Habitat models and their use in bycatch mitigation

Nerea Lezama-Ochoa

Who I am

Nerea Lezama-Ochoa
Postdoctoral researcher UCSC-NOAA
Co-founder of MobulaConservationProject

- Biology degree, University of Navarra (Spain)
- Master degree, University of Barcelona (Spain)
- PhD degree with Hilario Murua, AZTI (Spain)
  - *Biodiversity and habitat preferences of bycatch species in the PS fisheries in the AO, IO & EPO*
- Postdoc researcher, with Martin Hall IATTC (USA)
  - *Habitat preferences of mobulid rays in PS*
- Postdoc researcher, UCSC-NOAA
  - *Climate change projections of HMS in the CCS*
  - *Climate change projections of YFT in Hawaii*

https://nereota1.wixsite.com/nlezamaochoa
https://mobulaconservationproject.com

Index

1. Why habitat models?

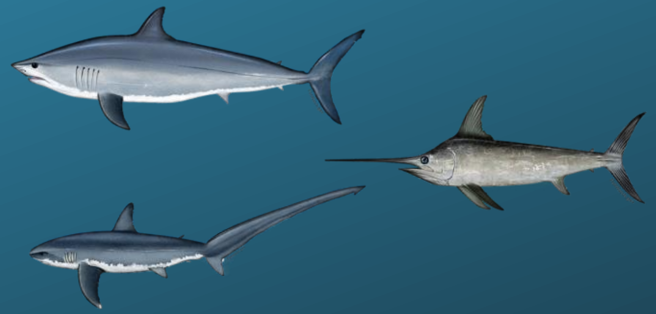
2. What is a habitat model?

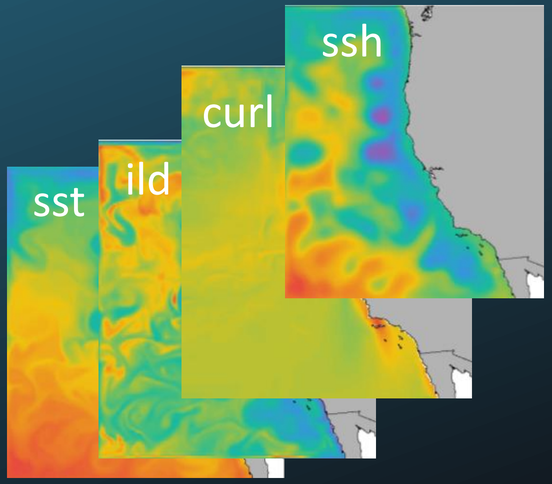
Why habitat models?

- Importance of environment in fisheries
- Vulnerable bycatch species (sharks, mobulids, turtles)
- Need to understand under which fishing operations are caught->try to avoid them
- Need to understand under which env. conditions are found
  - Understand:
    - Present, past
    - Near (annual) & distant (climatic)

What is a habitat model?

Relationship between the presence/abundance of a species and a set of environmental variables

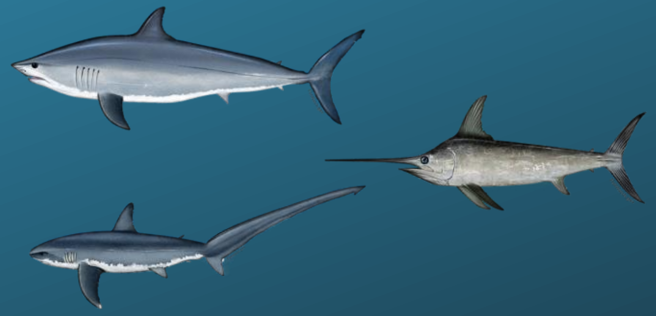




Environmental data

What is a habitat model?

Common names: climate envelope-modeling, habitat modeling and niche-modeling



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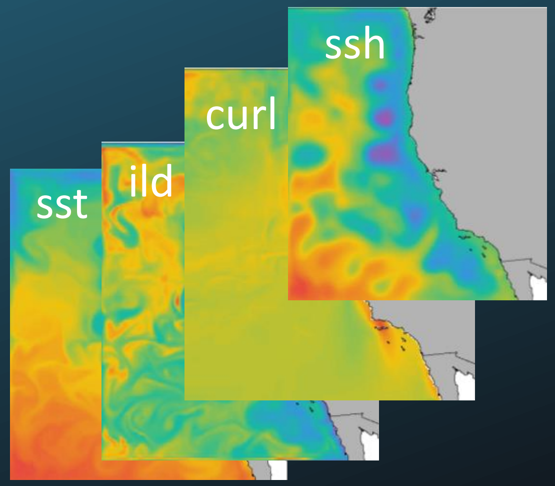


Environmental data

3. Types and sources of data

Data types to build a model

1. Personal collection: occurrences can be obtained during field sampling (i.e. diving)
2. Longer planned sampling (voluntary)
3. Data collection from natural history museums
4. Public data (online)

Global Biodiversity Information Facility (GBIF)

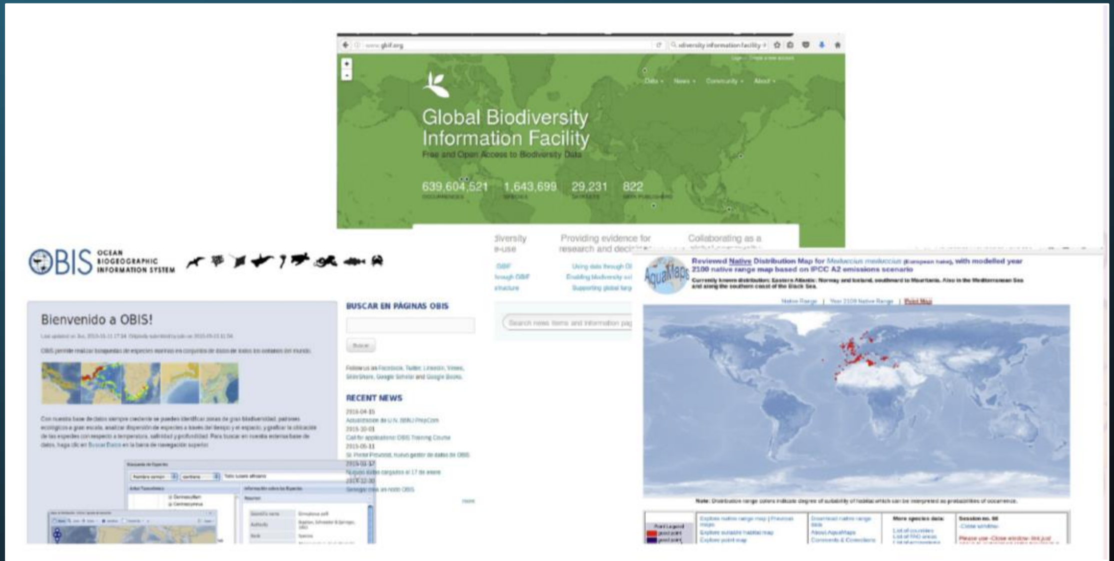
Registro 1066002662 (gbif.org)

Aquamaps

AquaMaps Search Page

Ocean Biogeographic Information System (OBIS)

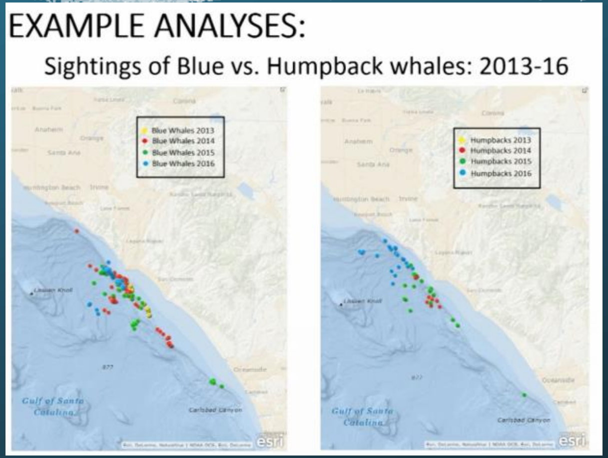
Ocean Biodiversity Information System (obis.org)



Data types to build a model

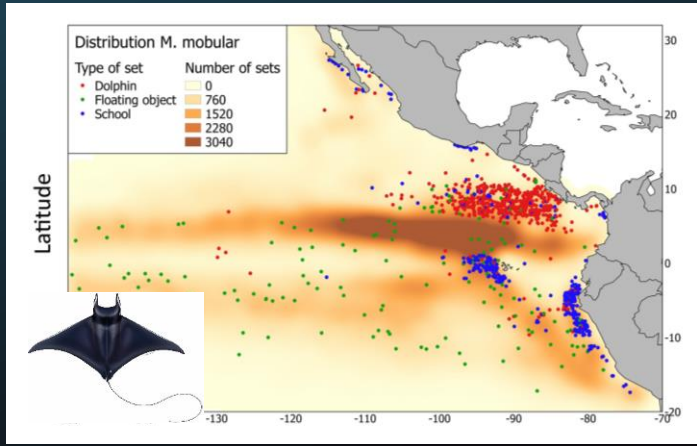
5. Opportunistic data collection (fisheries, sightings)
6. Scientific sampling (marking)

Sighting data
- **Presences**
- **Densities**



Tracking data
- **Satellite**
- **Acoustic**
- **Archive**

Fisheries data
- **Presences & Absences**
- **Abundances**



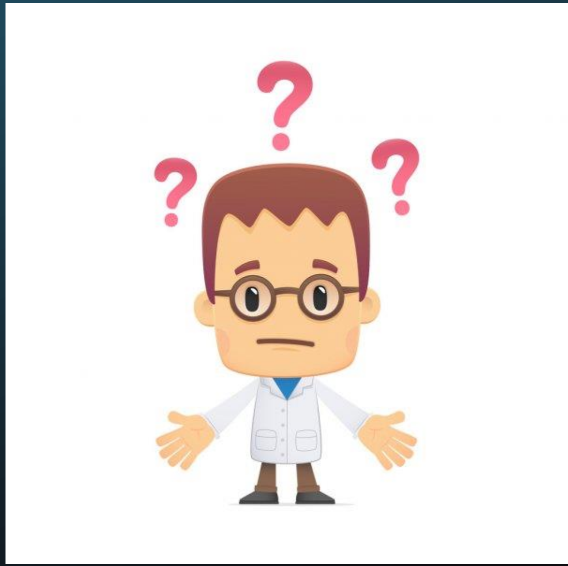
Data of the species of interest

The distribution species data can be:

1- Presence-data only: positions where the species has been observed

2- Presences & Absences: presence and absences of the species in the sampled locations

3- Abundance: number of individuals or weight of the species (kg or tons)



- **Background presences & pseudo-absences**

Data of the species of interest

Research | Open Access | Published: 17 February 2021

Where did they not go? Considerations for generating pseudo-absences for telemetry-based habitat models

Elliott L. Hazen, Briana Abrahms, Stephanie Brodie, Gemma Carroll, Heather Welch & Steven J. Bograd

Movement Ecology **9**, Article number: 5 (2021) | Cite this article

1. **Background sampling**

- Random locations are sampled across the entire domain

2. **Buffer sampling**

- Random locations are sampled within a certain distance from each presence location

3. **Correlated-random walks**

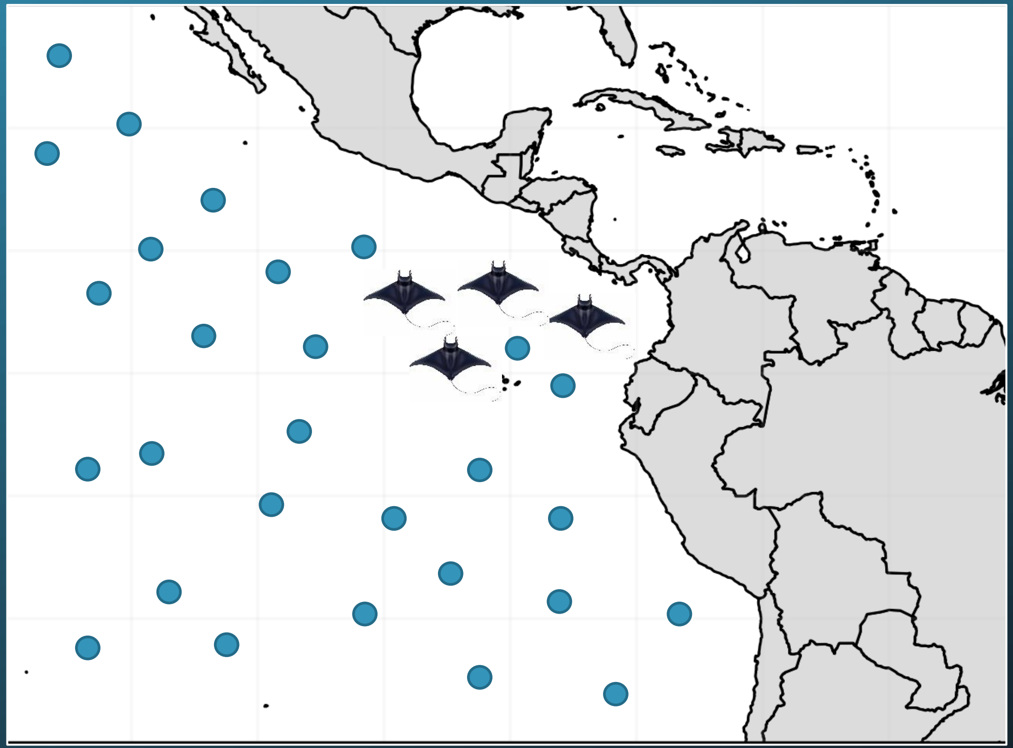
- Tracks are simulated from given start or end points respectively, based on observed step lengths and turn angles

***Pseudo-absences :**

- **Pseudo-absences based on environmental variables: selection of pseudo-absences in areas that are environmentally different from points of presence**

