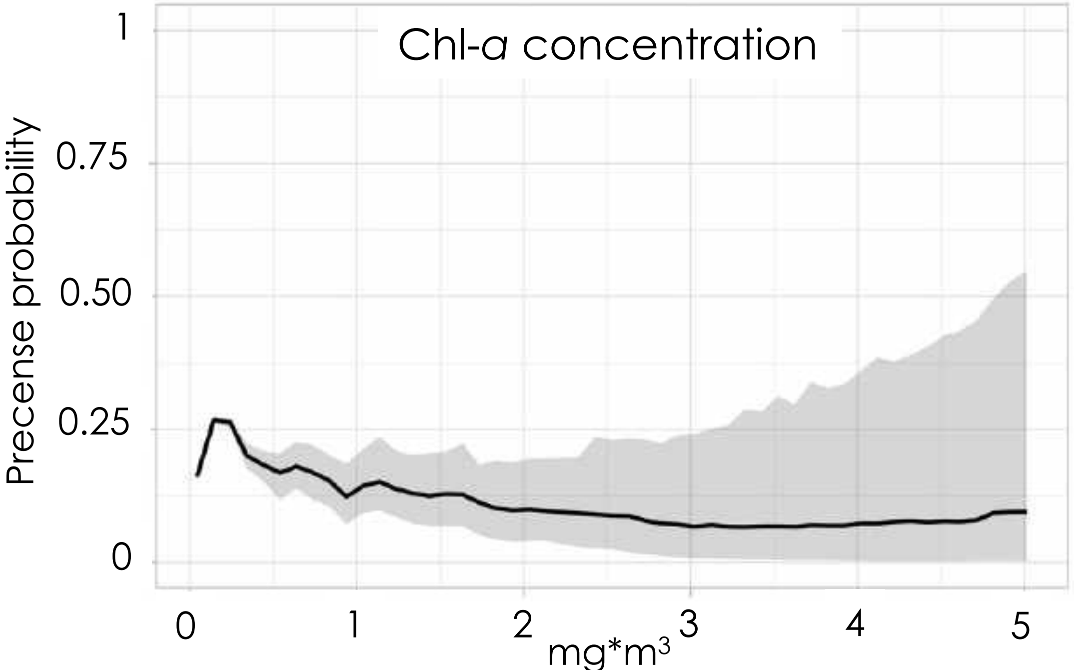


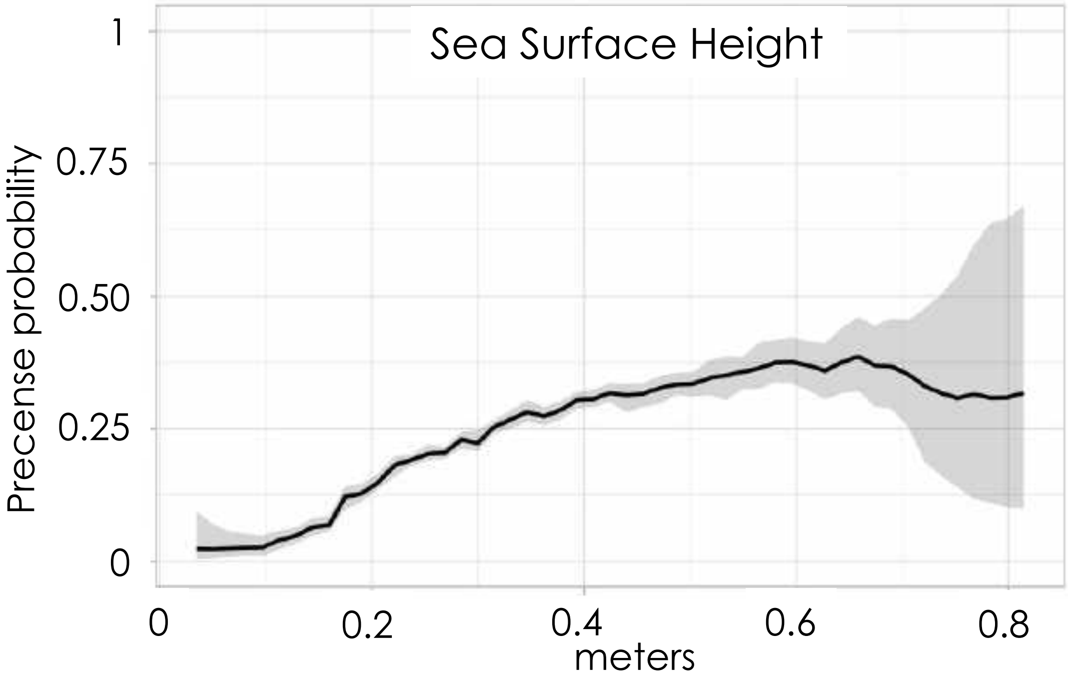
	AUC	Miller	TSS
Block 1	0.67	0.81	0.25
Block 2	0.71	1.11	0.32
Block 3	0.66	0.91	0.26
Block 4	0.68	0.89	0.27
Block 5	0.70	1.01	0.31

