# UPDATED TROPICAL TUNA BIOMASS INDICES FROM ECHOSOUNDER BUOYS IN THE EASTERN PACIFIC OCEAN

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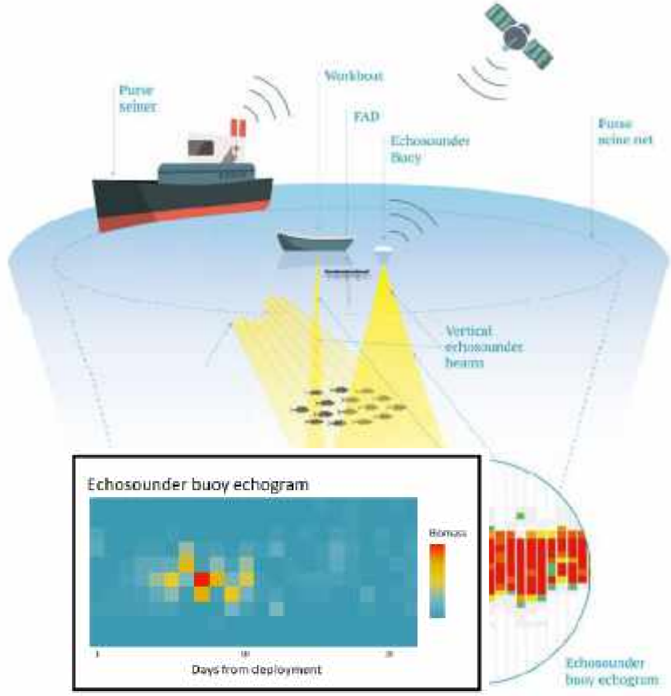
**Meeting document RVDTT-01**

# Introduction

# The FAD fishery



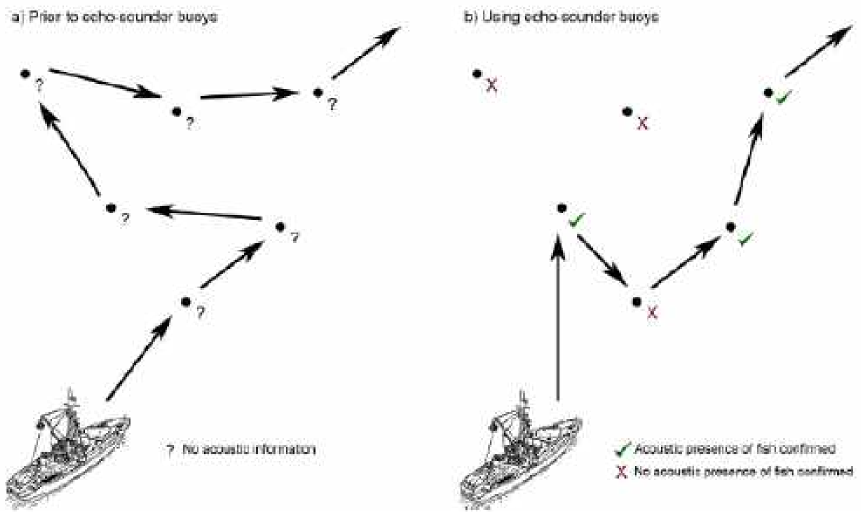






**Table 2**
Fishers' answers to questions about their use of echo-sounder buoys.

| Use of sounder buoys | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Question | Response | Indian Ocean | | | Atlantic Ocean | | | Pacific Ocean | | |
| | | 2010 % ([a]) | 2011 % ([a]) | 2012 % ([a]) | 2010 % ([a]) | 2011 % ([a]) | 2012 % ([a]) | 2010 % ([a]) | 2011 % ([a]) | 2012 % ([a]) |
| First year using sounder buoys | 2000–2003 | 11 (2) | – | – | – | – | 0 (0) | – | – | 0 (0) |
| | 2004–2007 | 45 (8) | – | – | – | – | 25 (1) | – | – | 25 (1) |
| | 2008–2011 | 33 (6) | – | – | – | – | 75 (3) | – | – | 75 (3) |
| | Never | 11 (2) | – | – | – | – | 0 (0) | – | – | 0 (0) |
| Percentage of buoys with echo-sounders | Without sounder | 32 (6) | 42 (6) | 0 (0) | – | 0 (0) | 0 (0) | – | 11 (1) | 0 (0) |
| | <25% | 41 (8) | 29 (4) | 25 (5) | – | 67 (4) | 0 (0) | – | 78 (7) | 8 (1) |
| | 25–50 | 16 (3) | 29 (4) | 15 (3) | – | 33 (2) | 37.5 (6) | – | 11 (1) | 23 (3) |
| | ≥50 | 11 (2) | 0 (0) | 60 (12) | – | 0 (0) | 62.5 (10) | – | 0 (0) | 69 (9) |
| Brands used | Brand 1 | 15 (2) | 0 (0) | 0 (0) | – | 0 (0) | 0 (0) | – | 0 (0) | 0 (0) |
| | Brand 2 | 31 (4) | 11 (1) | 5 (1) | – | 0 (0) | 25 (4) | – | 12.5 (1) | 8 (1) |
| | Brand 3 | 31 (4) | 44 (4) | 5 (1) | – | 40 (2) | 0 (0) | – | 62.5 (5) | 0 (0) |
| | Brand 1+2 | 0 (0) | 0 (0) | 25 (5) | – | 0 (0) | 0 (0) | – | 12.5 (1) | 0 (0) |
| | Brand 2+3 | 15 (2) | 22 (2) | 25 (5) | – | 40 (2) | 56 (9) | – | 12.5 (1) | 54 (7) |
| | Brand 1+3 | 8 (1) | 22 (2) | 25 (5) | – | 20 (1) | 0 (0) | – | 0 (0) | 0 (0) |
| | Brand 1+2+3 | 0 (0) | 0 (0) | 15 (3) | – | 0 (0) | 19 (3) | – | 0 (0) | 38 (5) |
| Choice reason | Owner's | 36 (8) | – | – | – | – | – | – | – | – |
| | Best brand | 45 (10) | – | – | – | – | – | – | – | – |
| | Price | 14 (3) | – | – | – | – | – | – | – | – |
| | Others | 5 (1) | – | – | – | – | – | – | – | – |

[a] Number of observations in parenthesis.

# The FAD fishery – technological evolution/effort creeep

From Vidal et al 2021 (WCPFC)

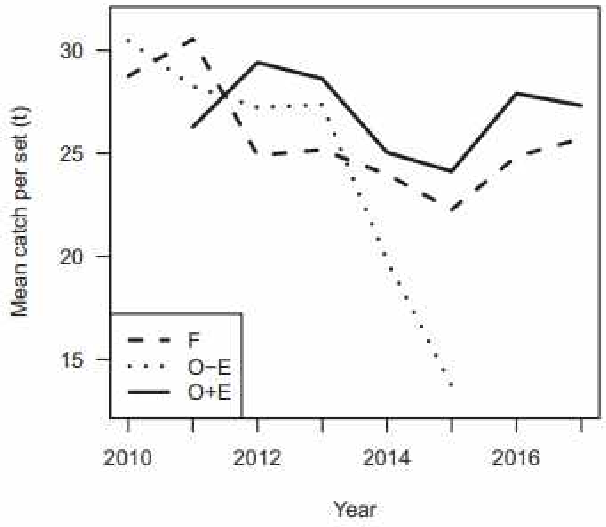
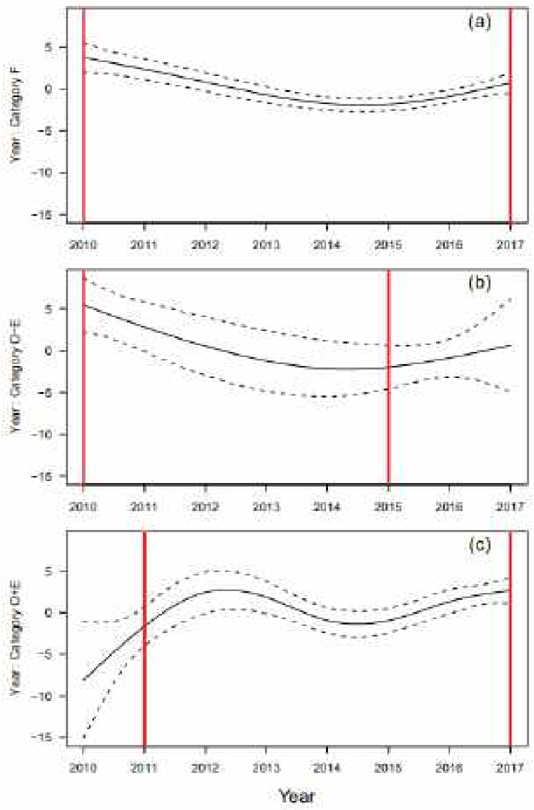



**Figure 4.** Mean catch per set between 2010 and 2017 for each of the three set categories. The set categories are: $F$ = foreign FOB; $O-E$ = owned buoy without echosounder; and $O+E$ = owned buoy with echosounder.