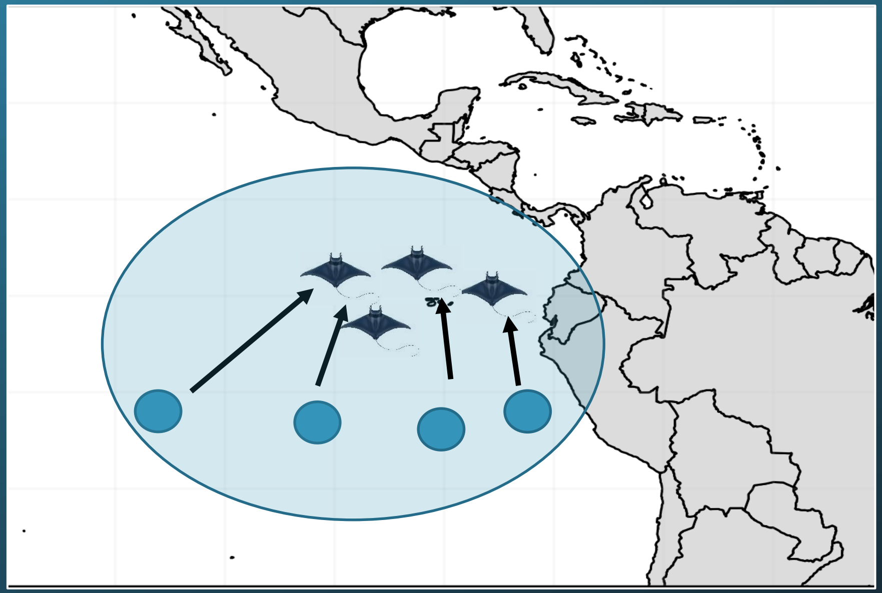
Data of the species of interest

1. Background sampling: Random locations are sampled across the entire domain



Data of the species of interest

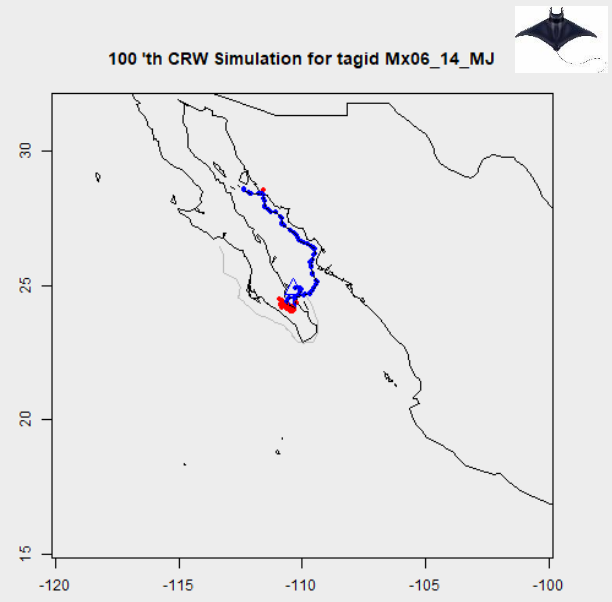
2. Buffer sampling: Random locations are sampled within a certain distance from each presence location



Data of the species of interest

3. Correlated-random walks

Tracks are simulated from given start or end points respectively, based on observed step lengths and turn angles



Data of the species of interest

Methods in Ecology and Evolution
BRITISH ECOLOGICAL SOCIETY

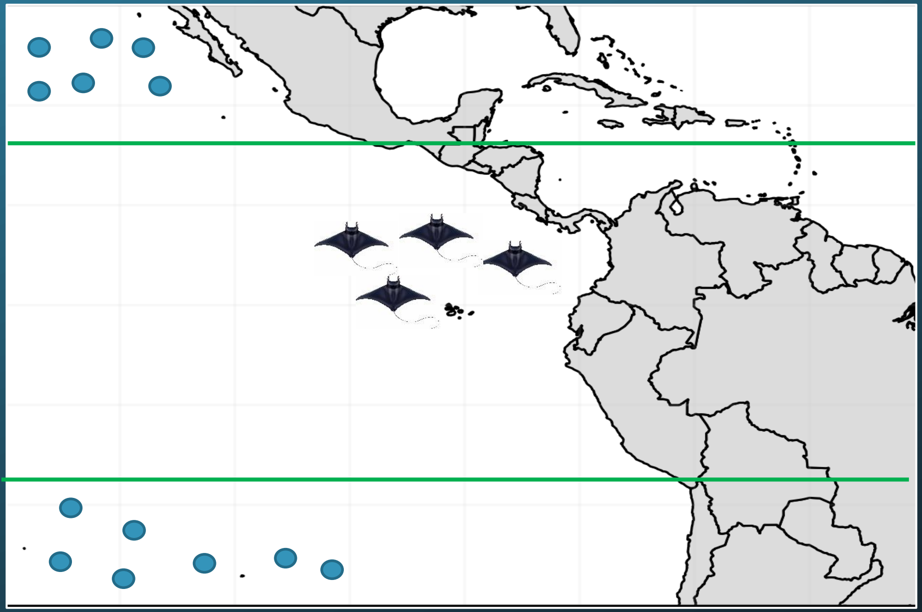
Free Access

Selecting pseudo-absences for species distribution models: how, where and how many?

Morgane Barbet-Massin, Frédéric Jiguet, Cécile Hélène Albert, Wilfried Thuiller

First published: 19 January 2012 | https://doi.org/10.1111/j.2041-210X.2011.00172.x | Citations: 1,068

***Pseudo-absences based on environmental variables: selection of pseudo-absences in areas that are environmentally different from points of presence**



Environmental variables

Environmental variables

Environmental variables can be used for very different Species Distribution Models. The most commonly used variables are related to:

- Oceanographic characteristics: temperature, salinity, etc.
- Topography: bathymetry
- Habitat type: coral, sandy, etc.

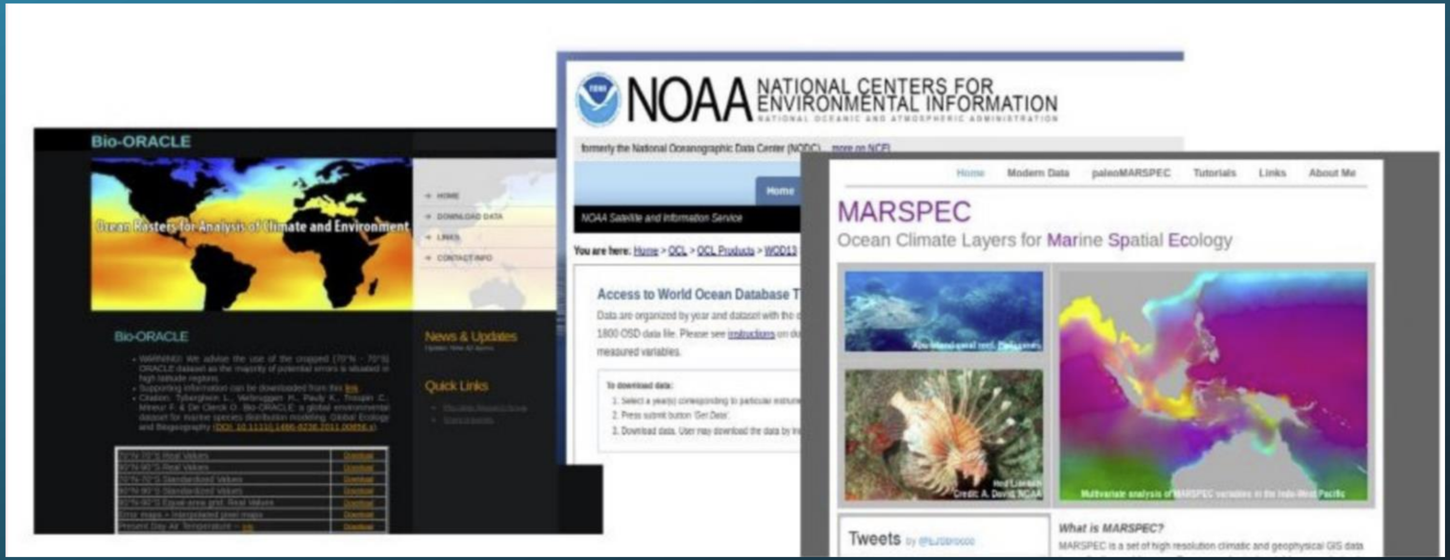
The environmental variables, in turn, can be classified as:

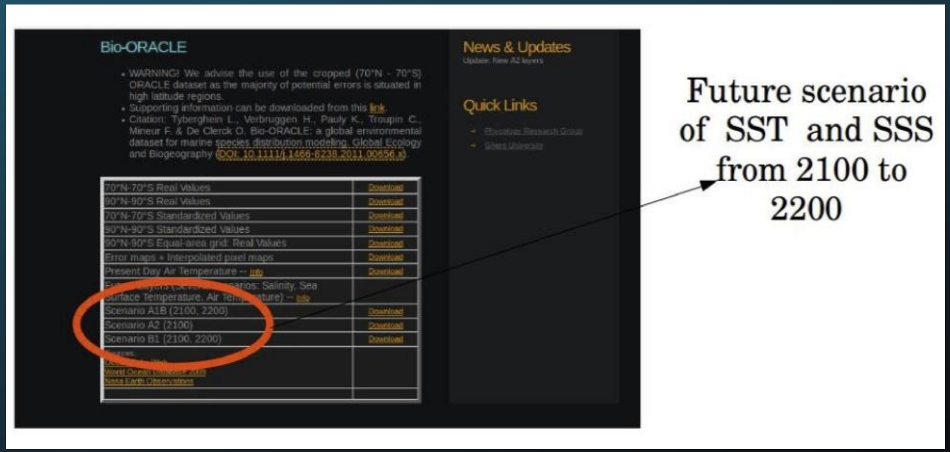
- Continuous variables: can take any value within a certain range (temperature)
- Categorical variables: they are divided into different categories (habitat type)

Environmental variables

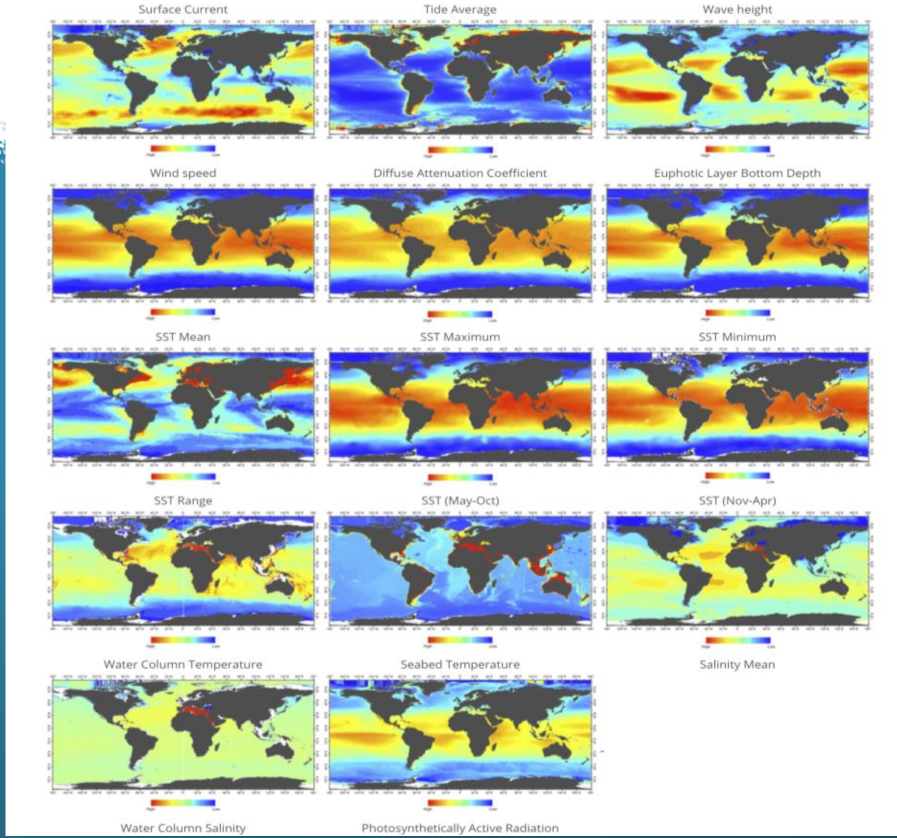
How do we obtain environmental variables?

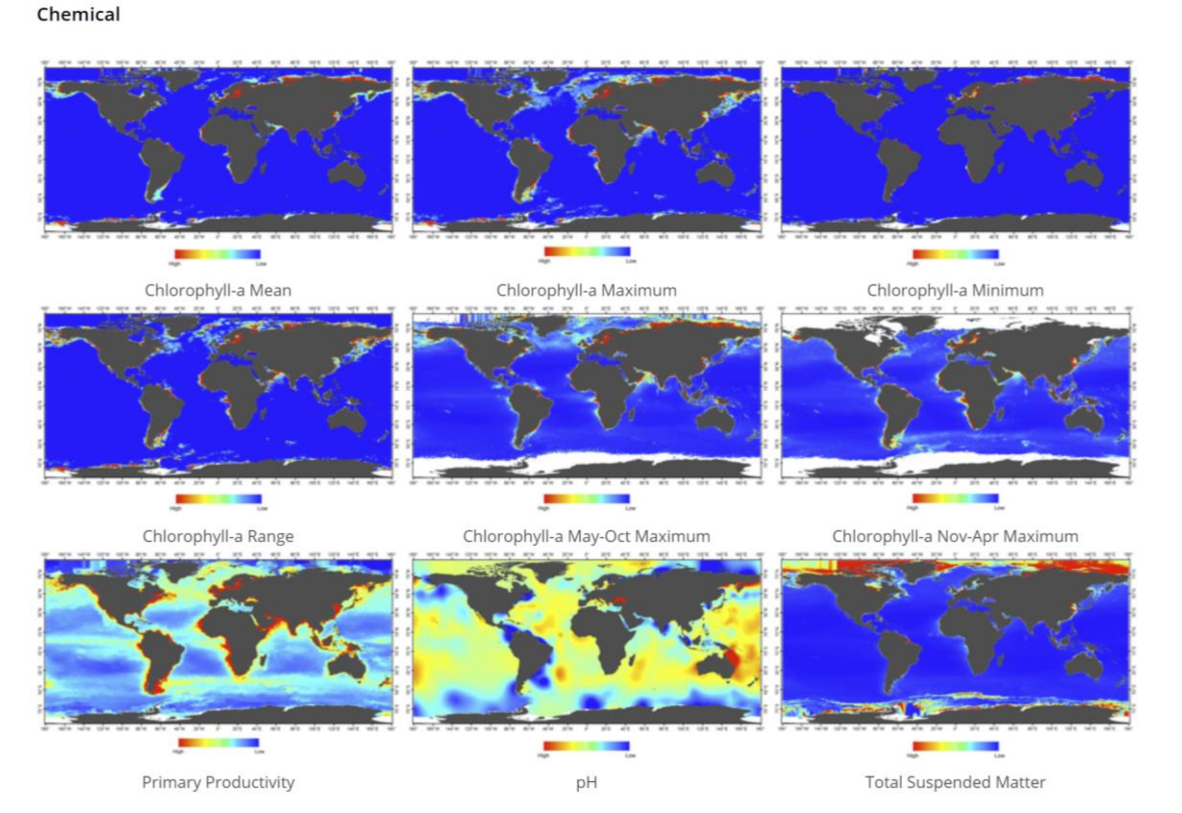
- Data collected locally: places where the species has been observed or research stations
- Remote sensing (satellite-observations): atmospheric and terrestrial products (chlorophyll, temperature)
- **Ocean models: climate change scenarios or past**





Environmental variables

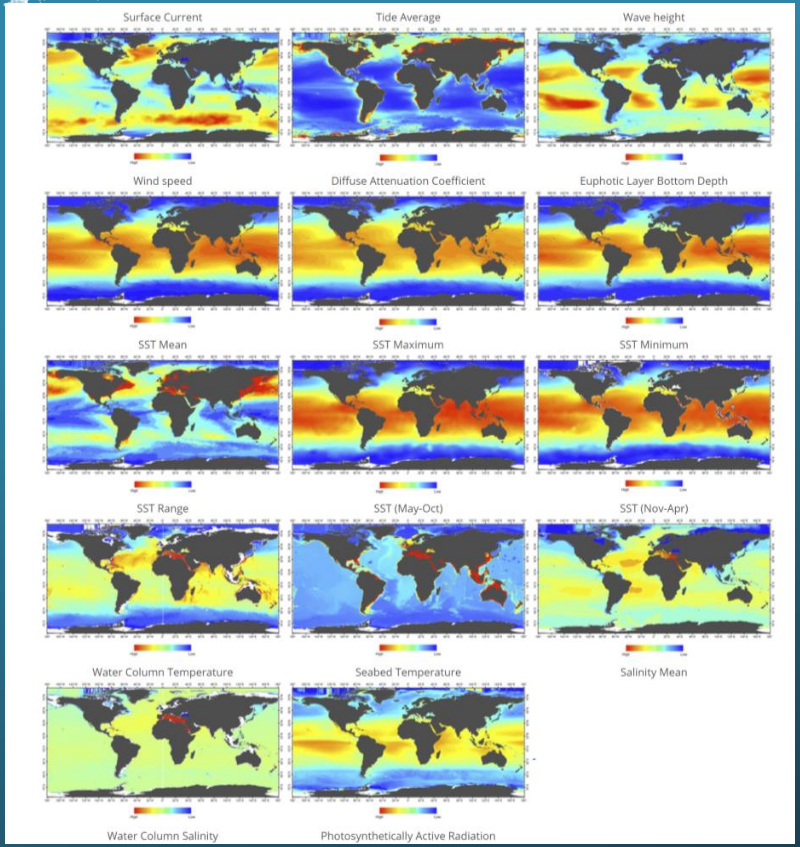




Physical variables
(temperature, salinity, current,...)