PURSE-SEINE

BART: partial effects

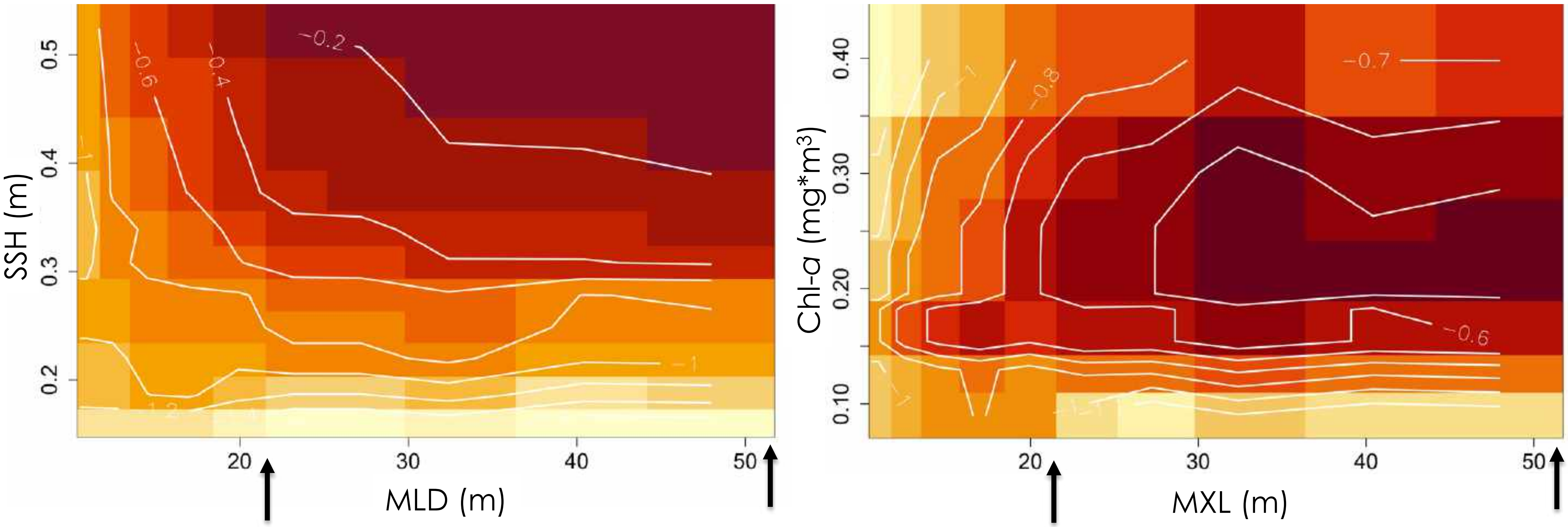






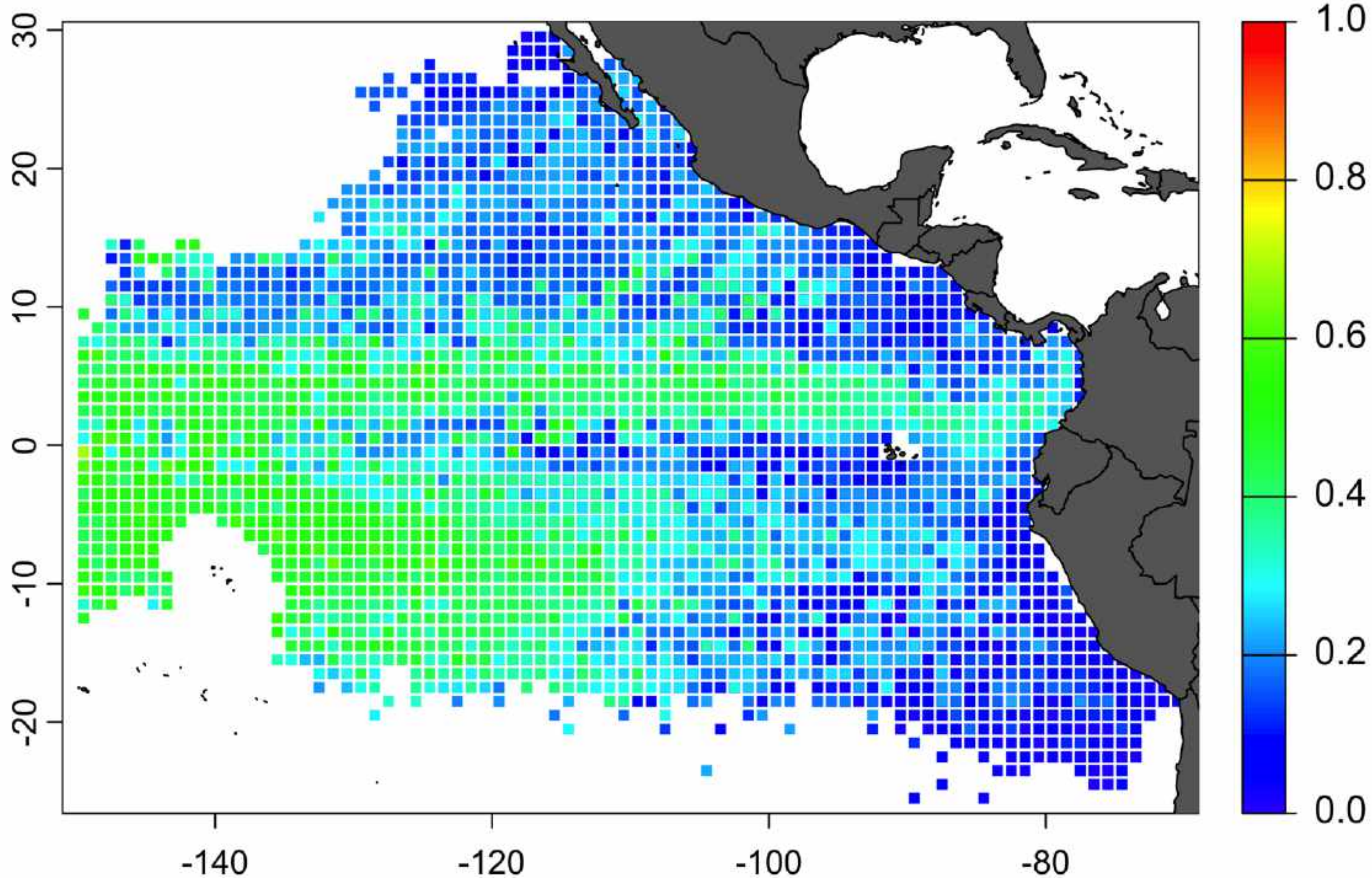
PURSE-SEINE