From Wain et al 2021
(French fleet in the Indian Ocean)

around 2012. Results indicate that echosounders do not increase the probability a set will be succesful, but they have a positive effect on catch per set, with catches on average increasing by $\approx 2-2.5$ tonnes per set ($\approx 10\%$) when made on the vessel's own dFADs equipped with an echosounder buoy.

**Table 1: Summary of recent (average 2018-19 vs 2016-17) and longer-term (2007-2019) trends in different indicators within and outside PNA EEZs.**

| Indicator | 2016/2017 vs 2018/2019 | | Per annum linear regression trend, 2007-2019[3] | |
|---|---|---|---|---|
| | PNA | Non-PNA | PNA | Non-PNA |
| Sets/year | +5% | +57% | +3% | +2% |
| Sets/day | +12% | +20% | +3% | +5% |
| Total tuna CPUE (mt/day) | +20% | +23% | +3% | +2% |
| Total tuna CPUE (mt/set) | +6% | +2% | 0% | -1% |
| Total tuna CPUE (mt/set) - ASS sets | +5% | +6% | 0% | 0% |
| Total tuna CPUE (mt/set) - UNA sets | +6% | +7% | 0% | 0% |
| Total tuna catch | +12% | +59% | +3% | +0% |
| Total skipjack catch | +24% | +57% | +3% | +0% |
| Vessel length (m) | -2% | | 0% | |
| Vessel gross registered tonnage (GRT) | -2% | | +1% | |
| Vessel horsepower (HP) | +0% | | 0% | |
| Well capacity (mt) | +2% | | +2% | |



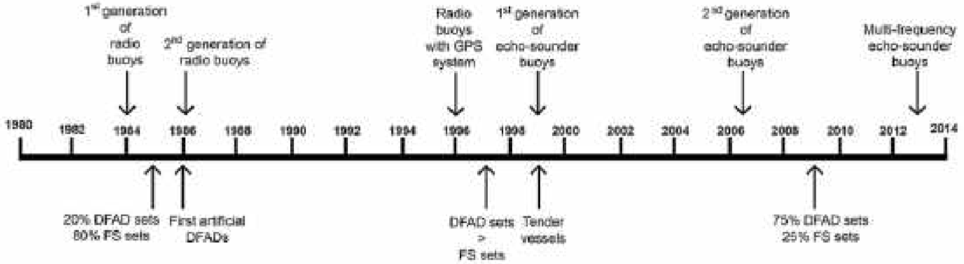
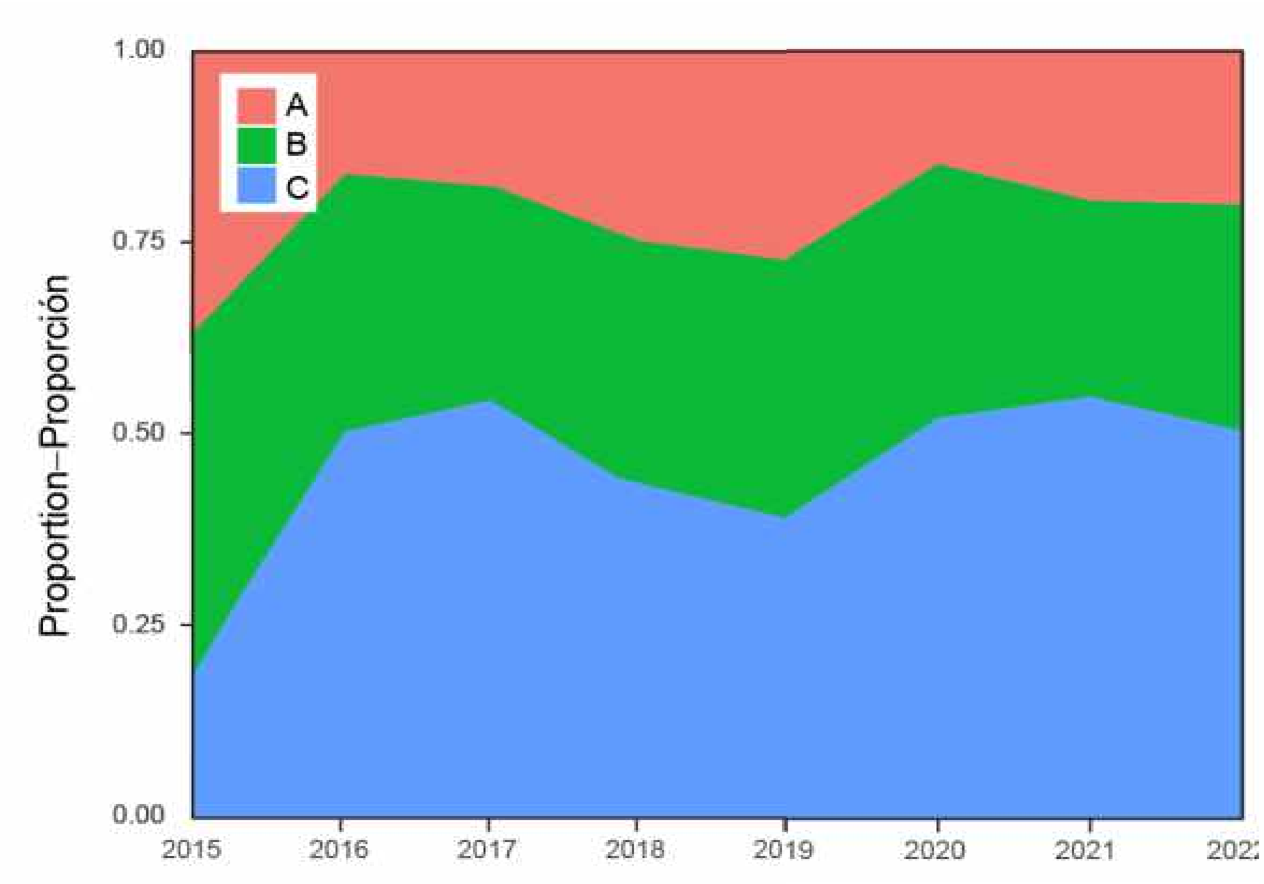



**Fig. 1.** Timeline of the most important events that occurred in the development of buoys technology and the Spanish tropical purse seine DFAD fishery in the Indian Ocean for the last 30 years.