Chemical variables & nutrients
(Chlorophyll, pH, nitrate...)

Environmental variables



Repositories/databases (raster or .nc format)

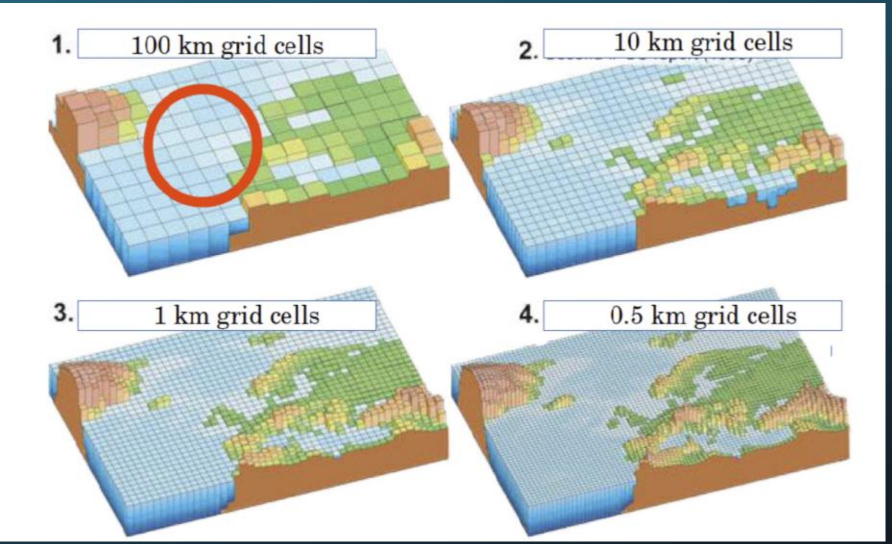
- Servidor de la NOAA
  - https://coastwatch.pfeg.noaa.gov/projects/r/
  - https://coastwatch.pfeg.noaa.gov/erddapinfo/index.html
- Copernicus
  - CMEMS (copernicus.eu)
- CLS
  - Applications & Services - CLS
- GMED
  - ..: GMED - Global Marine Environment Datasets :.. (auckland.ac.nz)
- Bio-Oracle
  - Bio-ORACLE : Marine data layers for ecological modelling (bio-oracle.org)
- GEBCO (batimetría)
  - https://neo.sci.gsfc.nasa.gov/view.php?datasetId=GEBCO_BATHY
- MARSPEC
  - http://www.marspec.org/
- WORDCLIM
  - WorldClim

Environmental variables

IMPORTANT: You have to take into account the spatial scale before choosing the data
The spatial scale has 2 components:

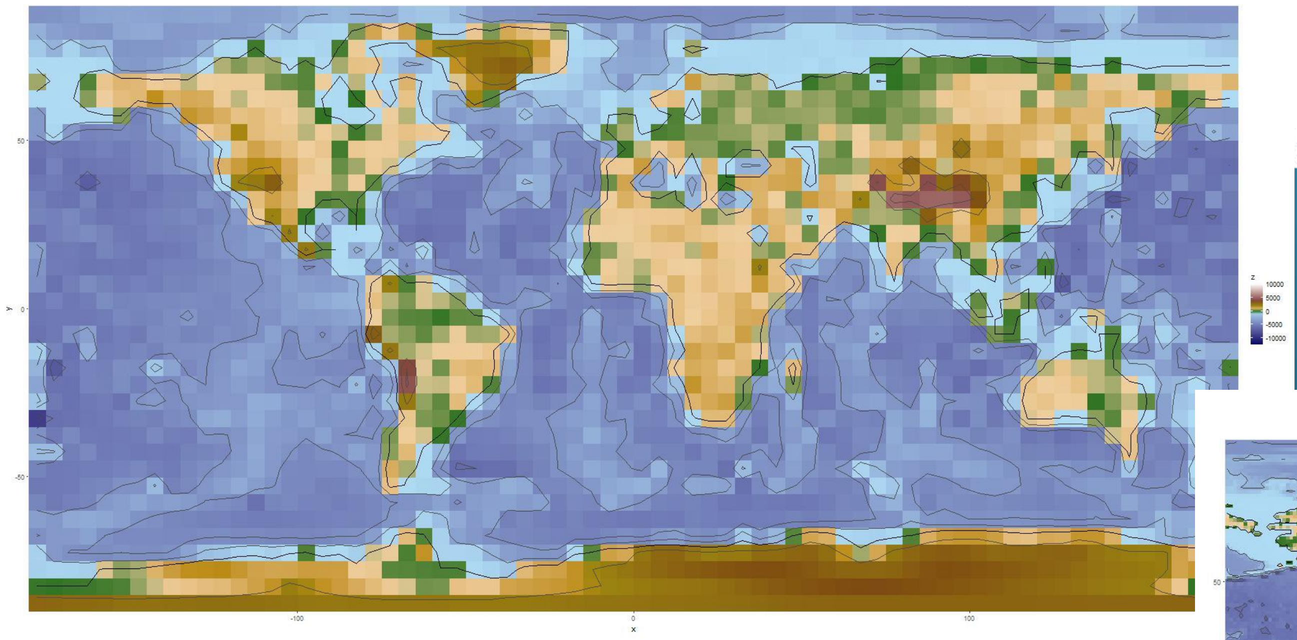
- **Extension: the size of the region where the model is to be run**

- **Resolution:**
    - **Temporary (annual, monthly, daily)**
    - **Spatial (size of cells)**



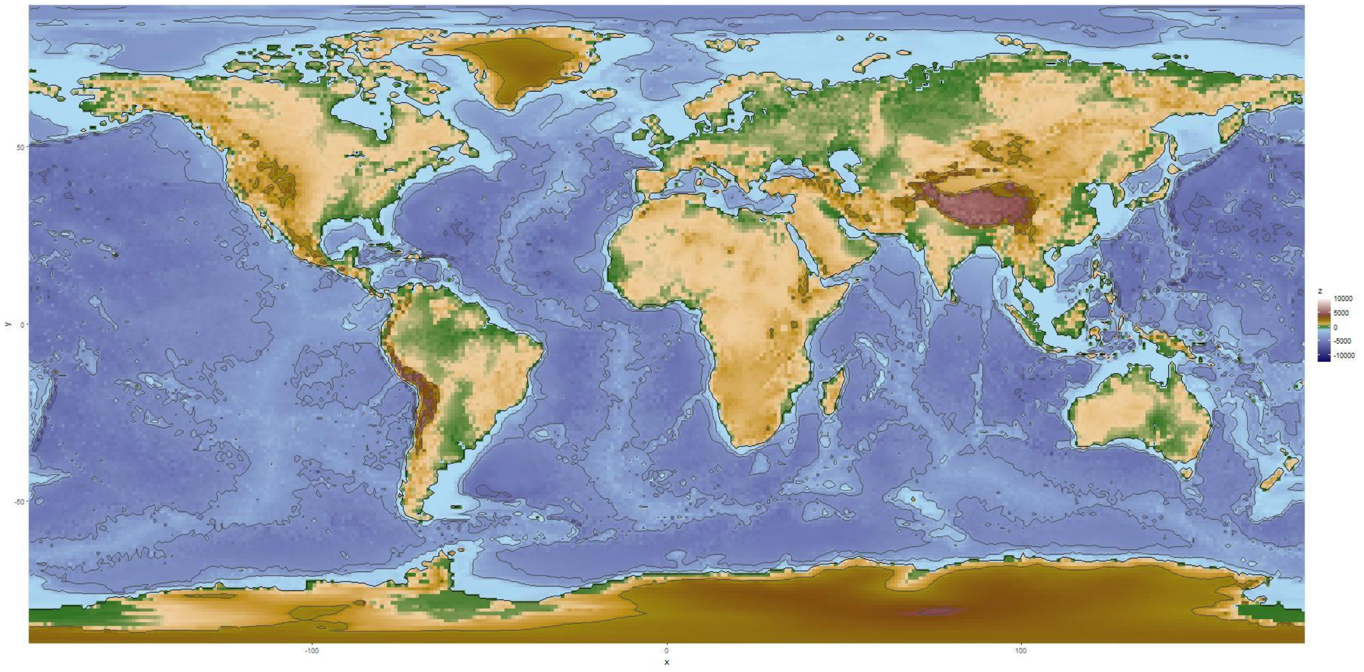
The resolution to study the distribution of the turtle in Baja California is not the same as throughout the Pacific
There is not always data at high resolution or it may be unfeasible (too much computational cost)

Environmental variables



5ºx5º

0.5ºx0.5º

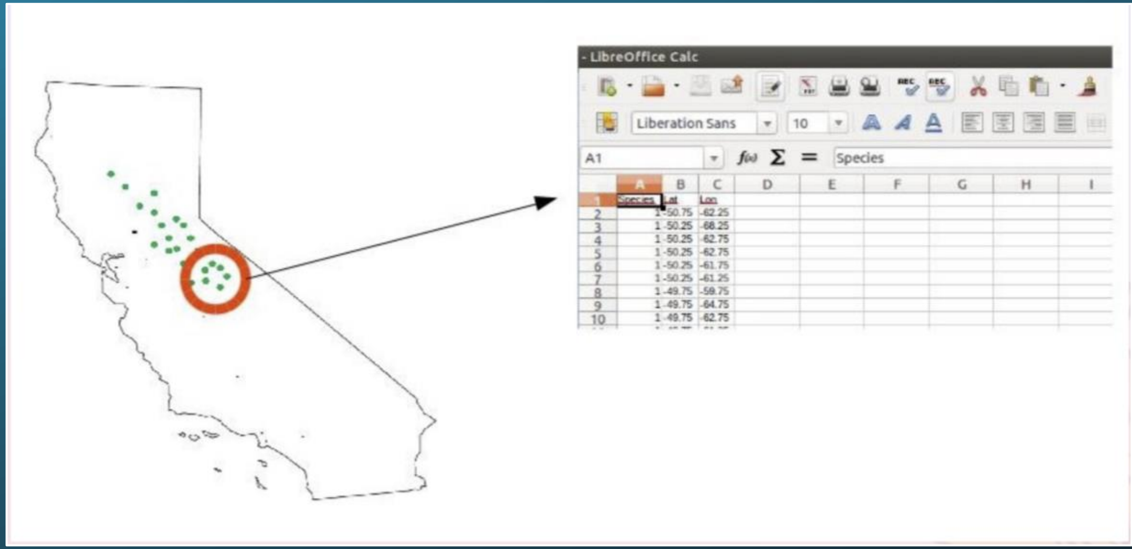


4. Model build: format

Formats for building a model

What do we need?

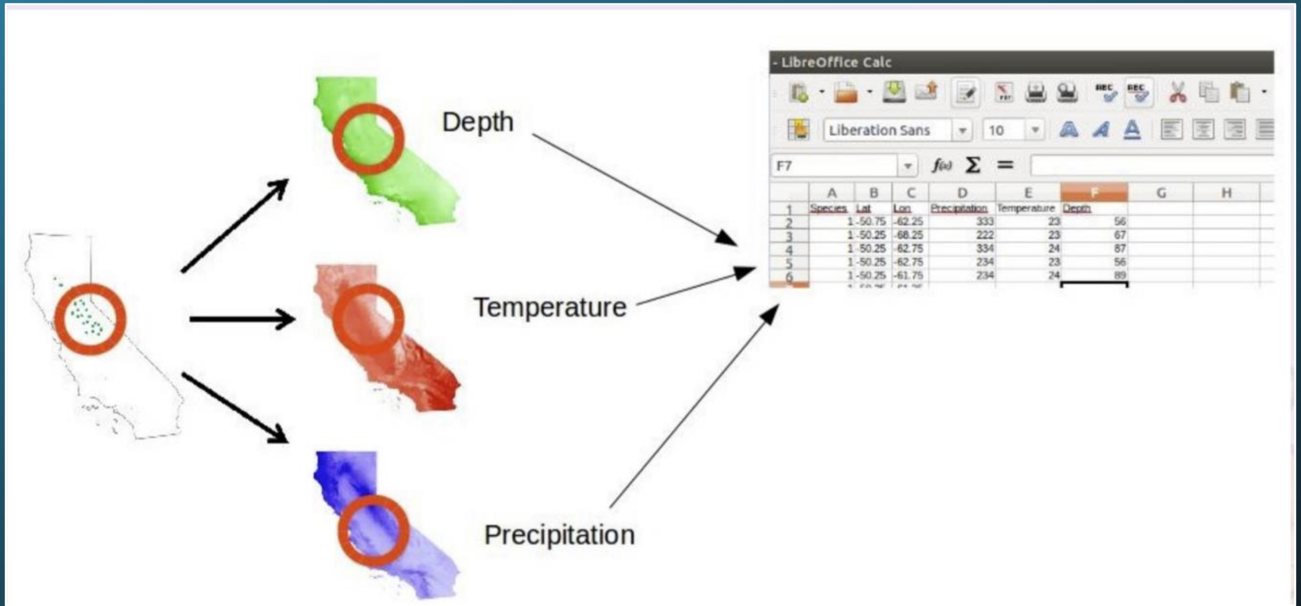
1. **Location of the ocurrence of the species**
   (each row is a position for each set)



Formats for building a model

What do we need?