BART: bidimensional partial dependence plots



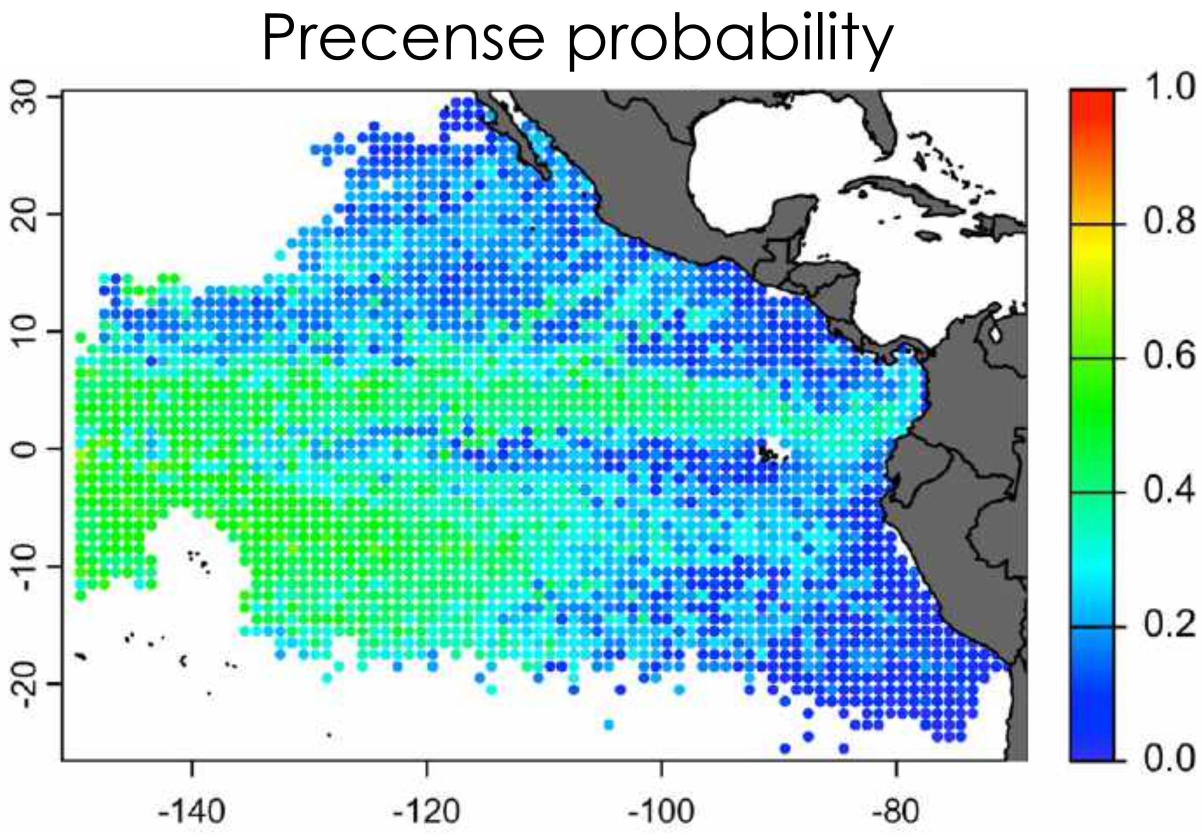
PURSE-SEINE

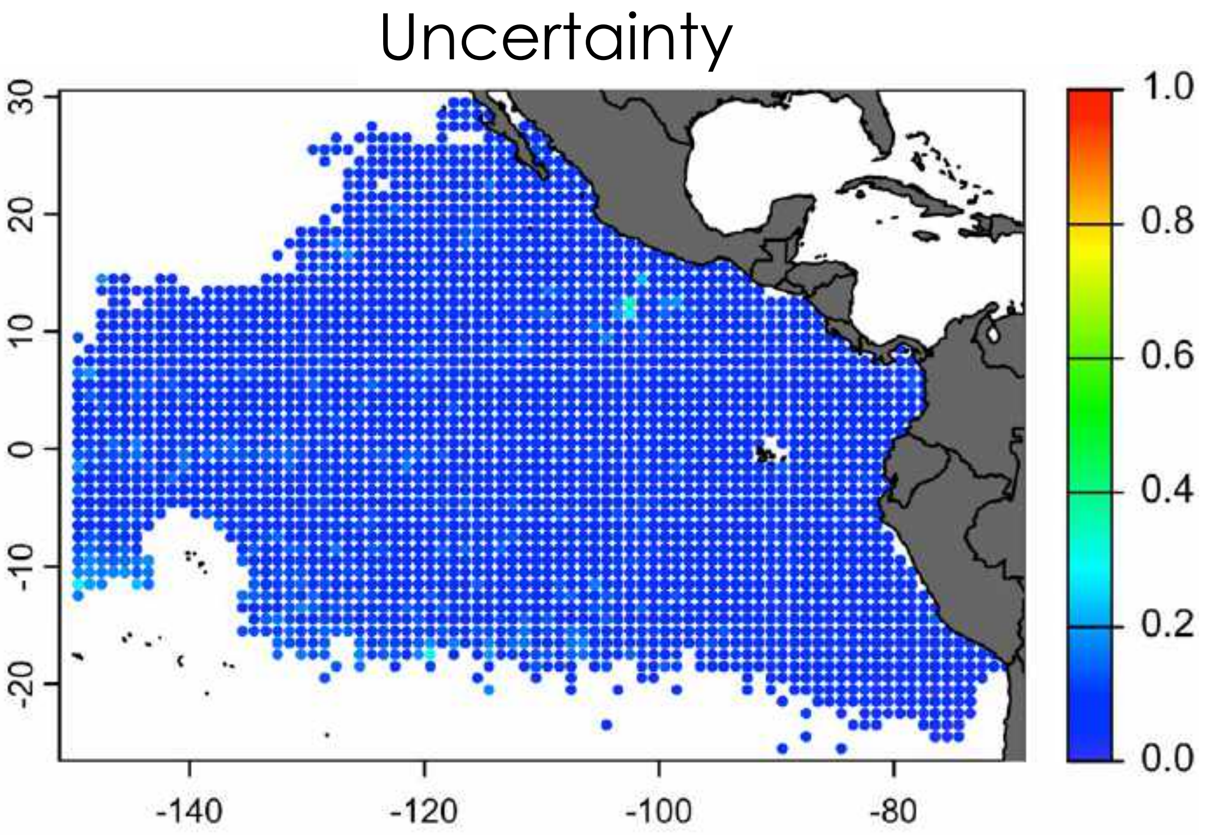