# The FAD fishery – fleet segments




**3.3.3. Evolution of activities by cluster**

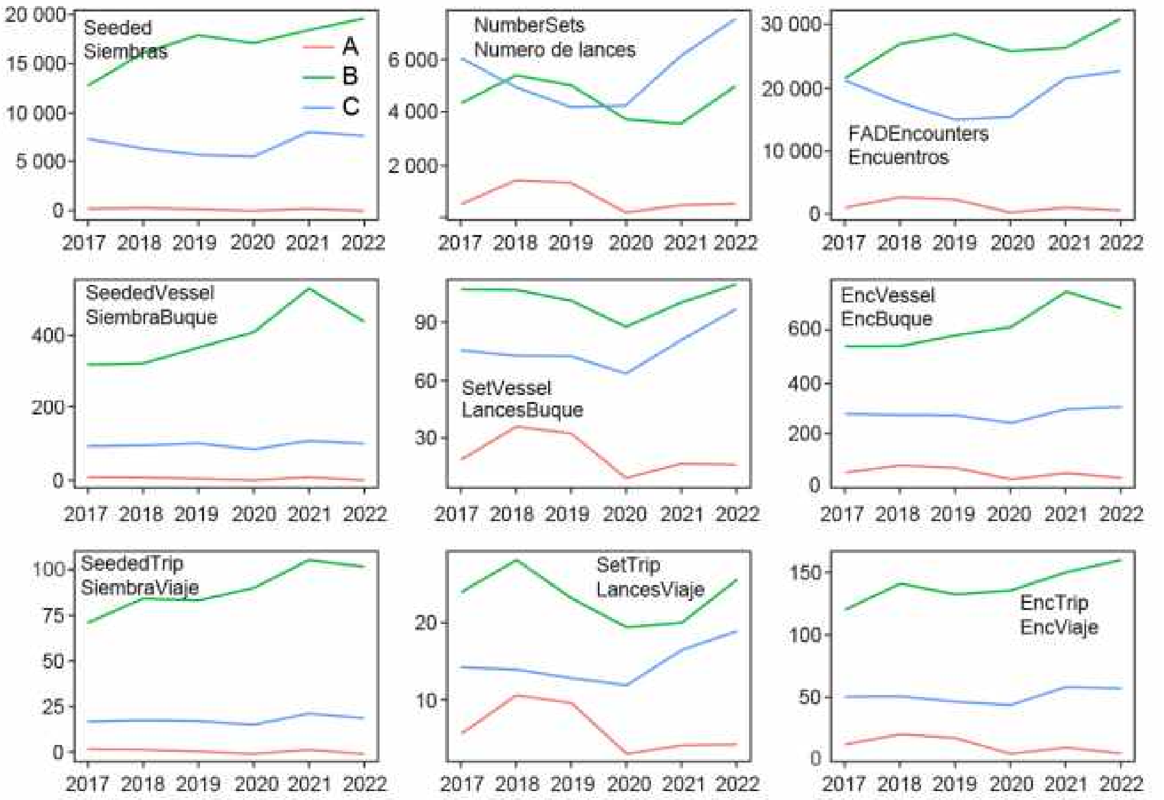
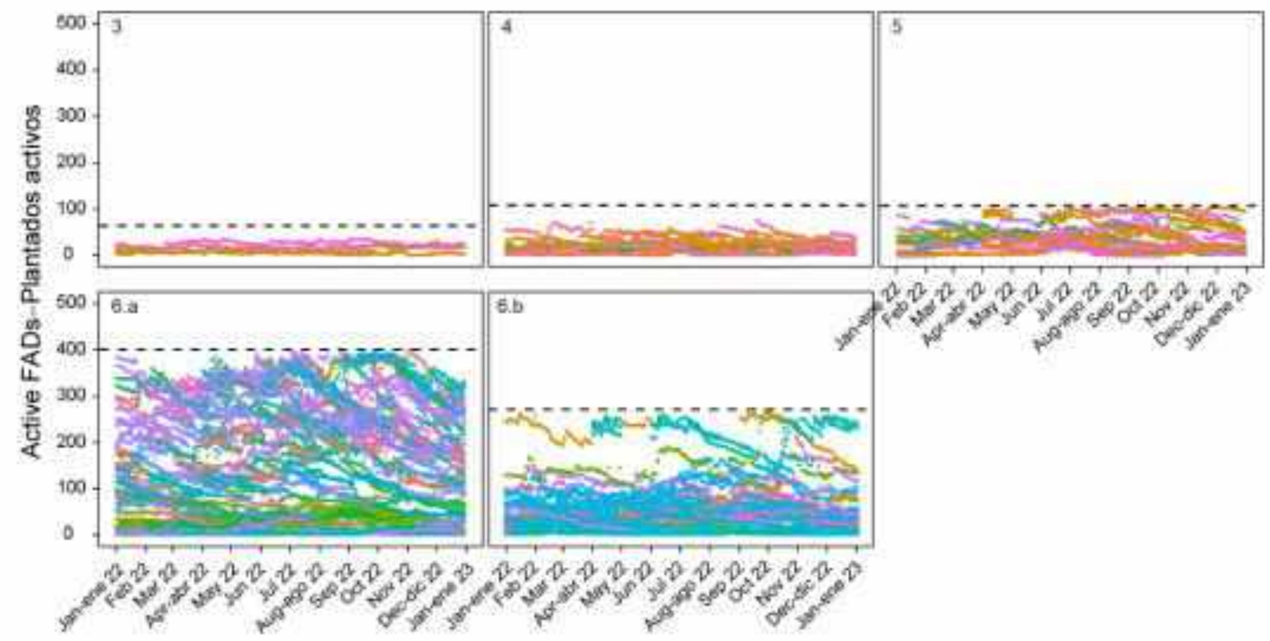
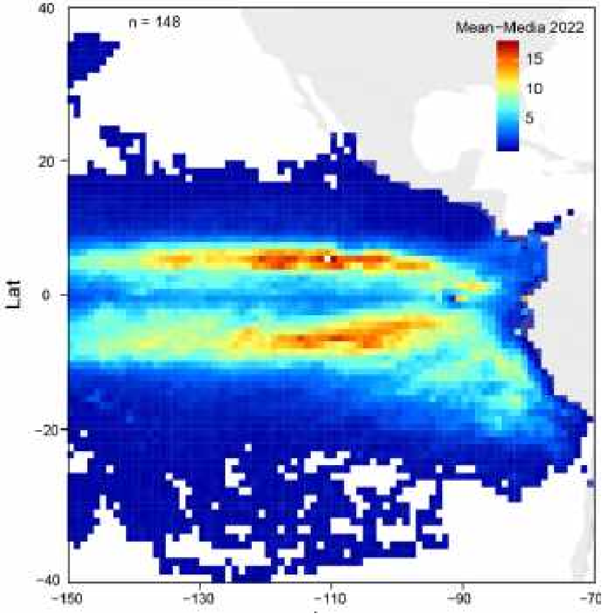



**FIGURE 12.** Top: Evolution of floating-object deployments, sets and encounters, by cluster, 2017-2022; Center: Evolution of floating-object deployments, sets and encounters, by cluster-vessel average, 2017-2022; Bottom: Evolution of floating-object deployments, sets and encounters, by cluster-trip average, 2017-2022.