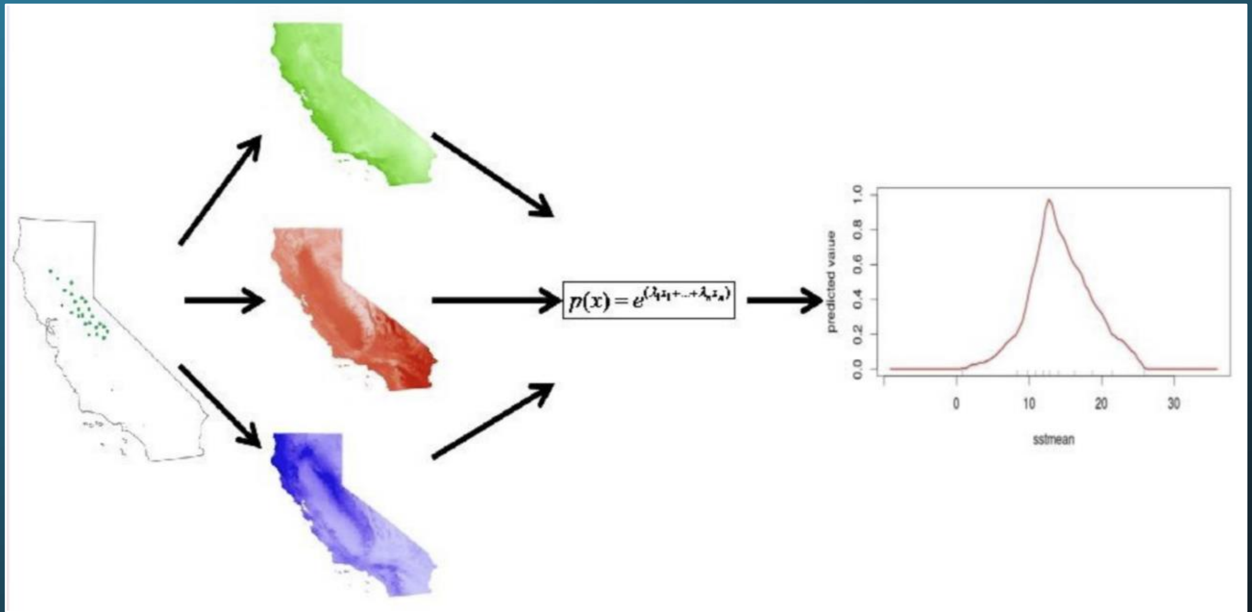
2. **Values of the env. variables of these locations**
   Each column we Will have the response variable (prsence-absence) + env. variables



Formats for building a model

What do we need?

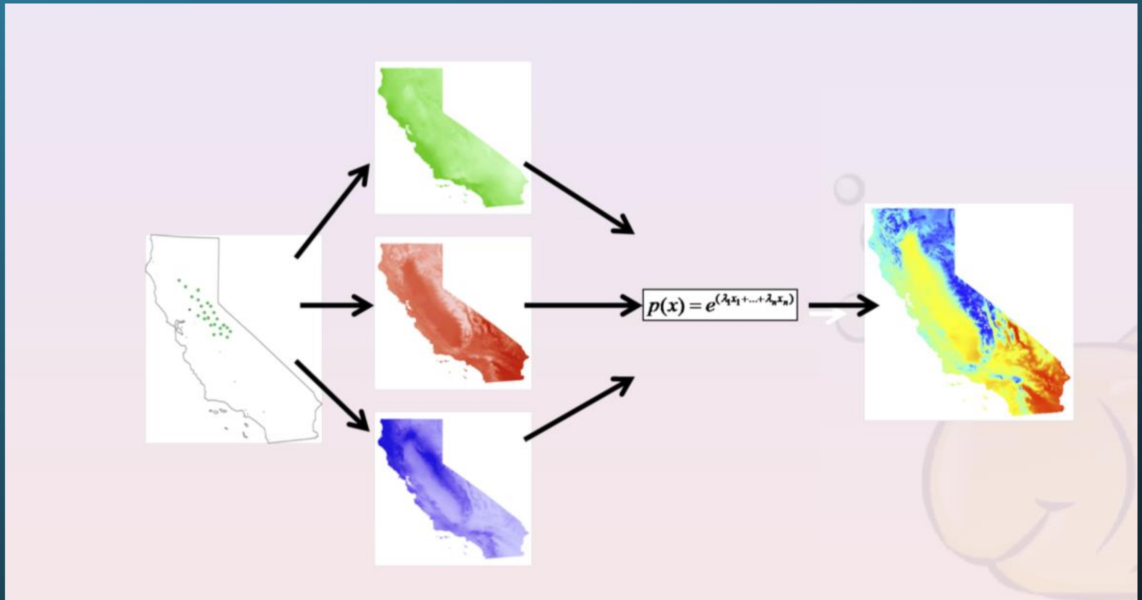
3. **Find relationships between the response variable and the env. Variables or use env. Variables to predict the occurrence of the species**



Formats for building a model

What are we going to do?

4. Once these relationships are found, the occurrence of the species in the area of interest (also past or future) is extrapolated and predicted.



4. Model build: Type of algorithms

Types of algorithms

- There are a large number of algorithms that have been applied to classify the probability of occurrence of a species (and its absence) based on a set of environmental variables.

- Its main task is to potentially identify complex linear and non-linear relationships in a multi-dimensional environmental space and predict the distribution of a species in unsampled areas or in future (or past) time periods.

sdm.pdf (uaem.mx)

Types of algorithms:

Presence only:

- Envelope-model: software BIOCLIM
- Gower Metric: software DOMAIN

Presence + background:

- Maximum Entropy: model/software MAXENT
- ENFA (Ecological Niche Factor Analysis): software BIOMAPPER

⚠ These methods focus on relating how the environment in which the species occurs with the environment throughout the rest of the study area (the background), including the points with occurrence

Types of algorithms

Presence + absences (or pseudo-absences)

- Genetic algorithm: GARP software
- Articial Neural Network (ANN): software SPECIES
- Regression: generalized linear model (GLM), generalized additive model (GAM), boosted regression trees (BRT), Random Forest (RF), multivariate adaptive regression splines (MARS)

Some of these may also include abundancies
Black Boxes (BRT, RF)

Points with occurrences in the generation of pseudo-absences are excluded

Types of algorithms

Okay... but which one do I use?
Initial reflection:
1- What kind of data do I have (presence?)
2- What kind of data (continuous, categorical)
3- What environmental data do you have access to?
3- What is the extent and resolution of this data?
4- What is the question to answer? Prediction or estimation?

4. Model build: Model Selection

Model selection

- Once the algorithm to use is decided, we need to select the best model from the set of potential predictors
- Previous steps to select the model:
  - Study of collinearity-correlation of variables
  - Variance Inflation factor (VIF)
  - What interactions I include
- Model selection attempts to simplify this task: test the accuracy of the prediction
  - Backward or Forward stepwise
  - Akaike Information Criteria (AIC); Deviance Information Criteria (DIC)

There is NO such thing as the perfect model

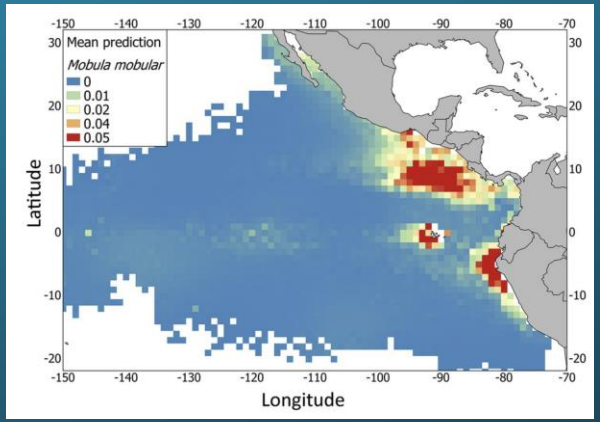
"Ensemble model"

Knowing the species is important

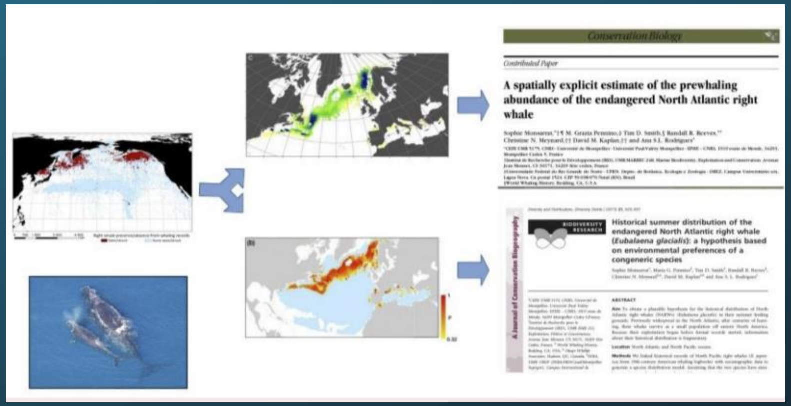
4. Model build: Prediction

Prediction

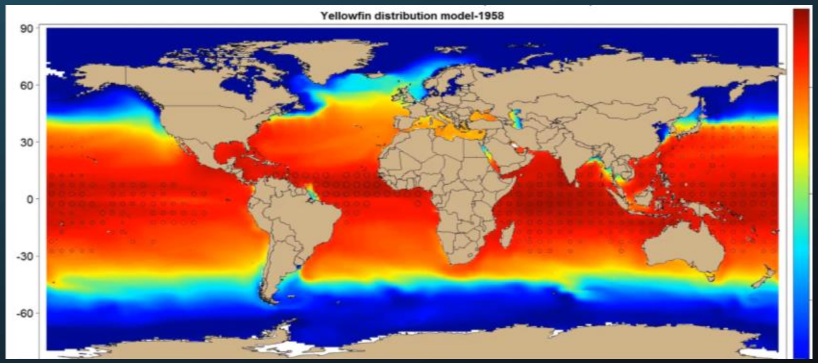
1- Predict on the same points: identify relationships with the medium (useful if we have the entire grid covered)
2- Predict about unsampled areas: identify new areas
3- Projection in the past
4- Projection in the future (under climate change scenarios)



Predict new areas

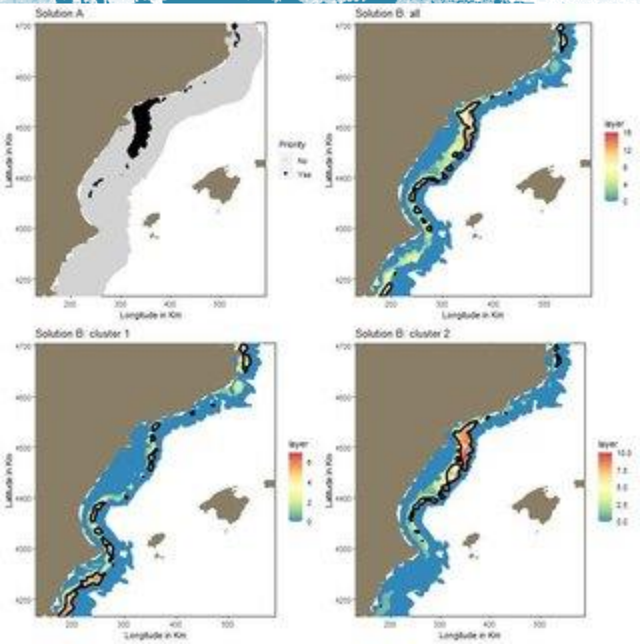


Projecting the past

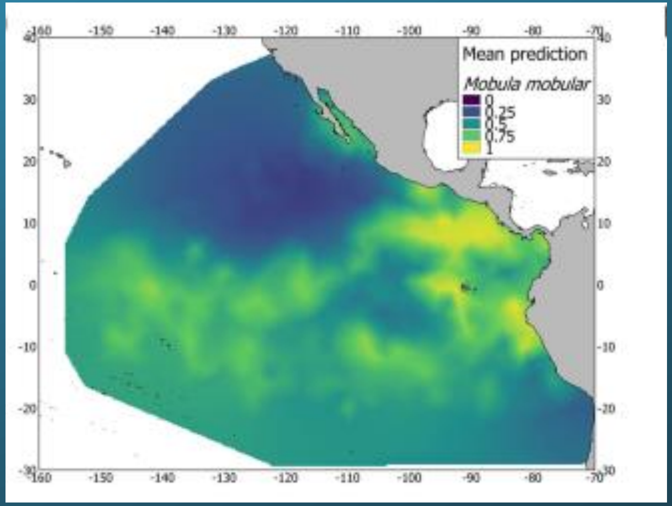


Projecting the future

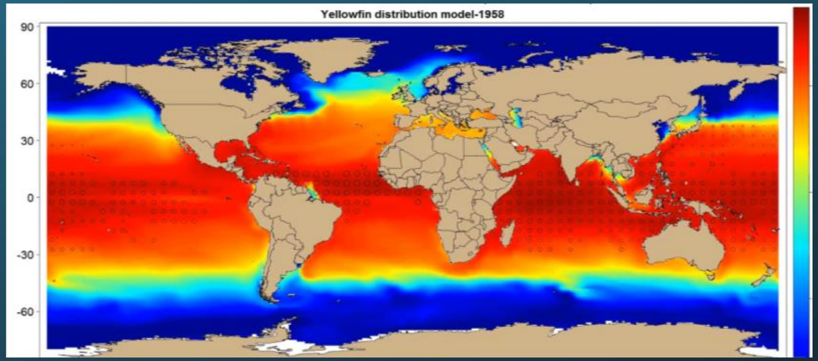
Different spatial scales of prediction



Small scale: Mediterranean Sea



Midscale: Pacific Ocean



Large scale: Global*

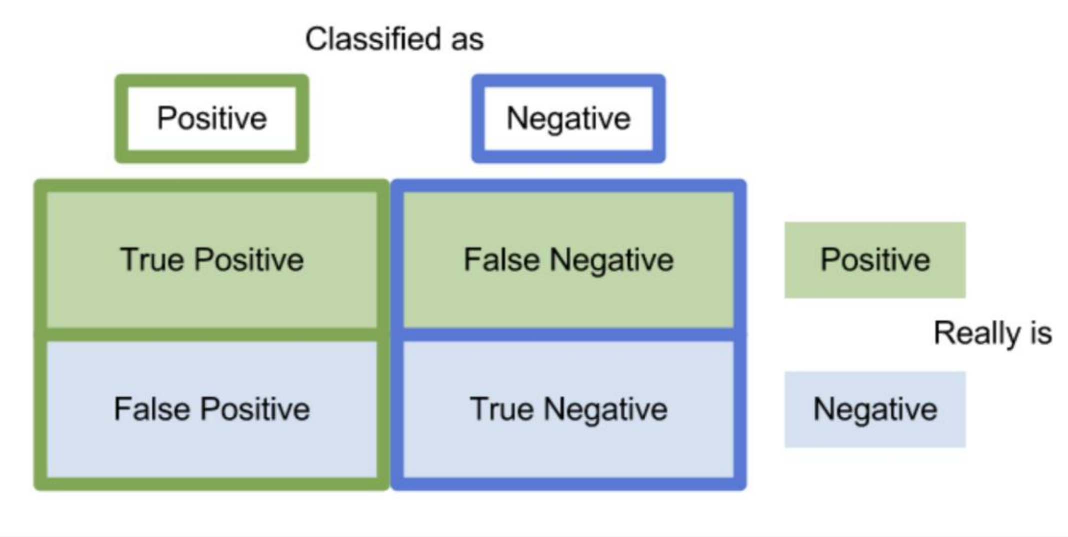
4. Model build: Validation

How good is the prediction?