Precense probability



PURSE-SEINE

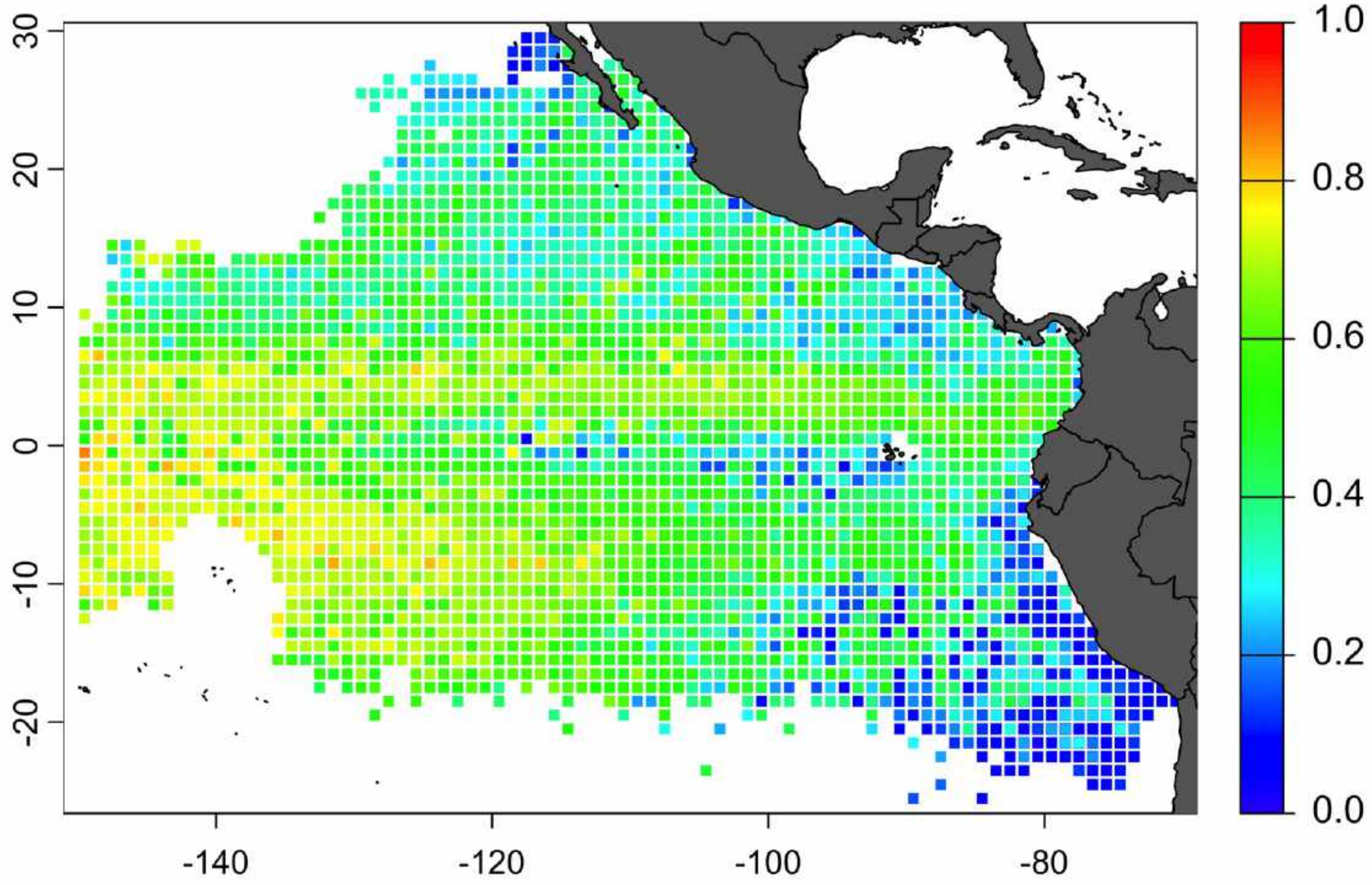
Uncertainty associated to presence probability