From IATTC Document FAD-07-01
Cluster analysis methods described in; ICES Journal of Marine Science (2018), 75(5), 1748–1757. doi:10.1093/icesjms/fsy046

# The FAD fishery – number of active buoys




From IATTC Document FAD-07-01

### 3.4.3. Daily total active buoys

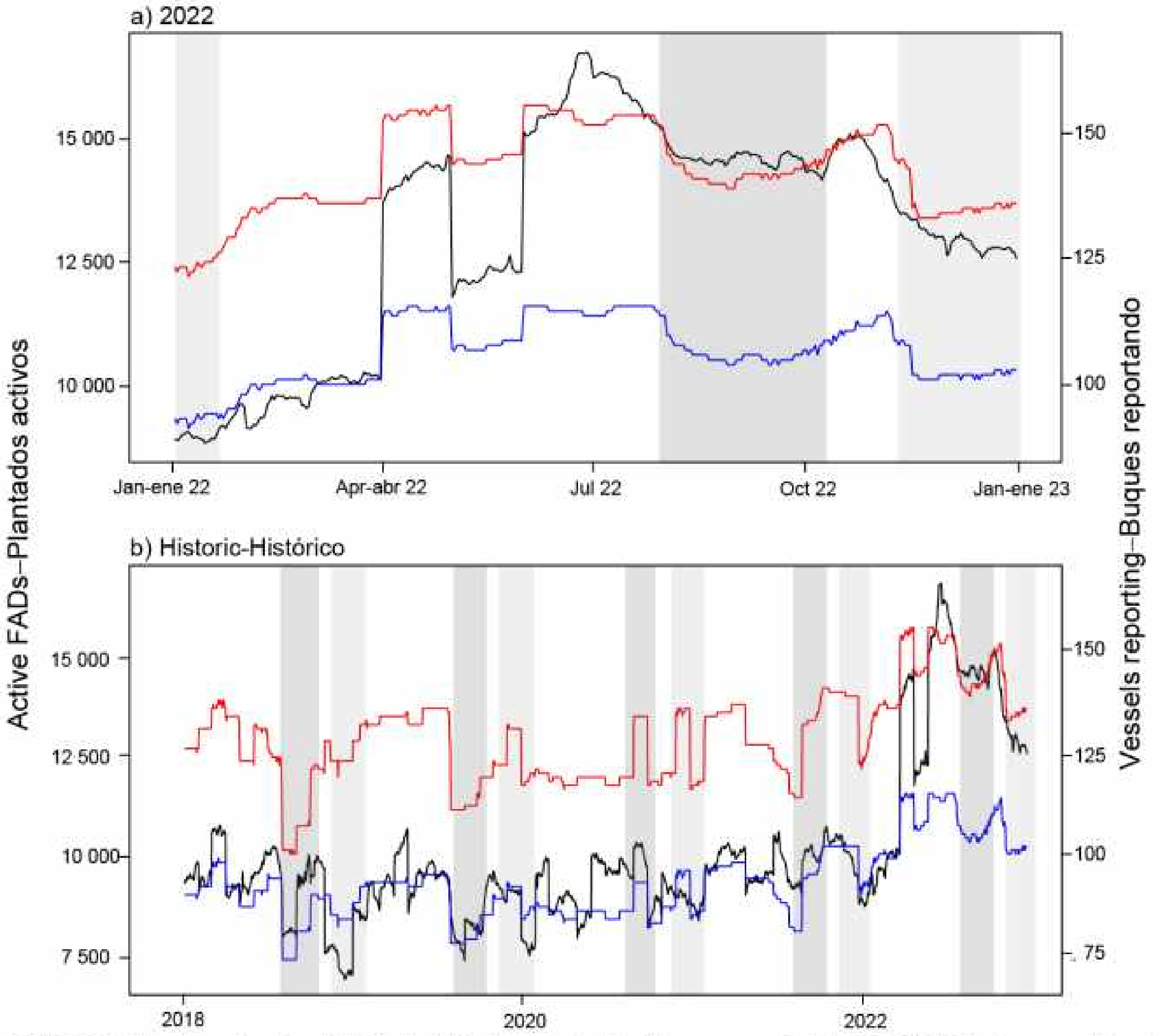



**FIGURE 22.** Number of active FADs (black line) reported by the purse-seine fleet in 2022 (a, top panel) and historically, 2018-2022 (b, bottom panel), and number of vessels reporting daily (red: total; blue: Class-6 vessels). Includes 115 Class-6 vessels, 21 Class-5, 17 Class-4, and 5 Class-2-3 in 2022. The number of total vessels reporting daily ranged from 122 to 158 (median = 143, average = 143). The number of total daily active buoys reported in 2022 ranged from 8800 to 16791 (median = 14052, mean = 13114), and historically from 7013 to 10813 (median = 9468, mean = 9350).

# Indices of abundance from acoustic buoys in t-RFMOs

- **ICCAT**

- **2015**: Towards a Tropical Tuna Buoy-derived Abundance Index (TT-BAI)
- **2019**: A novel index of abundance of juvenile yellowfin tuna in the Atlantic ocean derived from echosounder buoys ------- YFT Assessment
- **2021**: Index of abundance of juvenile bigeye tuna in the Atlantic ocean derived from echosounder buoys ------- BET Assessment
- **2022**: Index of abundance of skipjack tuna in the Atlantic Ocean derived from echosounder buoys (2010-2020) ------- SKJ Assessment