- Assess the accuracy of model predictions: **validation**
-
- How? Comparing the prediction with another dataset
    - Ideal! Independent data (tracking data)
    - Another option: cross-validation (repeated k times=10)
        - Divide the dataset into 2 parts:
            - **Training data**: used to train & fit the model
            - **Test data**: used to evaluate the model

*Another option: run the model for a few years, validate it with others

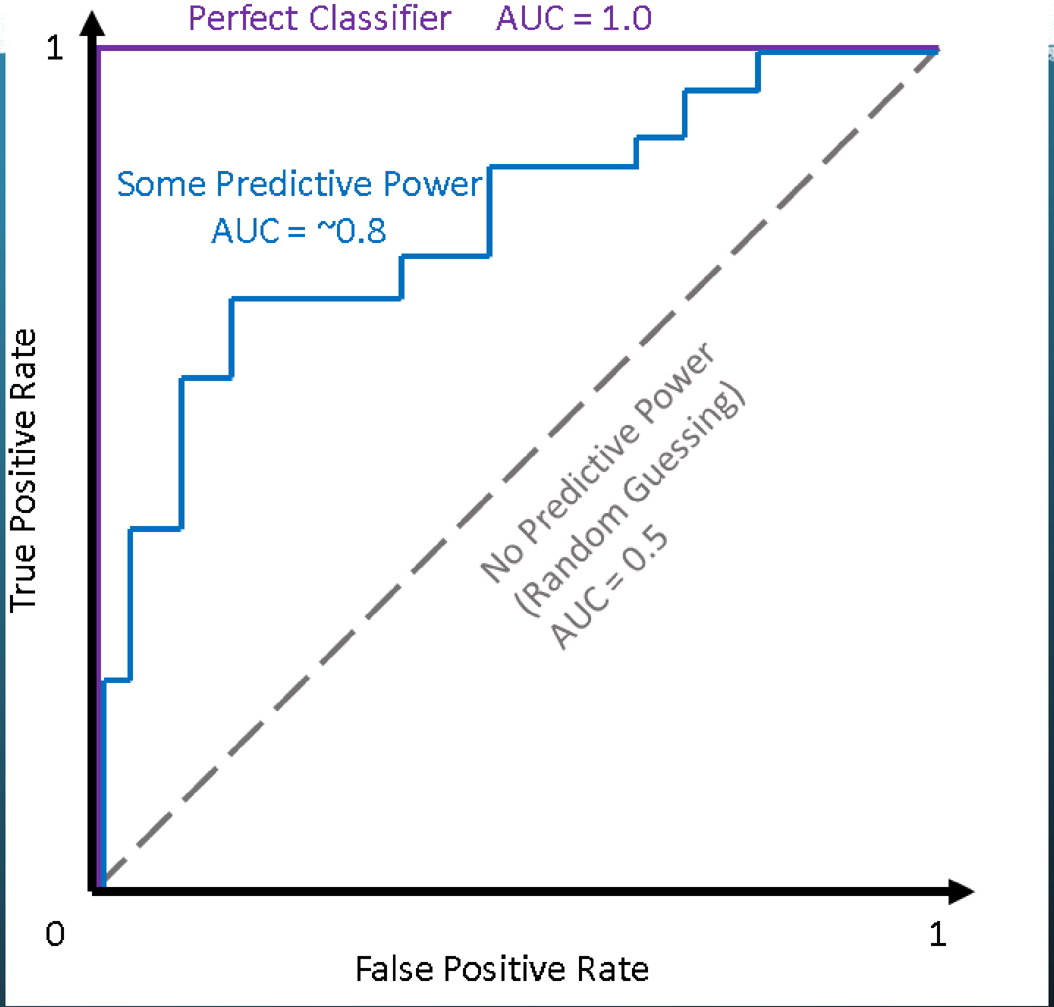
How good is the prediction?



- **True Positive:** The model predicts that the species is present and the test (observation) confirms it
- **False Positive:** The model predicts presence, but the test shows absence
- **False Negative:** The model predicts absence, but the test shows presence
- **True Negative:** The model predicts absence and the test shows absence

Area under the Curve (AUC): Correctly predicted presence ratio (0-1)
Sensitivity: ratio of correctly predicted presences (0-1)
Specificity: proportion of correctly predicted absences (0-1)

How good is the prediction?



4. Model build: Practical examples

- Distribution of *Mobula Mobular* in the Eastern Pacific

Practical example: Distribution of *Mobula Mobular* in the Eastern Pacific

Generalized Additive Model (GAM) (binomial; log-link function)

Response variable (Occurrence) → Independent variables (Oceanographic) → Prediction (Probability of occurrence)

Practical example: Distribution of Mobular Mobula in the Eastern Pacific

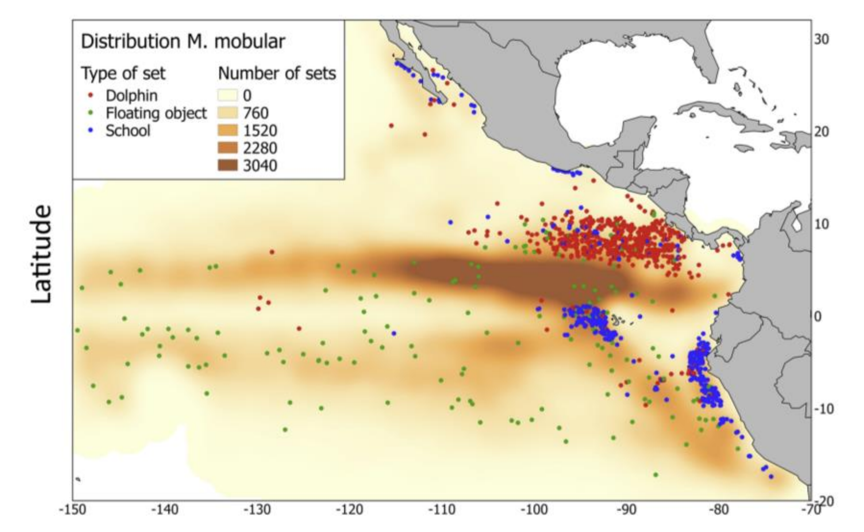
Generalized Additive Model (GAM) (binomial; log-link function)

Data

- 1270 occurrences of Mobula mobular observer IATTC
- 2005-2015

Environmental data

- Copernicus Marine Environment Monitoring Service (CMEMS)
- For each set (date and position for the years 2005-2015)
- Daily resolution
- 0.25° spatial resolution

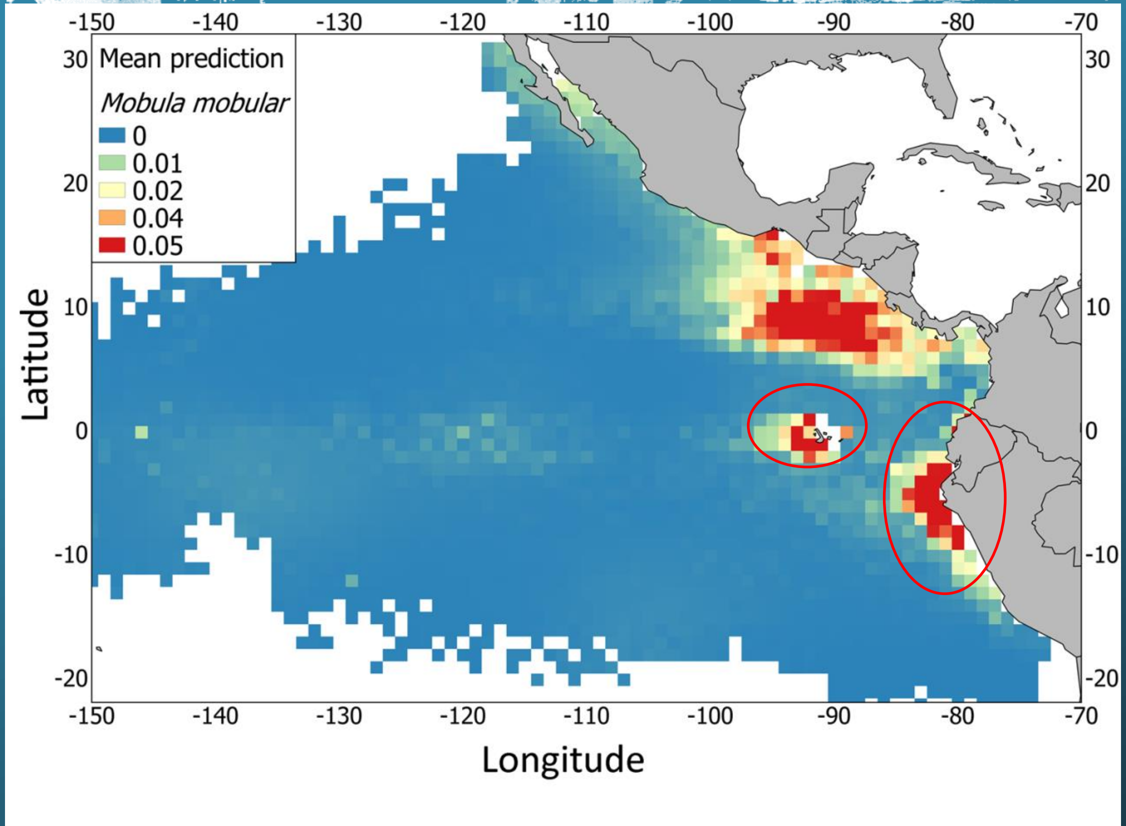


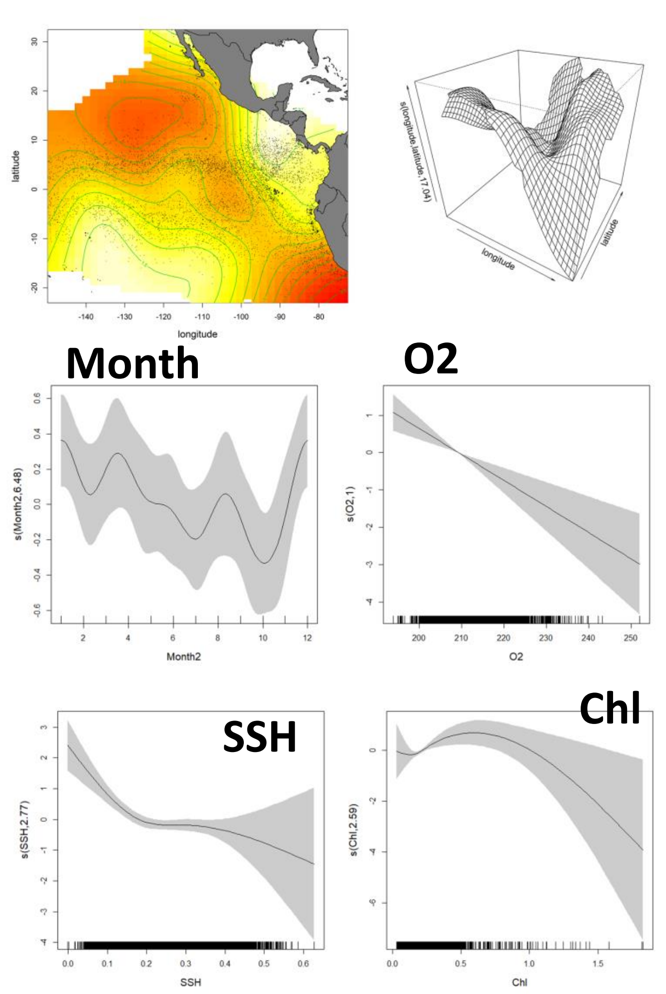
RESEARCH ARTICLE

Environmental characteristics associated with the presence of the Spinetail devil ray (*Mobula mobular*) in the eastern tropical Pacific

Nerea Lezama-Ochoa[1,2]*, Martin A. Hall[1], Maria Grazia Pennino[3], Joshua D. Stewart[4,5], Jon López[1], Hilario Murua[2,6]

Practical example: Distribution of Mobular Mobula in the Eastern Pacific





Deviance: 51%
SSH: 13.5%
Chl: 13%
AUC: 0.92

Lezama-Ochoa et al. 2019

5. Limitations of SDMs

Limitations

- Spatial autocorrelation
- Temporary autocorrelation
- Uncertainty throughout the sampling process
- Detection problem
- Data not collected with random sampling
- Presence of physical barriers
- Sometimes there is an excess of zeros in our response variable
- Misalignment of environmental variables

How might this affect the management of natural resources?

Examples of experience in marine ecology
Biased estimation and predictions of species distribution (or other spatial processes) lead to ill-informed decision-making and inefficient or adequate management of natural resources.

- Today, 30% of MPAs are failing in their goals (Watson et al., 2014).
- Most problems arise in the designation process (e.g. extremely large areas, which in most contexts are poorly manageable, especially given the social and economic relevance of fishery resources)


what's next?

Bayesian models

Let's do it using a Bayesian approach WHY?

- Can account for spatial autocorrelation
- Can account for temporal correlation
- Better estimate of uncertainty
- Inclusion in the prior information model
- Allow to correct sampling error
- Allow you to model data and more complicated situations

6. Applicability of habitat models

Now what? Main uses

- **Fisheries management**
  - Spatial management
  - Closure of areas (temporary spatial closures, marine protected areas)
  - Avoid areas: Ecocast (avoid bycatch species-SDMs): EcoCast Home | CoastWatch-West Coast (noaa.gov)
- **Impact of the fishery**
  - Use output models: EASI-Fish Inter Research » MEPS » v625 » p89-113 (int-res.com)
  - Use output from models to study ecosystems (EcoOcean)
- **Conservation**
  - Understand the relationships between the presence of the species and the environment
  - Identify the main areas of importance for the species (conservation)

May 17th
Elliott Hazen!
Dynamic ocean management

Now what? Main uses

Conservation + Management: predicting possible environmental impacts

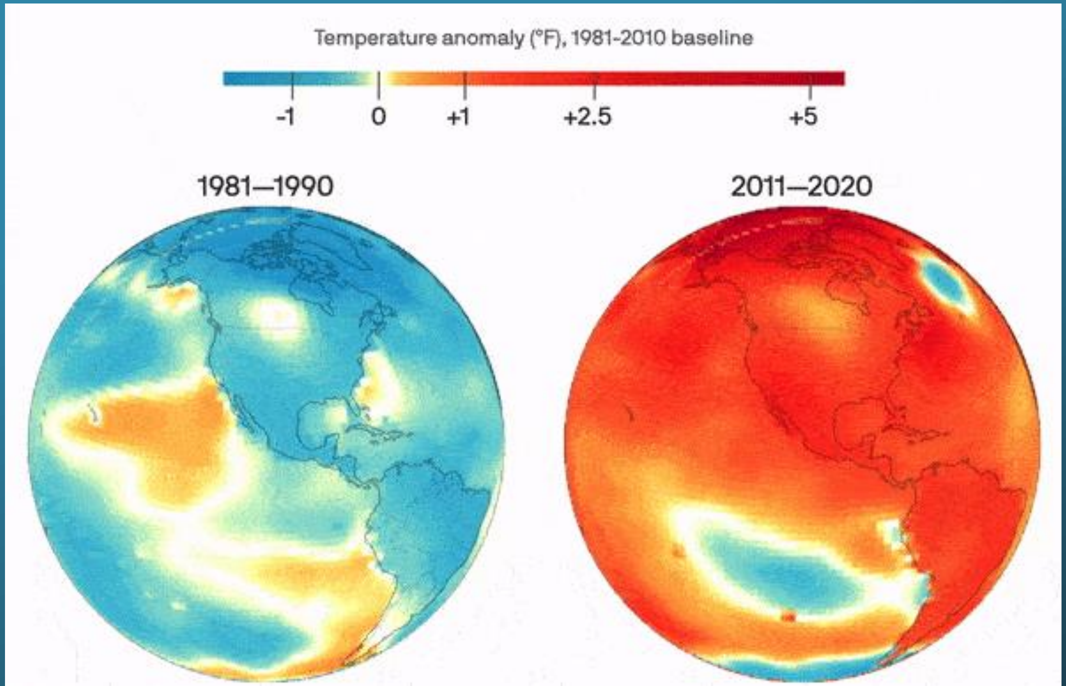
- Short term: monthly forecast, annual (MarineView, Ecocast)
- Long-term: **climate change scenarios**