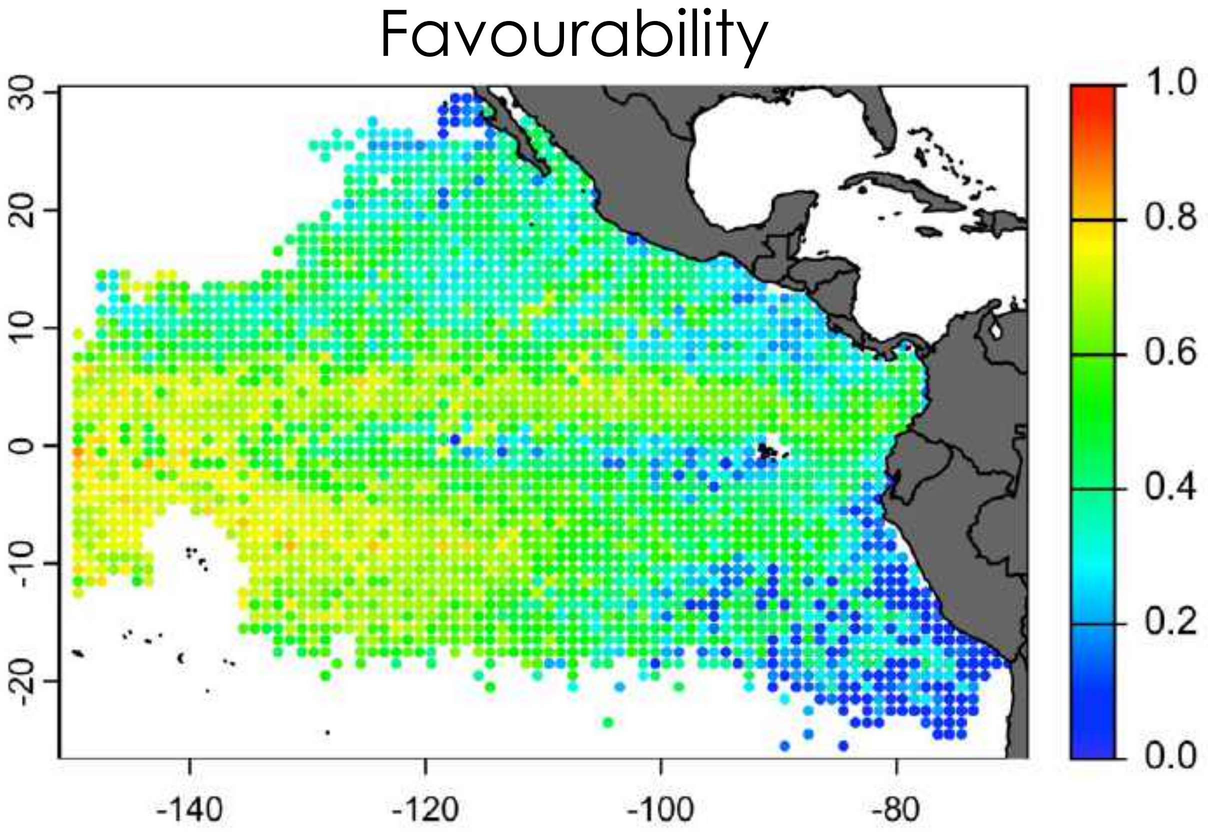
PURSE-SEINE

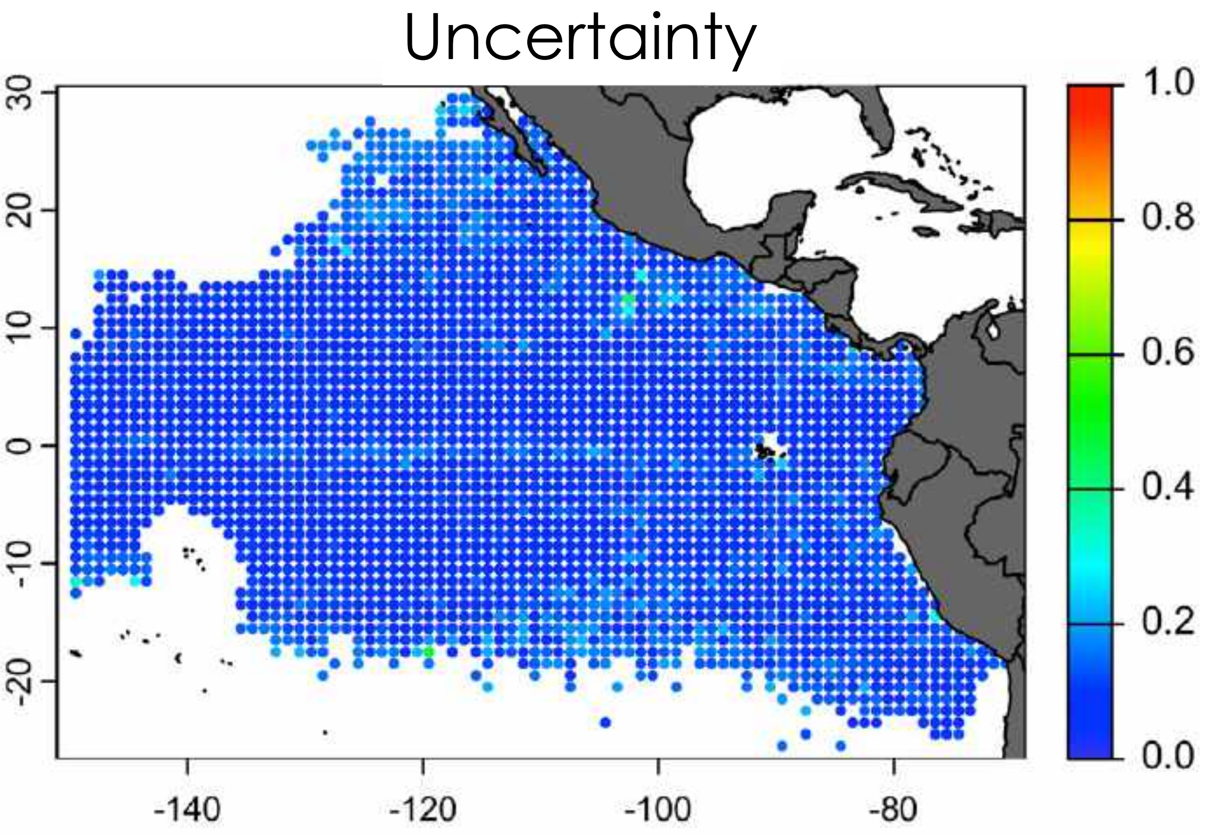
Favourability



PURSE-SEINE

Uncertainty associated to favourability





Aknowledgments

PELAGICOS MAYORES
IPN-CICIMAR

CIAT