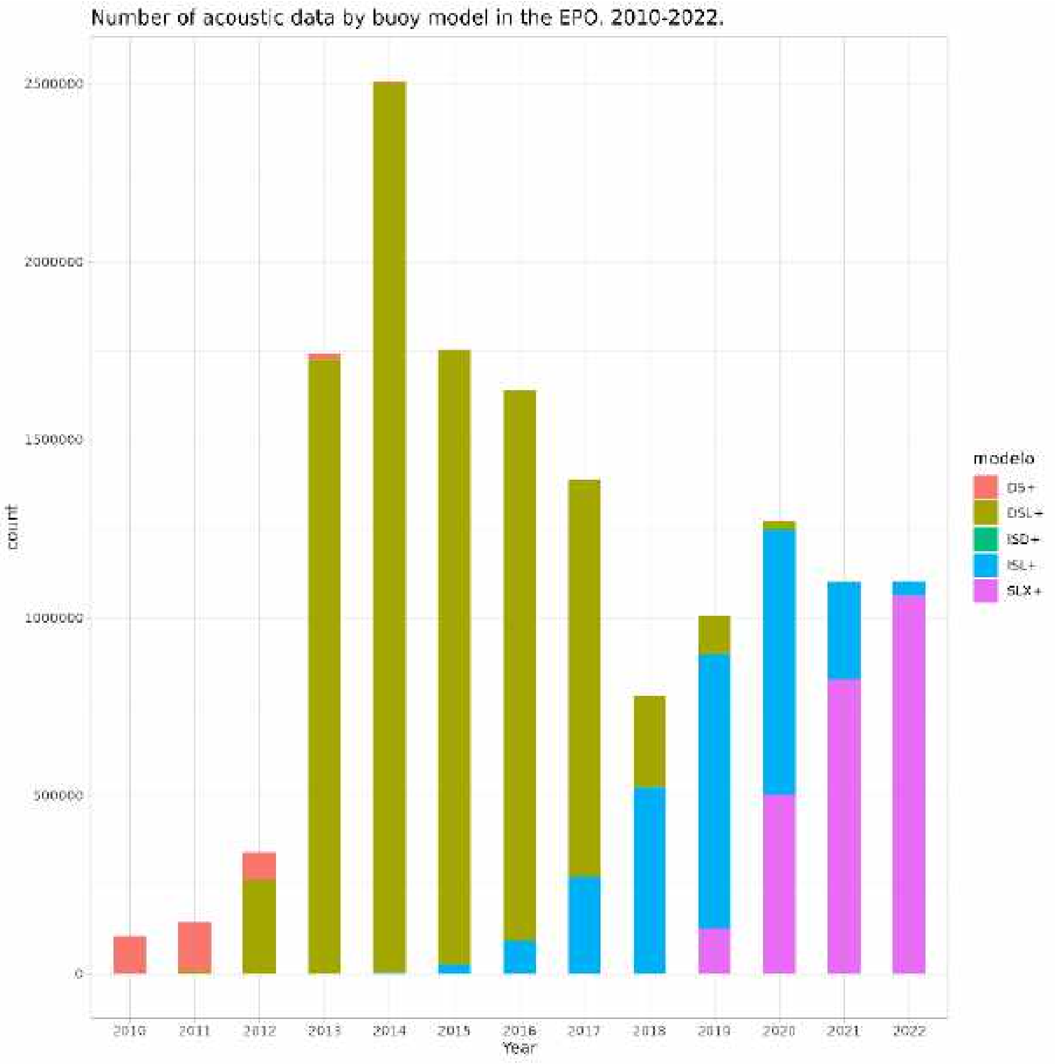
- **IOTC**

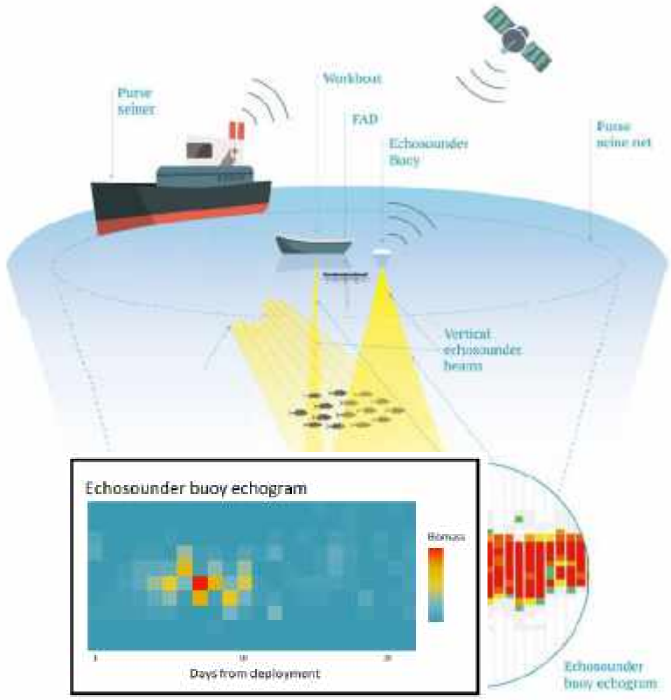
- **2019**: A novel index of abundance of juvenile yellowfin tuna in the Atlantic ocean derived from echosounder buoys
- **2020**: A novel index of abundance of skipjack in the Indian Ocean derived from echosounder buoys

- **IATTC**

- **2021:** Informational paper TROPICAL TUNA BIOMASS INDICATORS FROM ECHOSOUNDER BUOYS IN THE EPO (2012-2020)
- **2020-2022**: Agreement between the IATTC and AZTI for the development and implementation of a project on “developing alternative buoy-derived tuna biomass indexes”
- **2022: interim skipjack assessment conducted by IATTC staff in 2022 (SAC-13-07)**

# Satellite linked echo-sounder buoys



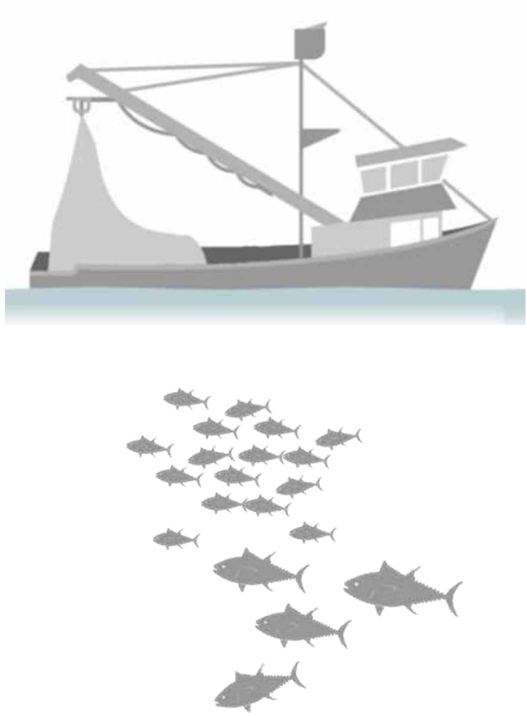



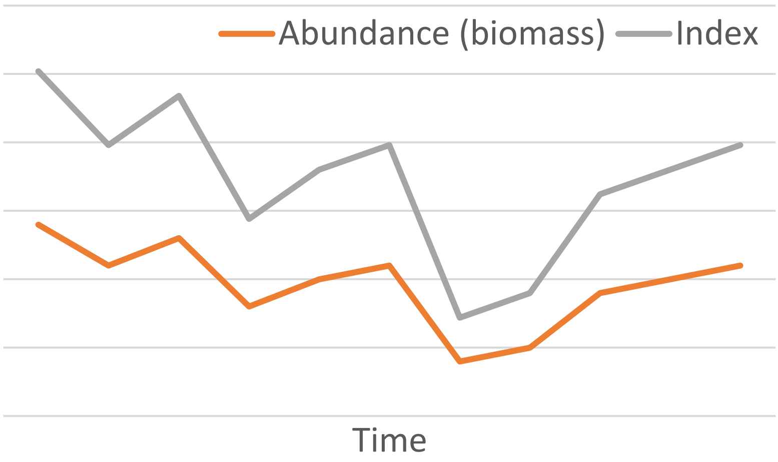

The framework of collaborative work between the Inter-American Tropical Tuna Commission (IATTC) and AZTI Foundation, together with echosounder buoy providers and tropical tuna purse seiner fishing companies operating in the eastern Pacific Ocean (EPO) (companies integrated in OPAGAC-AGAC and Cape Fisheries) has facilitated the recovery of information from echosounder buoys (2010-2022).

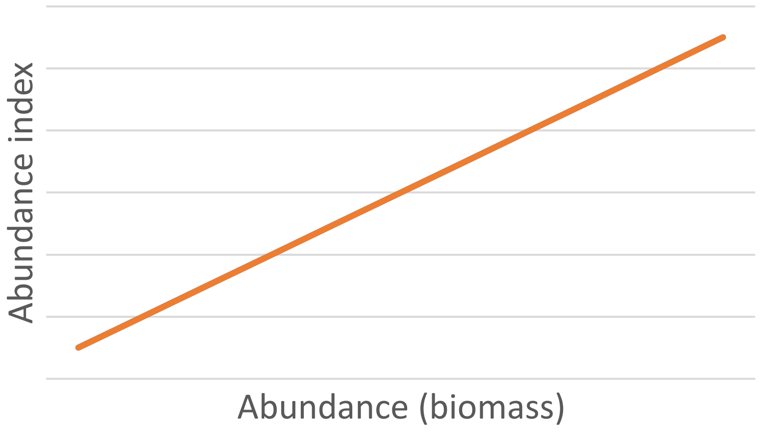
**~27,16 million acoustic records [SATLINK]**

23 purse-seine vessels from 5 different countries (Panama, Spain, Ecuador, El Salvador, USA)