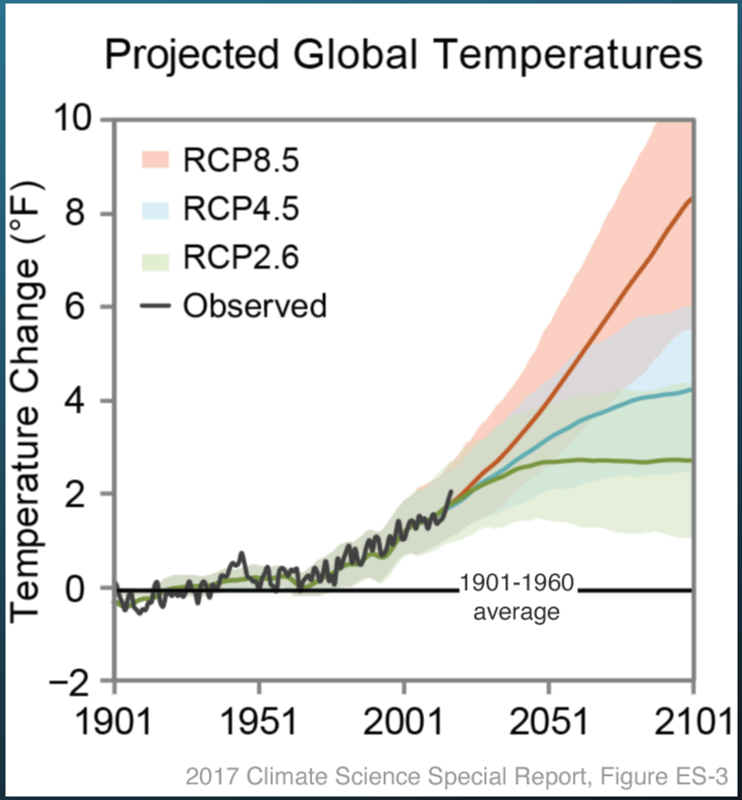
May 17th
Elliott Hazen!
Dynamic ocean management

6. Highly Migratory Species habitat Projections in the California Current

N. Lezama-Ochoa, S. Brodie, H. Welch, M. Jacox, M. Pozo Buil, J. Fiechter, M. Cimino, B. Muhling, H. Dewar, E. Becker, K. Forney, D. Costa, S. Benson, N. Farchadi, C. Braun, R. Lewison, S. Bograd, E. Hazen

Highly Migratory Species habitat projections in the CCS

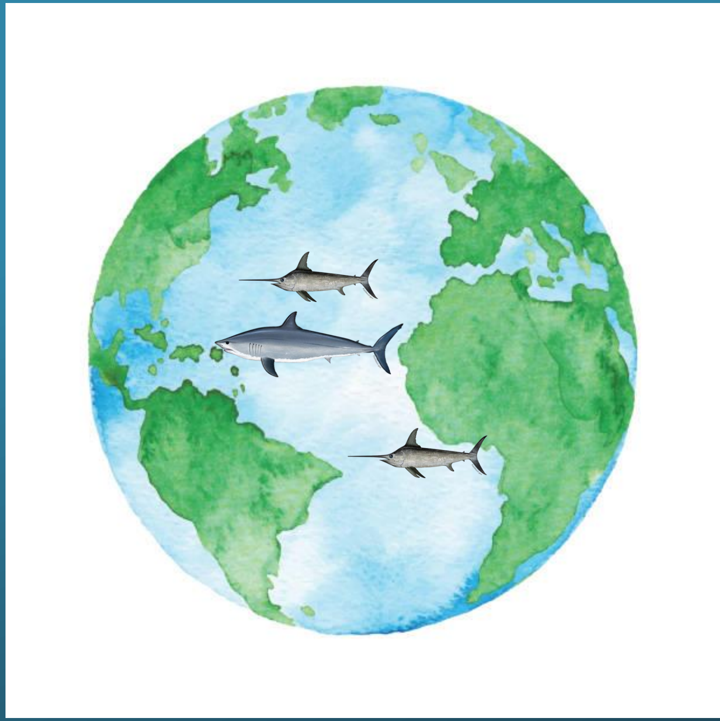




NASA Goddard Institute for Space Studies

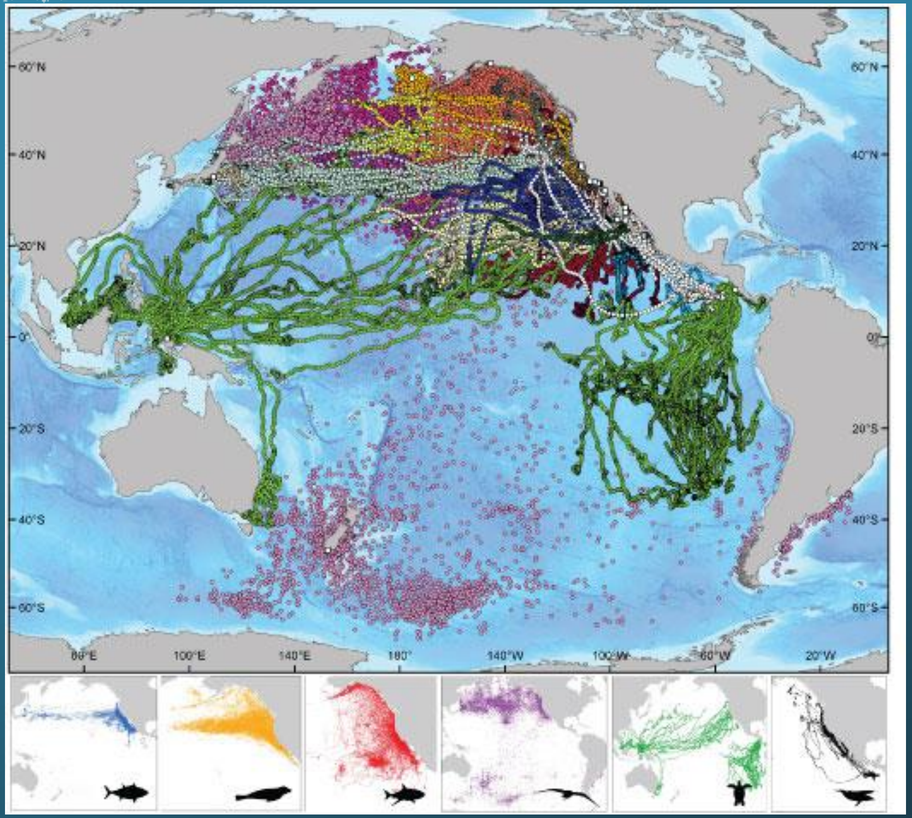
NASA Goddard Institute for Space Studies

Highly Migratory Species habitat projections in the CCS



Species' distribution shifts: poleward / deeper

Highly Migratory Species habitat projections in the CCS

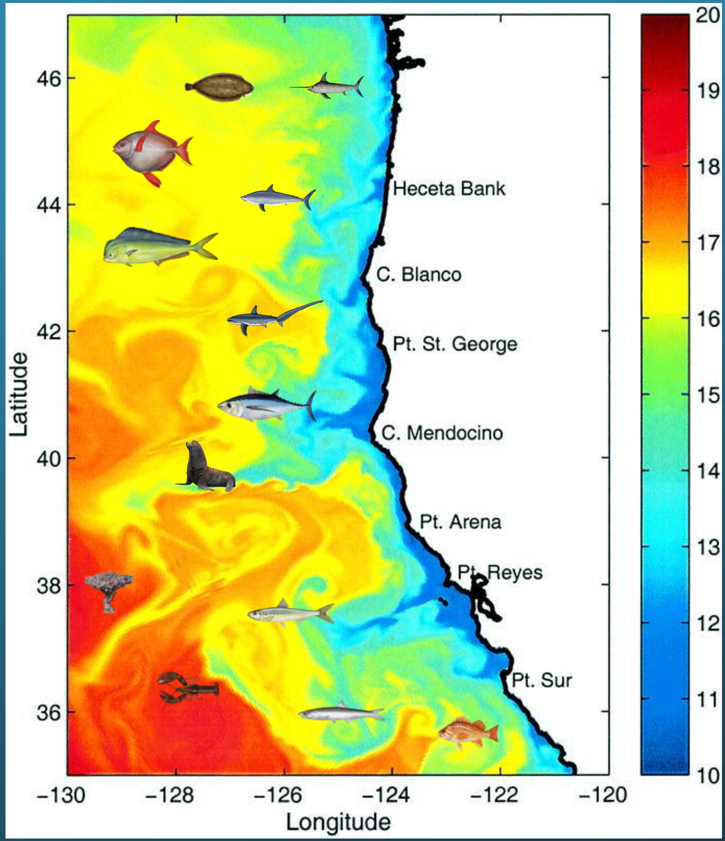


Block et al., 2011

Highly migratory species

- Species that travel long distances
- Often cross domestic and international boundaries
- Live in the open ocean; they may spend part of their life cycle in nearshore waters
- Exposed to different impacts
  - Habitat degradation
  - Fisheries
  - Pollution
  - **Climate change**

Highly Migratory Species habitat projections in the CCS



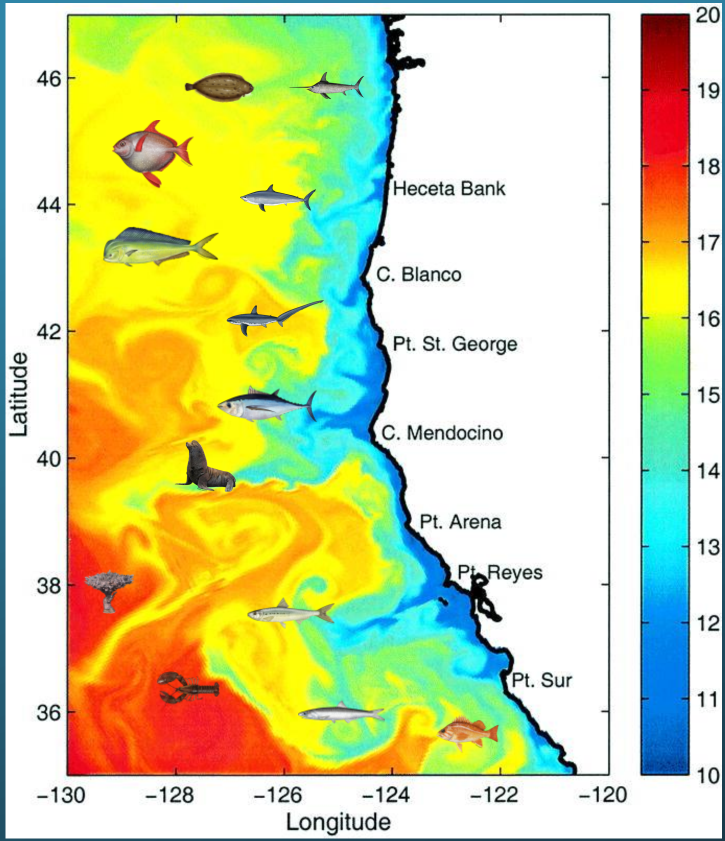
California Current System

- One of the most productive systems
- Provides habitat and foraging for HMS

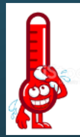
Highly Migratory Species in CCS

- Target species, vulnerable species, iconic species
- Important component of the food web

Highly Migratory Species habitat projections in the CCS



Species shifts



- Alter marine food web
- Affect target fishing industry
- Impact coastal communities & economies
- Exposure vulnerable species to new impacts

Highly Migratory Species habitat projections in the CCS

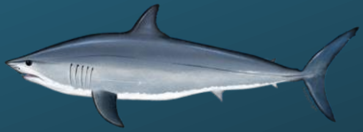
Swordfish
Xiphias gladius

California sea lion
Zalophus californianus

Leatherback turtle
Dermochelys coriacea

Blue shark
Prionace glauca

Common thresher shark
Alopias vulpinus



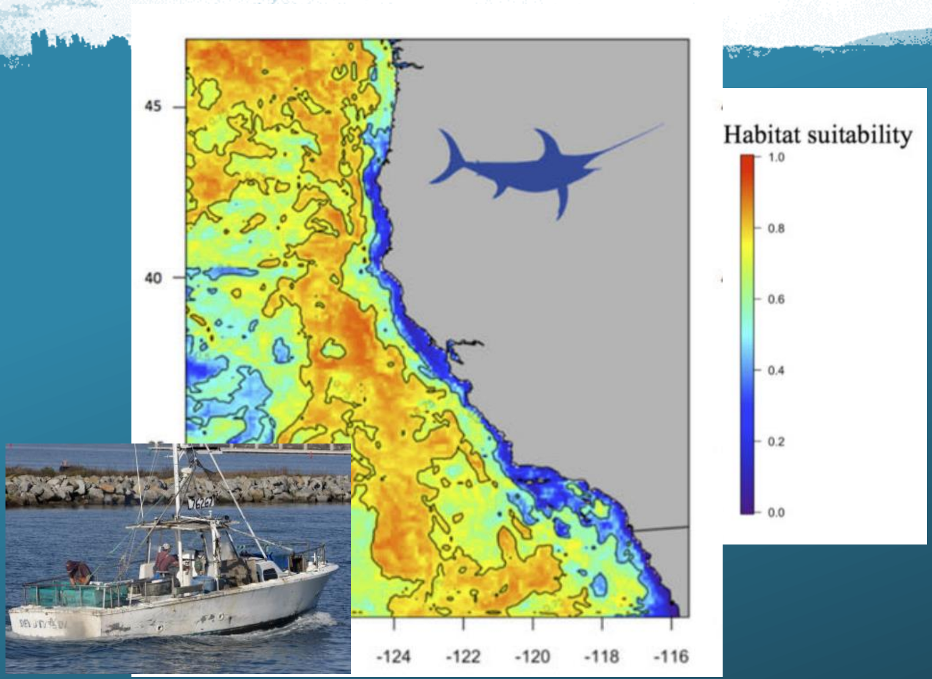
Mako shark
Isurus oxyrinchus

Humpback whale
Megaptera novaeangliae

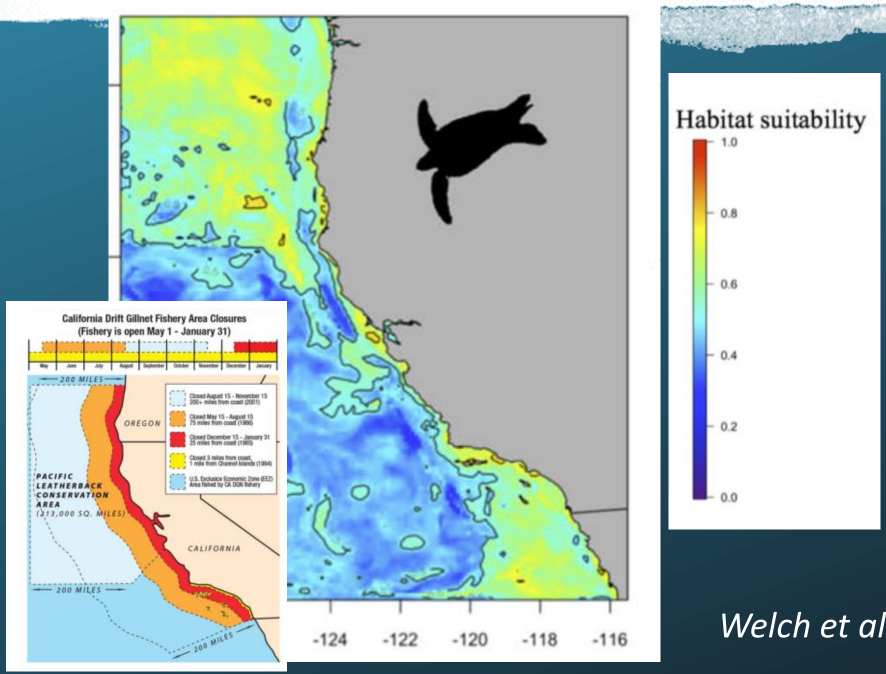
Source: https://www.fisheries.noaa.gov/species/