IATTC

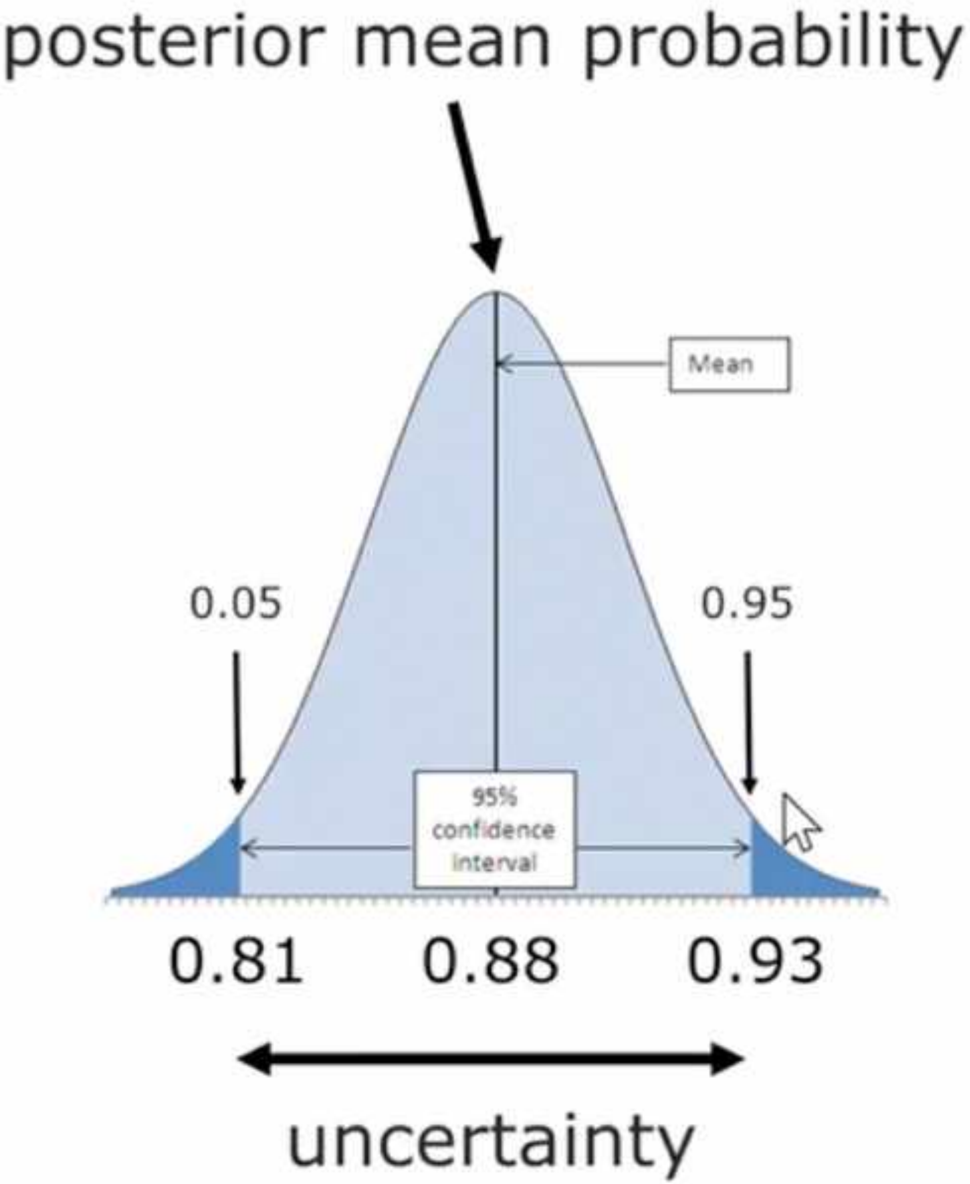
CICIMAR-IPN

BEIFI

CONACYT

Supplementary material

Bayesian Additive Regression Trees (BART)



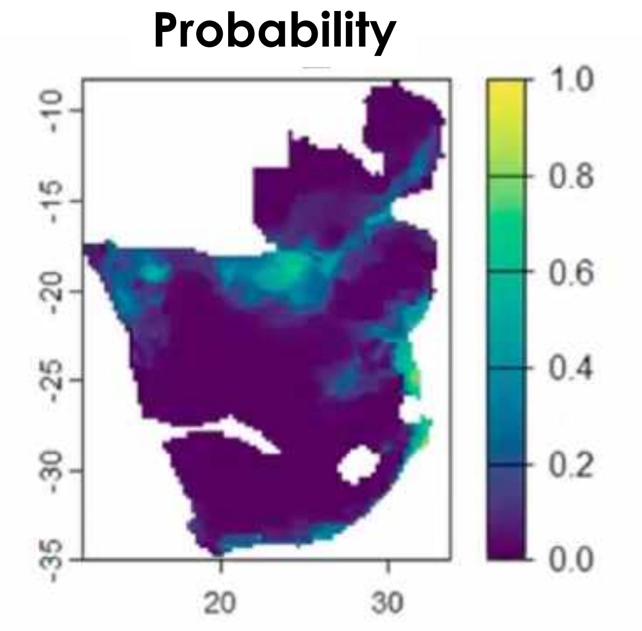
Uncertainty
(Confidence interval)