# CPUE

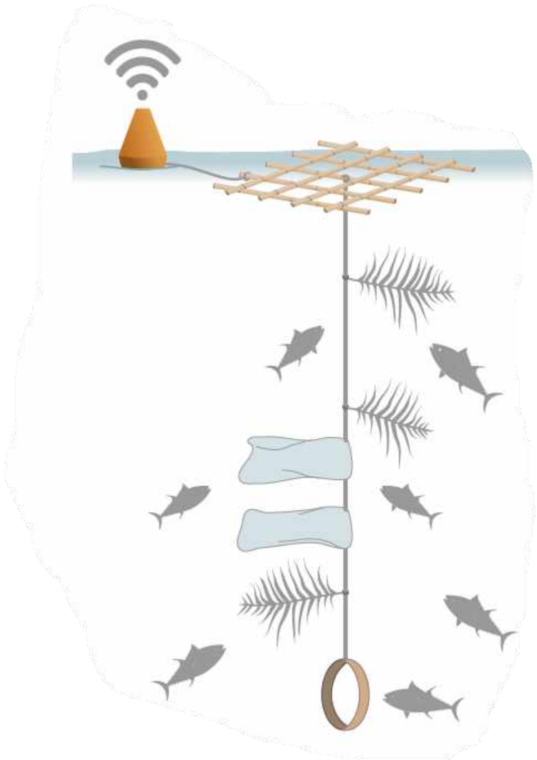





$$CPUE = q \cdot biomass$$

# BAI



BAI = λ · biomass

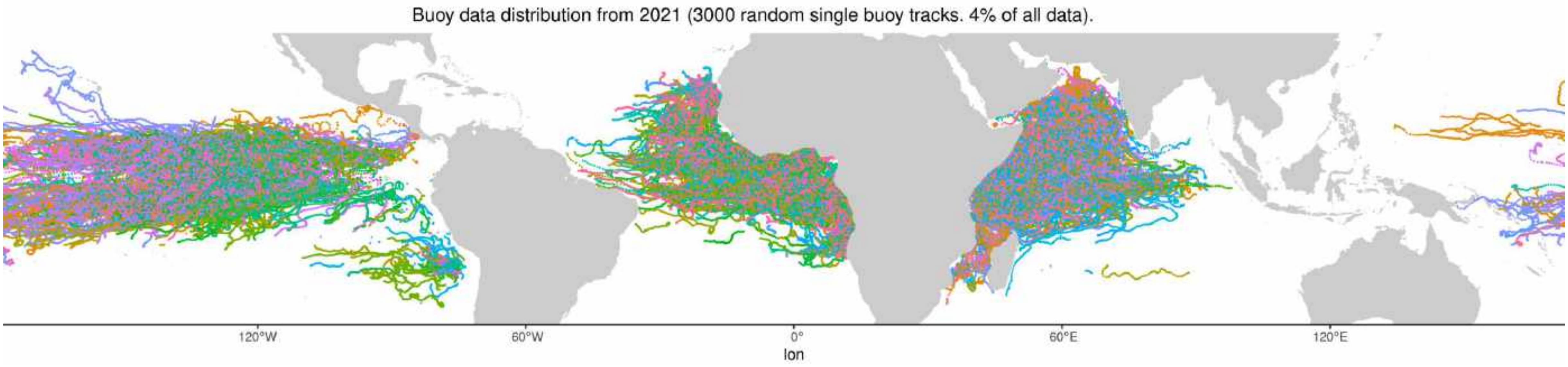
**From CPUE = q . biomass**
**to BAI = λ . Biomass**

**Key assumptions:**

- Relationship between BAI and abundance is linear (proportional).
- The relationship doesn’t change over time or space.
- The proportion of the abundance associated to FADs is proportional to the total abundance

# Data and methods

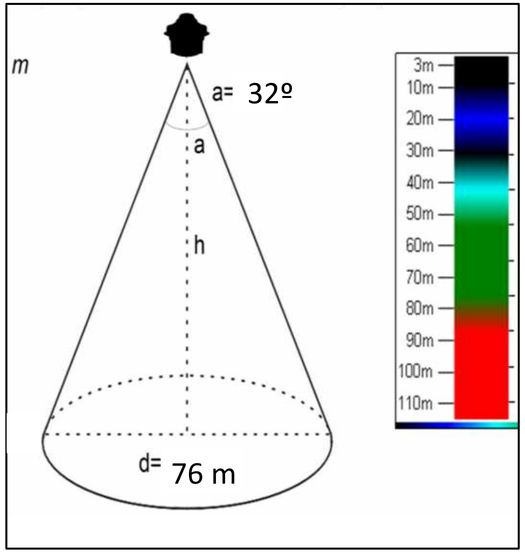
# Data and methods

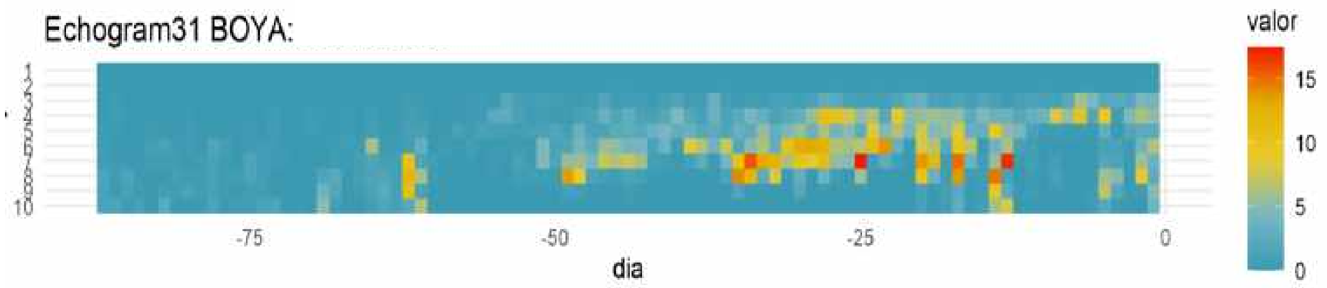



Acoustic data recorded by a single buoy echogram

# Data and methods

**The acoustic (raw) data: Satlink**




Units used by the buoy brand (0-63 tones range per layer)

Decibels

Recalculated biomass by species

$$Biomass_i = \frac{s_V \cdot Vol \cdot p_i}{\sum_i \sigma_i \cdot p_i} \quad ; \ \sigma_i = \frac{10^{(TS)/10}}{w_i} \quad ; TS \ = \ 20log(Li) \ + b20$$

- Sv is the volume backscattering strength, Vol is the sampled volume of the beam and $p_i$ and $\sigma_i$ are the proportion and linearized target strength of each species i respectively.
- TS: from (Boyra et al. 2018) for SKJ, from (Bertrand and Josse 2000; Oshima 2008, Sobradillo et al 2023) for YFT and from (Boyra et al. 2018) for BET.
- Since acoustic records do not always have information on catch composition for the same time-area strata, we followed a three-step hierarchical process to get this correspondence: 1) use species catch composition data from the same 1ºx1º grid, year and month; 2) alternatively, use the same quarter and 1ºx1º grid; and finally, as a last resort 3), use the mean values of species and size composition data at same quarter and region from SA areas. Length information at 5x5.

# Data and methods

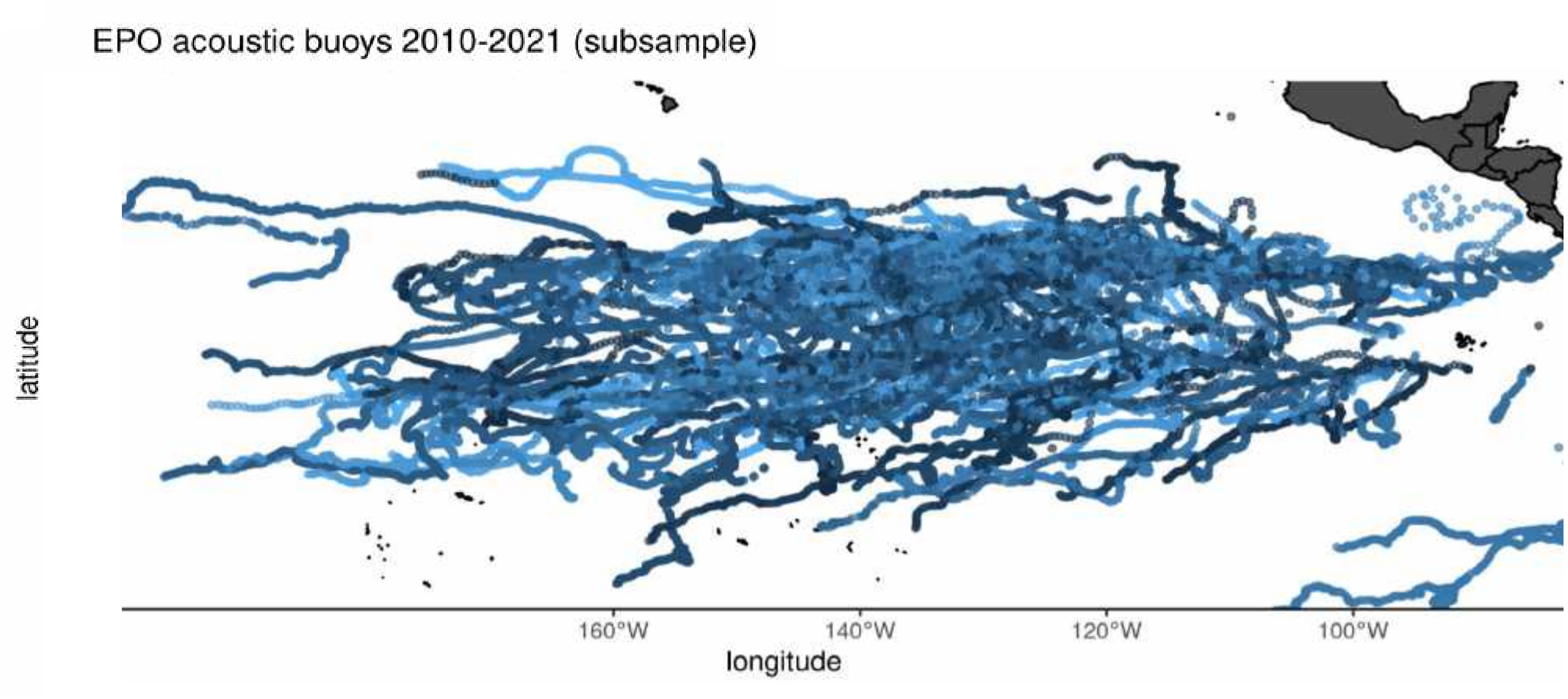
## Acoustic data cleaning and filtering

DATA CLEANING: Remove records without acoustic information, duplicates, outliers, bad geolocation, time, or other general variables.