Highly Migratory Species habitat projections in the CCS

1. Important species for their economic value/conservation



SWORDFISH
Target species
High economic value

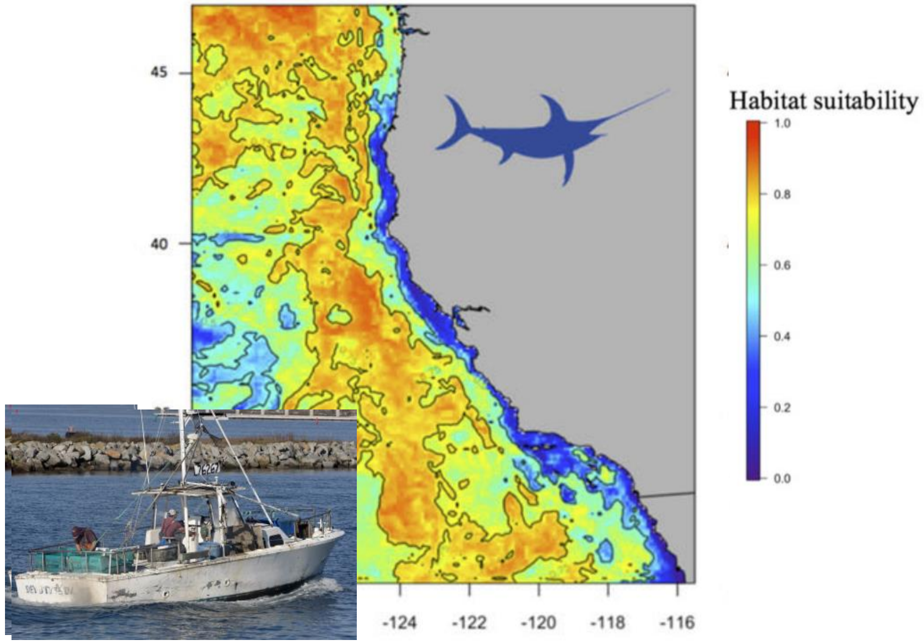


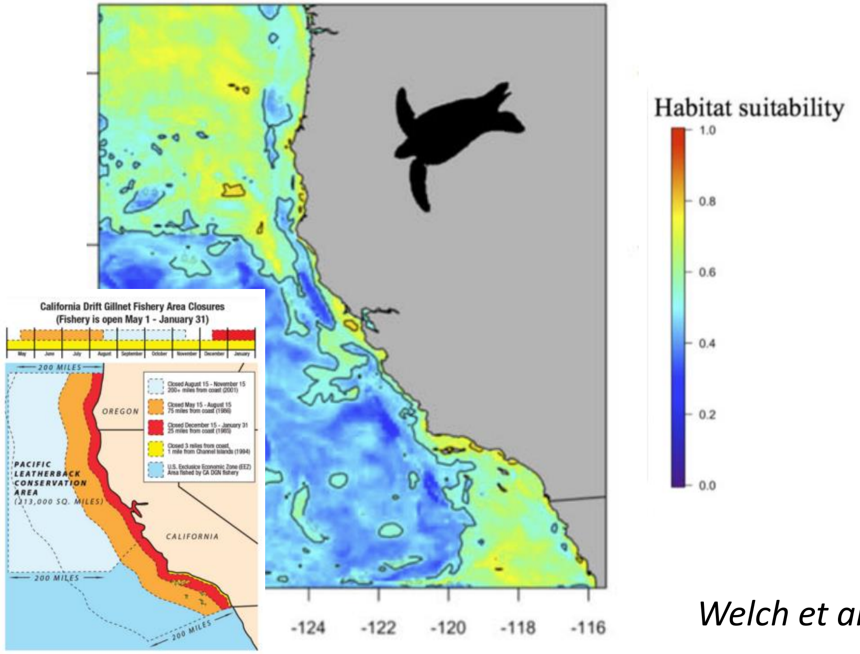
Welch et al., 2019

LEATHERBACK TURTLE
Bycatch species
High conservation value

Highly Migratory Species habitat projections in the CCS

1. Important species for their economic value/conservation





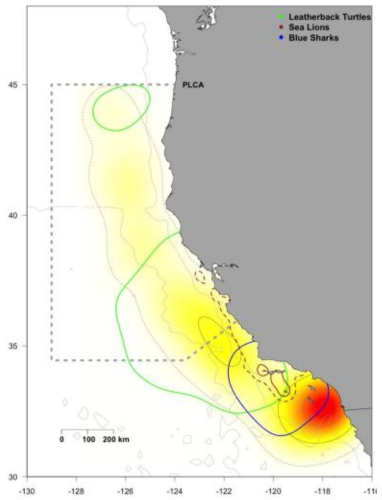
Welch et al., 2019

SWORDFISH
Target species
High economic value

LEATHERBACK TURTLE
Bycatch species
High conservation value

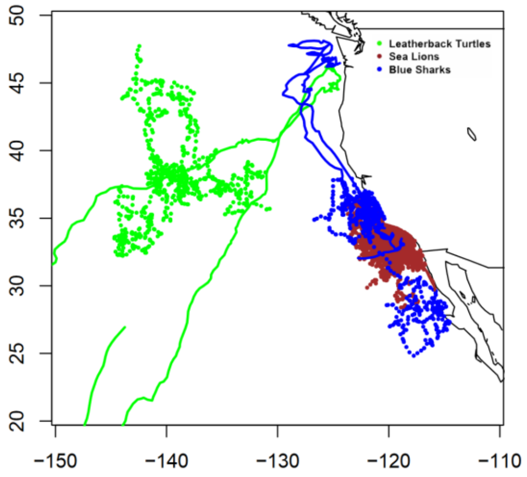
Highly Migratory Species habitat projections in the CCS

2. Data availability (fisheries/tagging data/sightings)



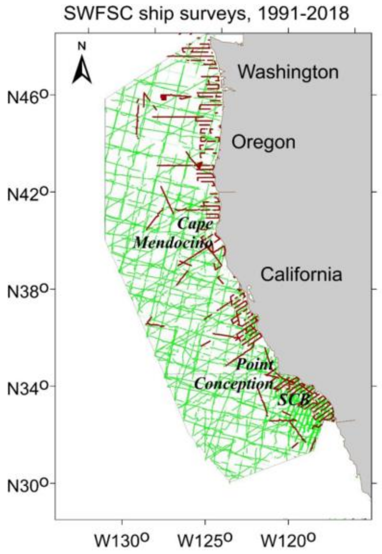
Drift gillnet fishery

Hazen et al., 2018
Brodie et al., 2018



Tracking data

Hazen et al., 2018

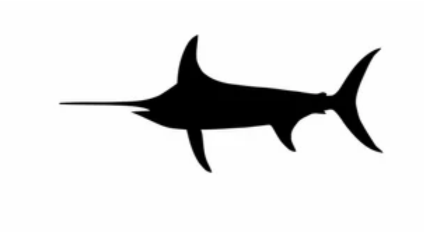


Ship Surveys (sightings)

Becker et al., 2020

Highly Migratory Species habitat projections in the CCS

2. Data availability (fisheries/tagging data/sightings)



Integrating Dynamic Subsurface Habitat Metrics Into Species Distribution Models

Stephanie Brodie[1,2*], Michael G. Jacox[1,2,3], Steven J. Bograd[1,2], Heather Welch[1,2], Heidi Dewar[4], Kylie L. Scales[5], Sara M. Maxwell[6], Dana M. Briscoe[1], Christopher A. Edwards[1], Larry B. Crowder[7], Rebecca L. Lewison[8] and Elliott L. Hazen[1,2]

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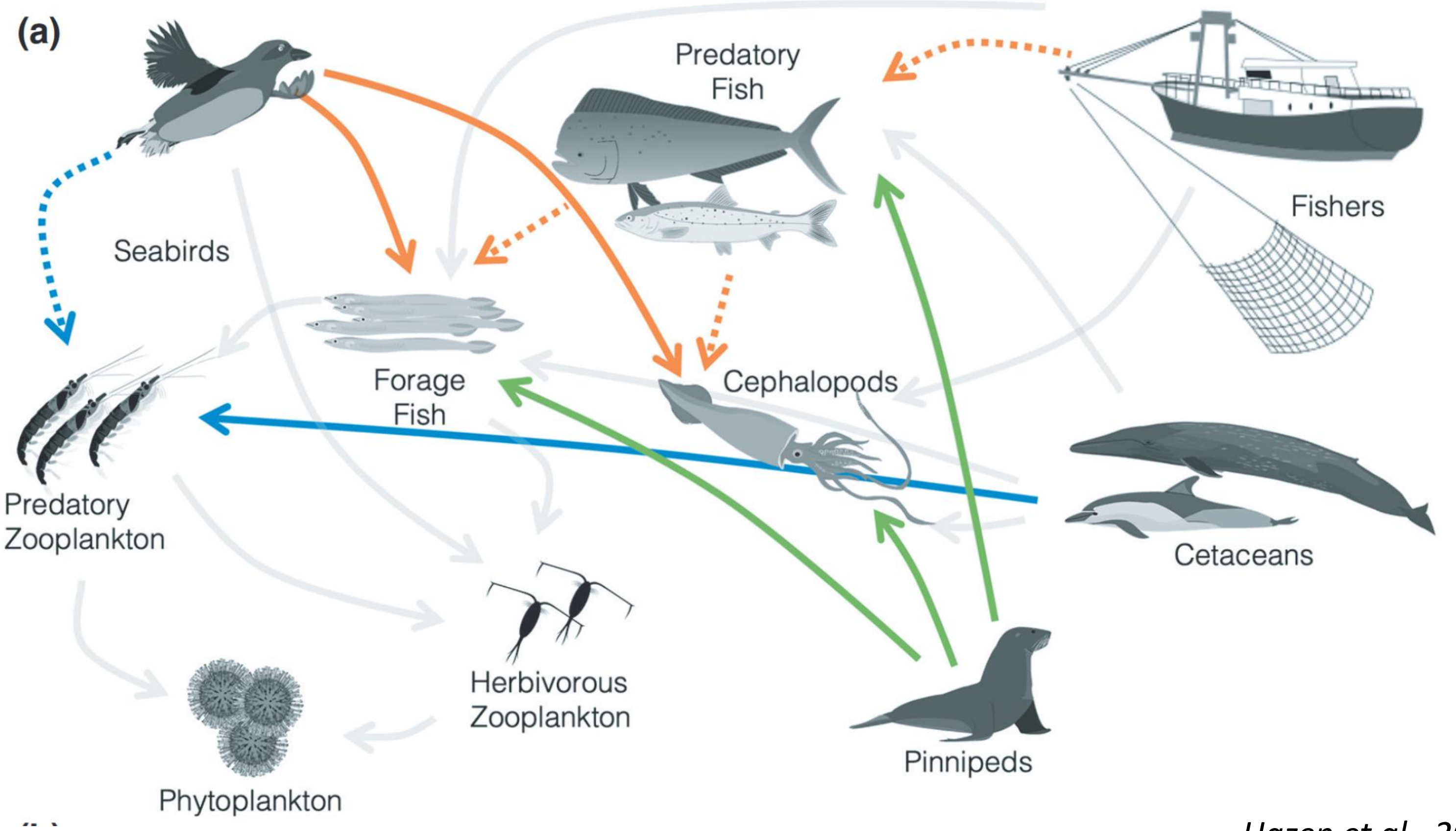
Highly Migratory Species habitat projections in the CCS

3. Important component of the CC food web system



Hazen et al., 2019

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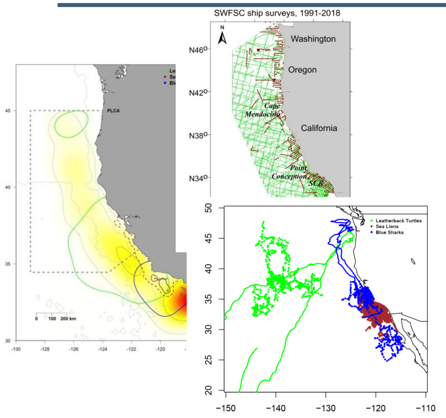
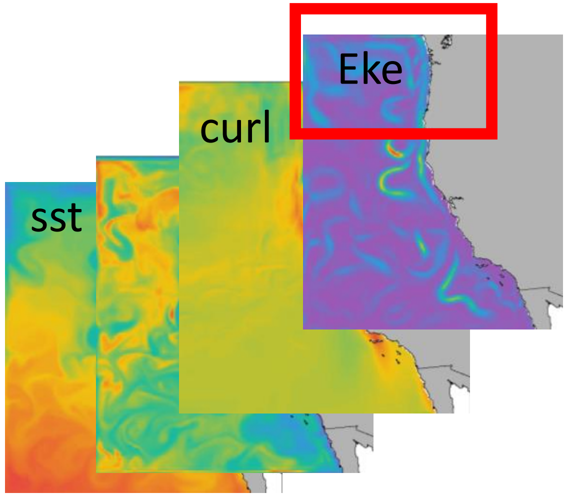
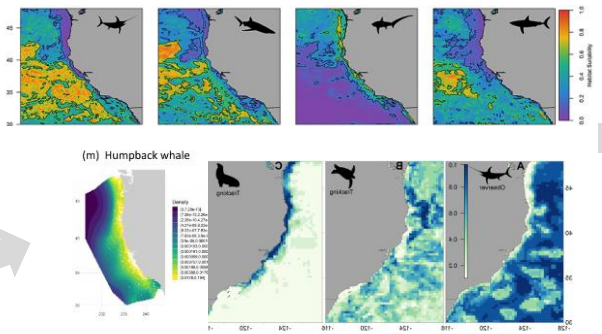