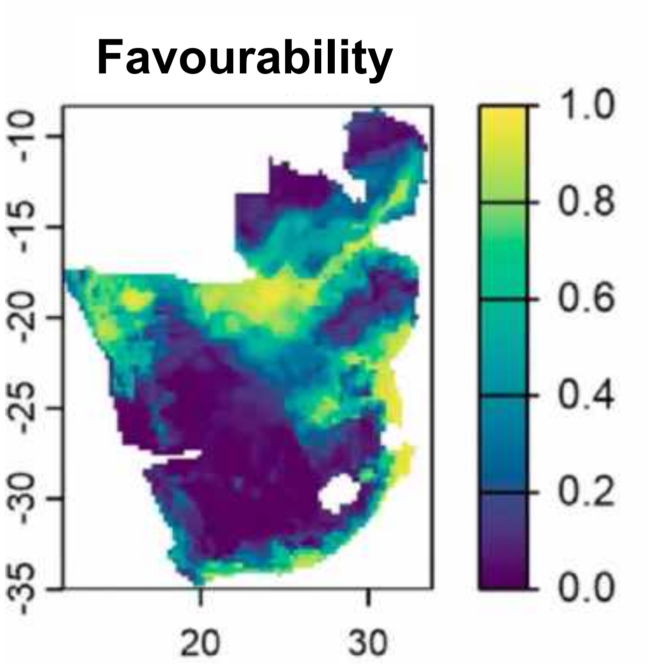
- predict_bart_df
- embarcadero

Bayesian Additive Regression Trees (BART)

Favourability

How much does the environment favor the presence of the species?





Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. Variable selection
4. New model
5. Variable importance
6. Discrimination and Calibration
7. Cross validation

Presence ~ environmental variables

- embarcadero
- dbarts

Methods

Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. Variable selection
4. New model
5. Variable importance
6. Discrimination and Calibration
7. Cross validation

> 0.7

- collinear

Methods

Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. **Variable selection**
4. New model
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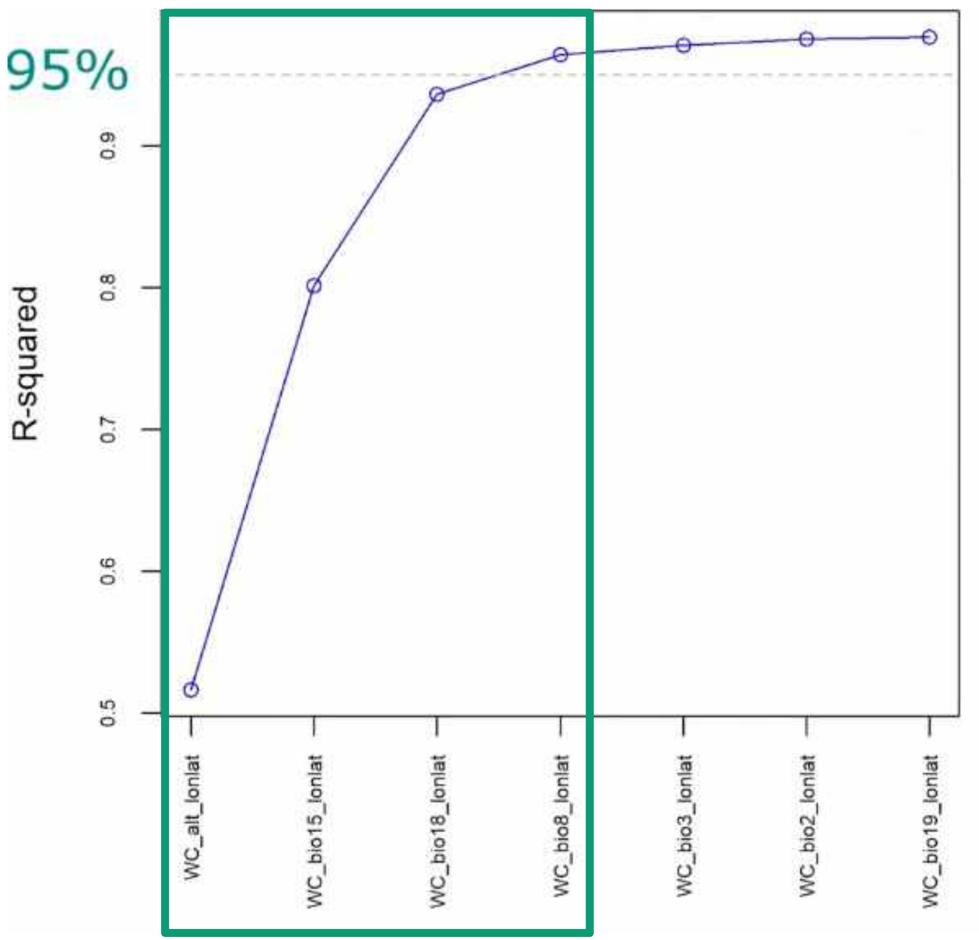

o embarcadero

Methods

Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. Variable selection
4. **New model**
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6. Discrimination and Calibration
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Presence ~ environmental variables

- embarcadero
- dbarts

Methods

Bayesian Additive Regression Trees (BART)