DATA FILTERING:

- shallower layers of acoustic data[<25 m] discarded.
- bottom shallower than 200m discarded.
- onboard signals discarded.
- only data from 4-8 AM.
- days since deployment: only records between 20 and 35 days were used (“virgin” segments)

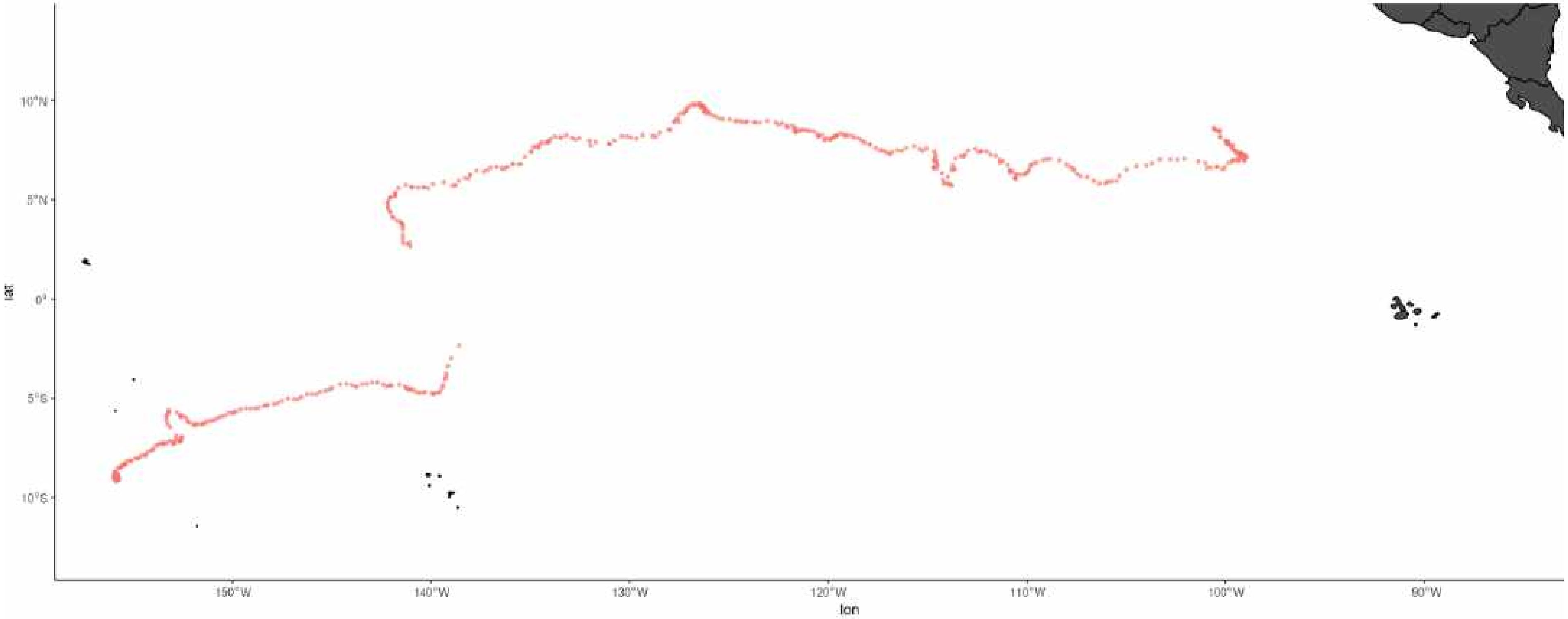
# Data and methods




**“Concept of “virgin segment”:** segment of a buoy trajectory whose associated FAD **likely represents a new deployment or re-deployment** which has been **potentially colonized** by tuna and **probably not already fished**

# Data and methods

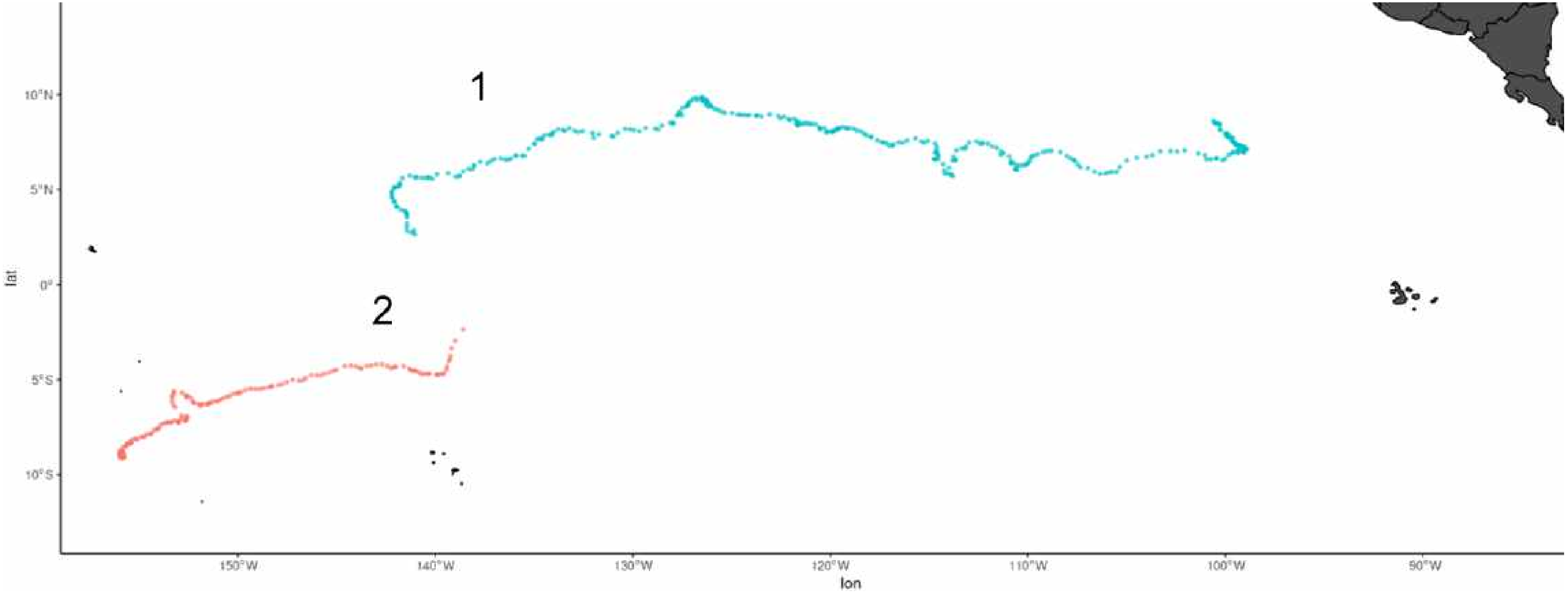
Concept of “virgin segment”