Species data
7 species

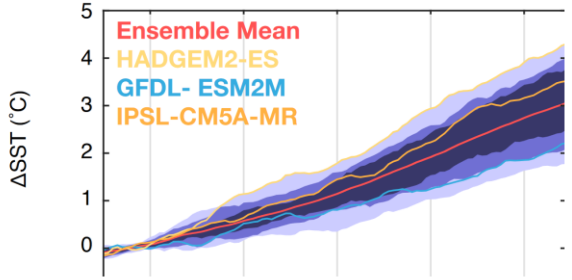


Environmental data

Species Distribution Model outputs
BRTs/GAMs



Hazen et al., 2018
Brodie et al., 2018
Becker et al., 2020

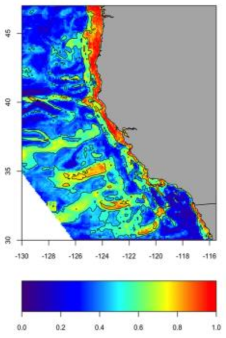


Three high-resolution (~10 km) downscaled ocean models under the high emissions scenario (RCP8.5)

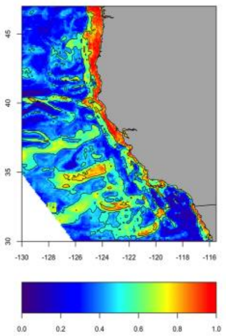
Pozo Buil et al., 2020

Daily projections
(1980-2100)

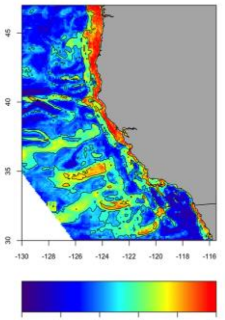
GFDL



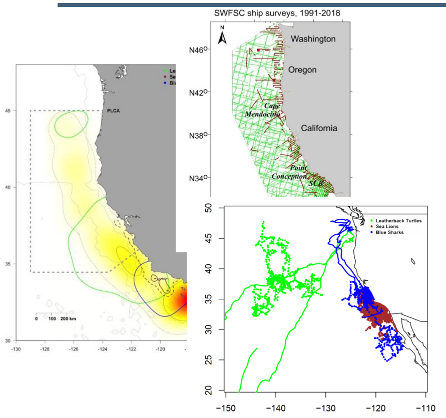
HAD



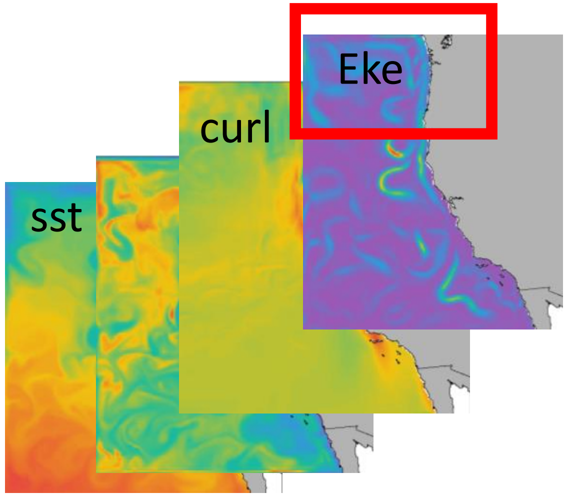
IPSL



Highly Migratory Species habitat projections in the CCS

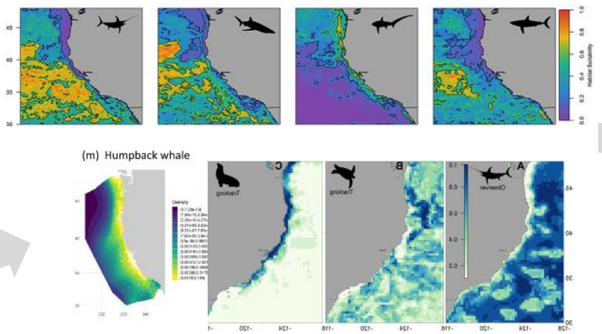


Species data
7 species



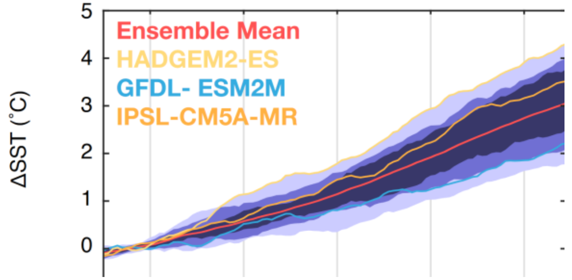
Environmental data

Species Distribution Model outputs
BRTs/GAMs



Hazen et al., 2018
Brodie et al., 2018
Becker et al., 2020

Daily metrics (ESMs)
(1980-2100)



Three high-resolution (~10 km) downscaled ocean projections under the high emissions scenario (RCP8.5)

Pozo Buil et al., 2020

Temporal shift

Spatial shift

Highly Migratory Species habitat projections in the CCS

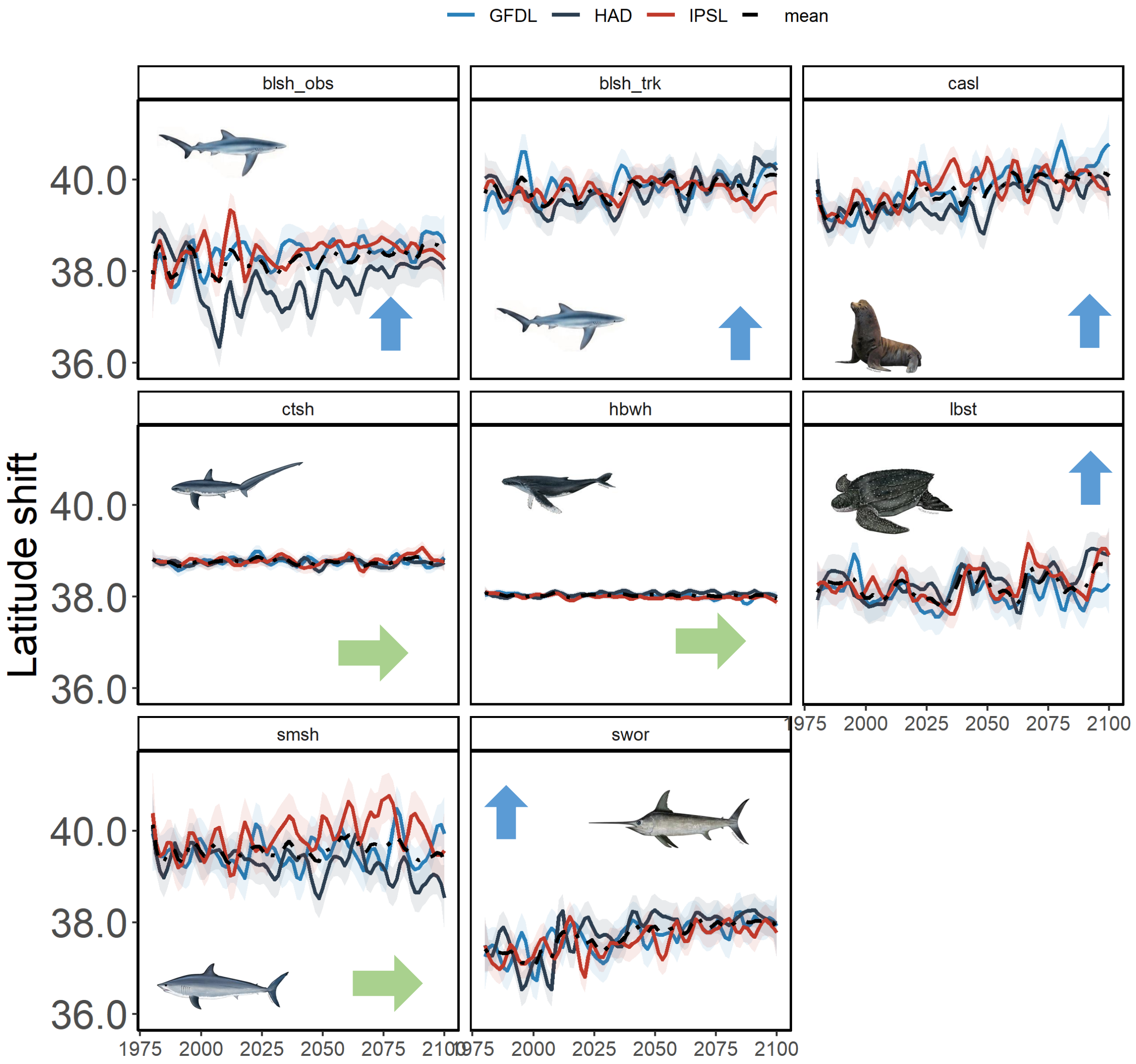
1. Temporal shift distribution (1980-2100)

2. Spatial shift distribution (1980-2100)

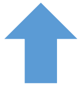
3. Case study: **swordfish**

Highly Migratory Species habitat projections in the CCS

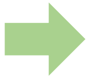
temporal distribution



Latitudinal shift



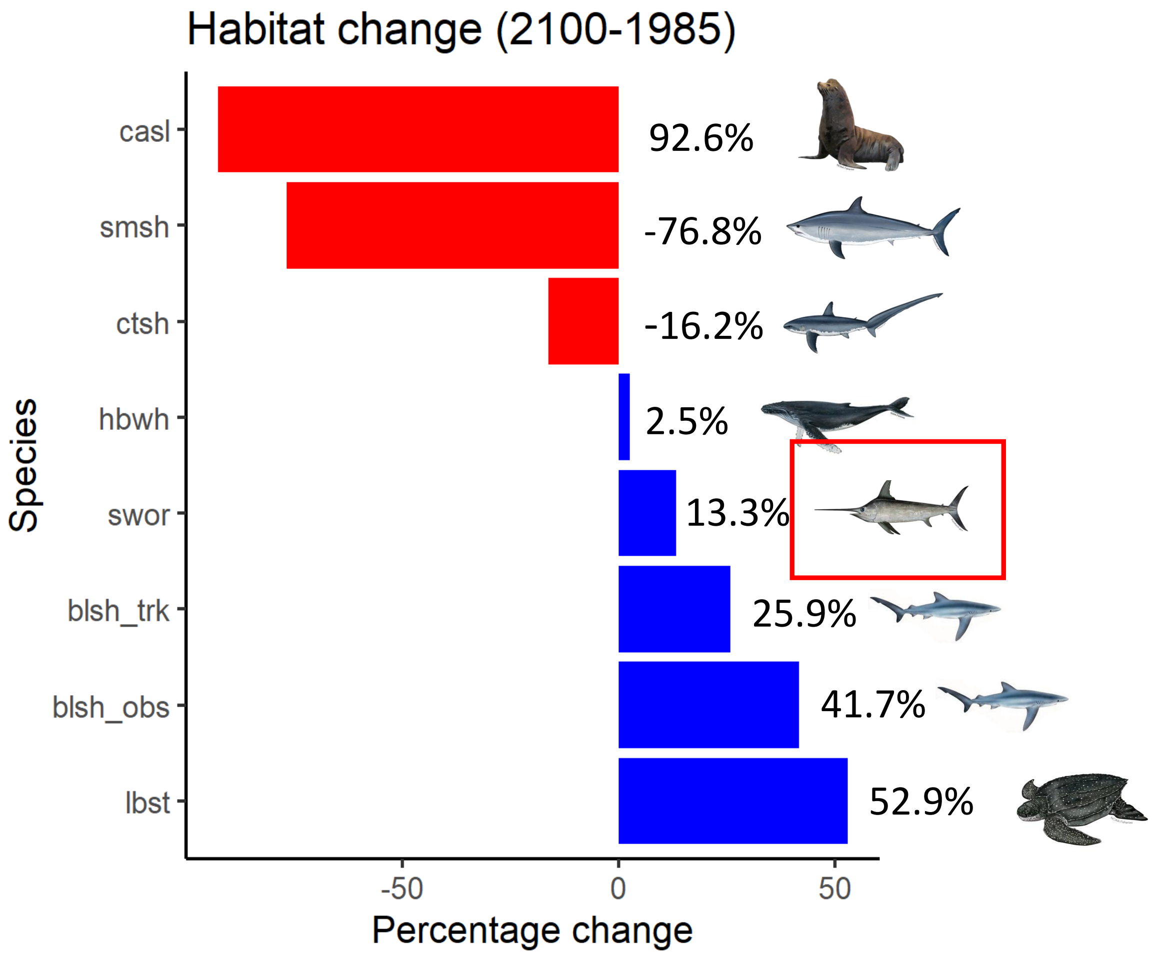
Shifting northward



Not specific trend

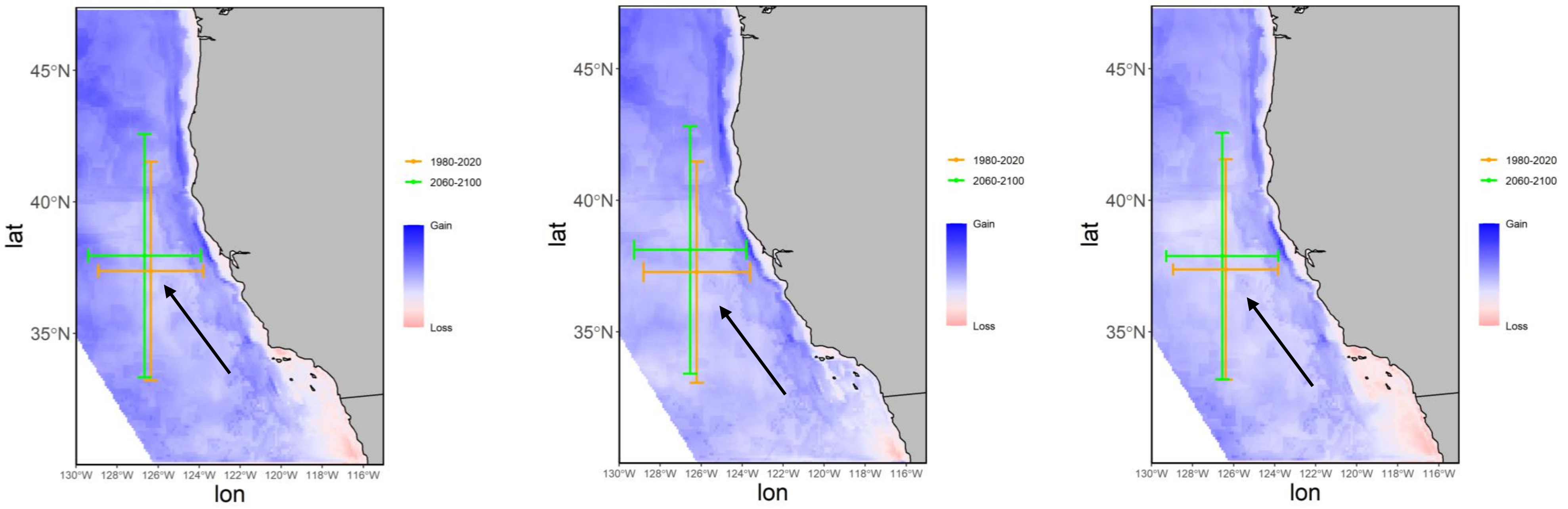
Highly Migratory Species habitat projections in the CCS spatial distribution

Total habitat change$_{(2100-1985)}$=future habitat $_{(1970-2100)}$- historical habitat $_{(1985-2015)}$



Highly Migratory Species habitat projections in the CCS: swordfish

GFDL | HAD | IPSL



Index

1. Why habitat models?
2. What is a habitat model?
3. Types and sources of data
4. Model build
5. Limitations
6. Applicability of habitat models
   *Effects of climate change

Thanks!!

- NOAA/University of California
- ERD group
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