1 Model

2 Correlation between variables

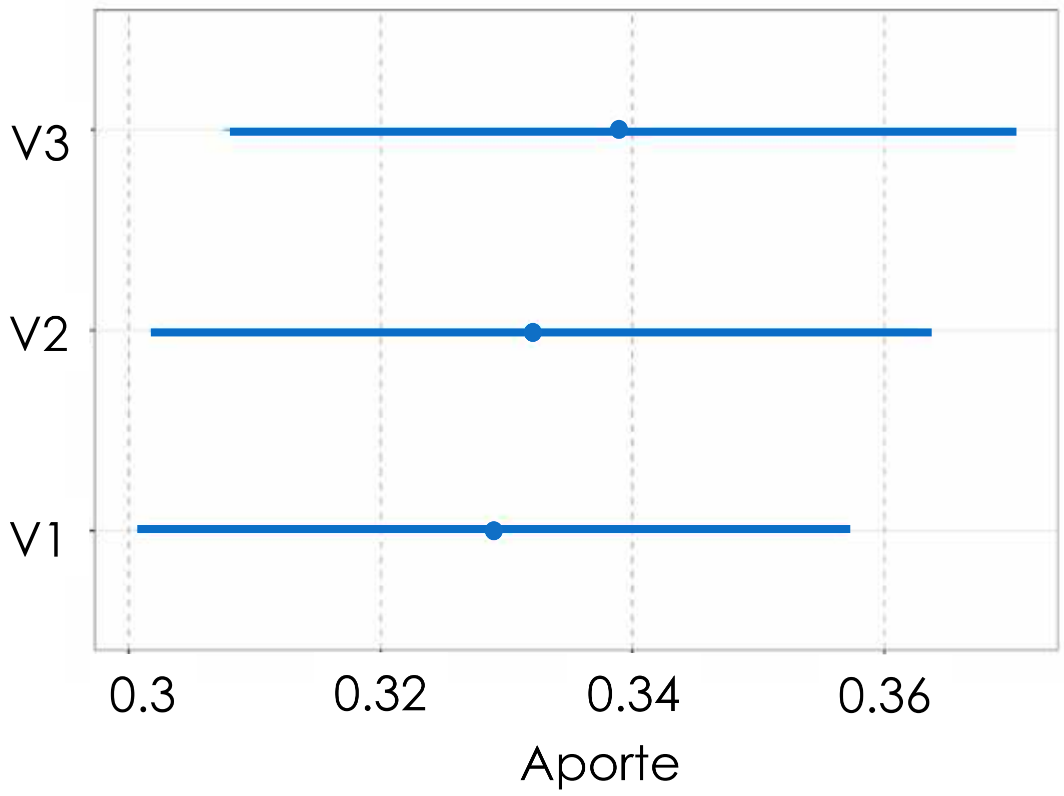
3 Variable selection

4 New model

5 Variable importance

6 Discrimination and Calibration

7 Cross validation



- embarcadero

Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. Variable selection
4. New model
5. Variable importance
6. **Discrimination** and Calibration
7. Cross validation

➢ Ability to distinguish between locations with and without presence

	Range
Sensibility	0 - 1
Specificity	0 - 1
Precision	-1 – 1
TSS	-1 – 1

○ modEvA

Methods

Bayesian Additive Regression Trees (BART)

1. Model
2. Correlation between variables
3. Variable selection
4. New model
5. Variable importance
6. Discrimination and **Calibration**
7. Cross validation

- Ability of the predicted values to reflect the frequency with which the species occurs and its variation over time

Miller Calibration (~1)

- modEvA

Methods

Bayesian Additive Regression Trees (BART)

1 Model

2 Correlation between variables

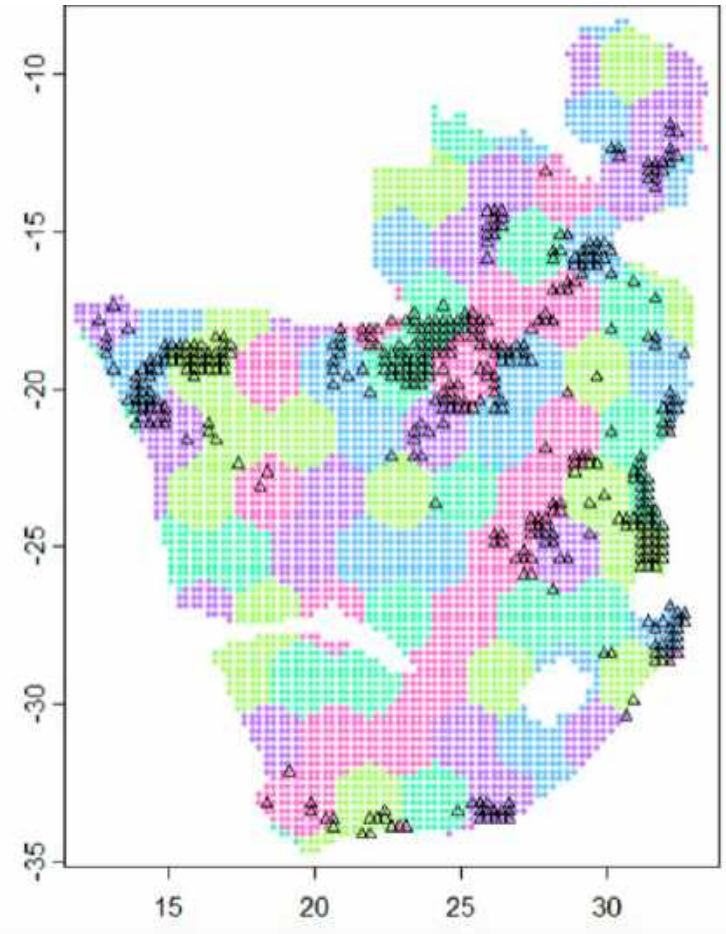
3 Variable selection

4 New model

5 Variable importance

6 Discrimination and Calibration

7 Cross validation



(AUC, TSS, Miller)

- BlockCv
- crossval