1 buoy

# Data and methods

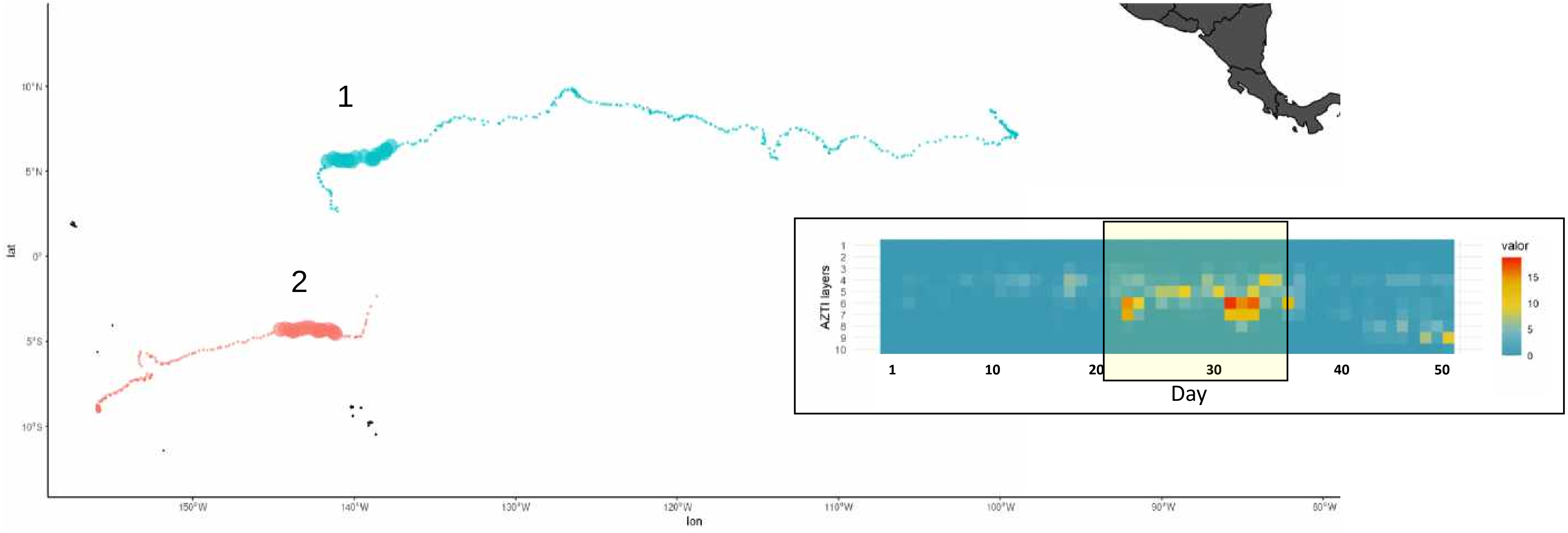
Concept of “virgin segment”




(1 buoy – 2 trajectories)

# Data and methods

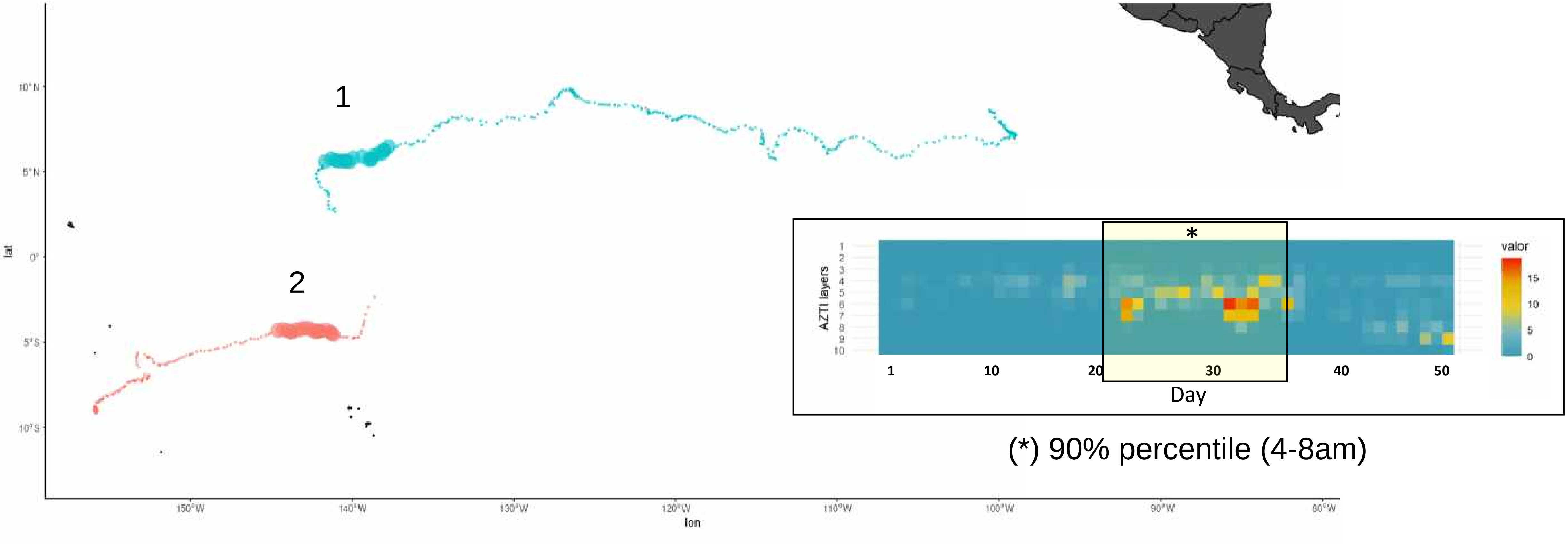
Concept of “virgin segment”




(1 buoy – 2 trajectories – 2 sections)

# Data and methods

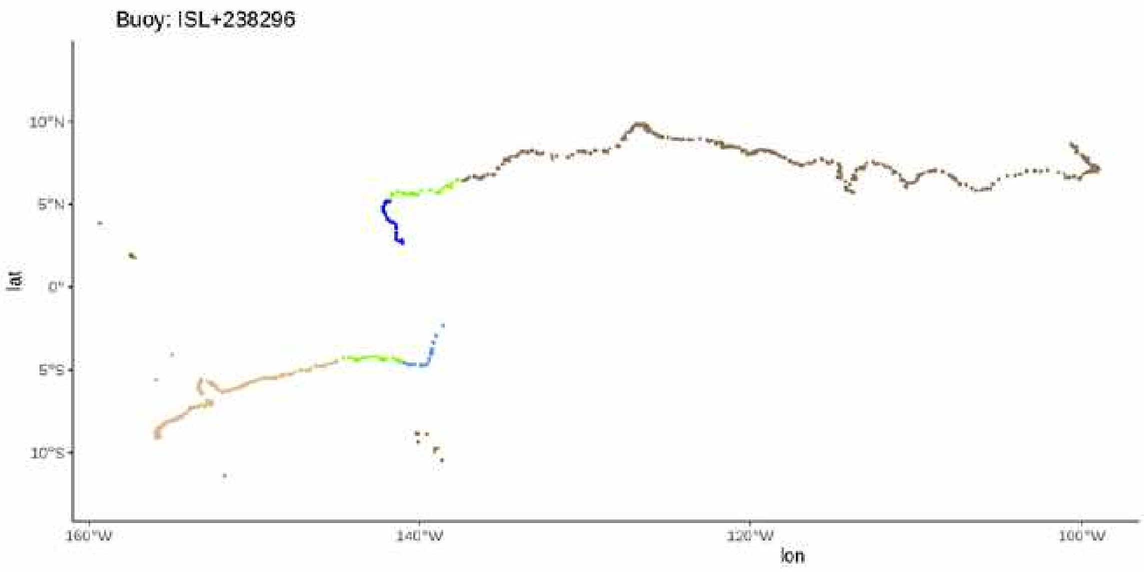
Concept of “virgin segment”

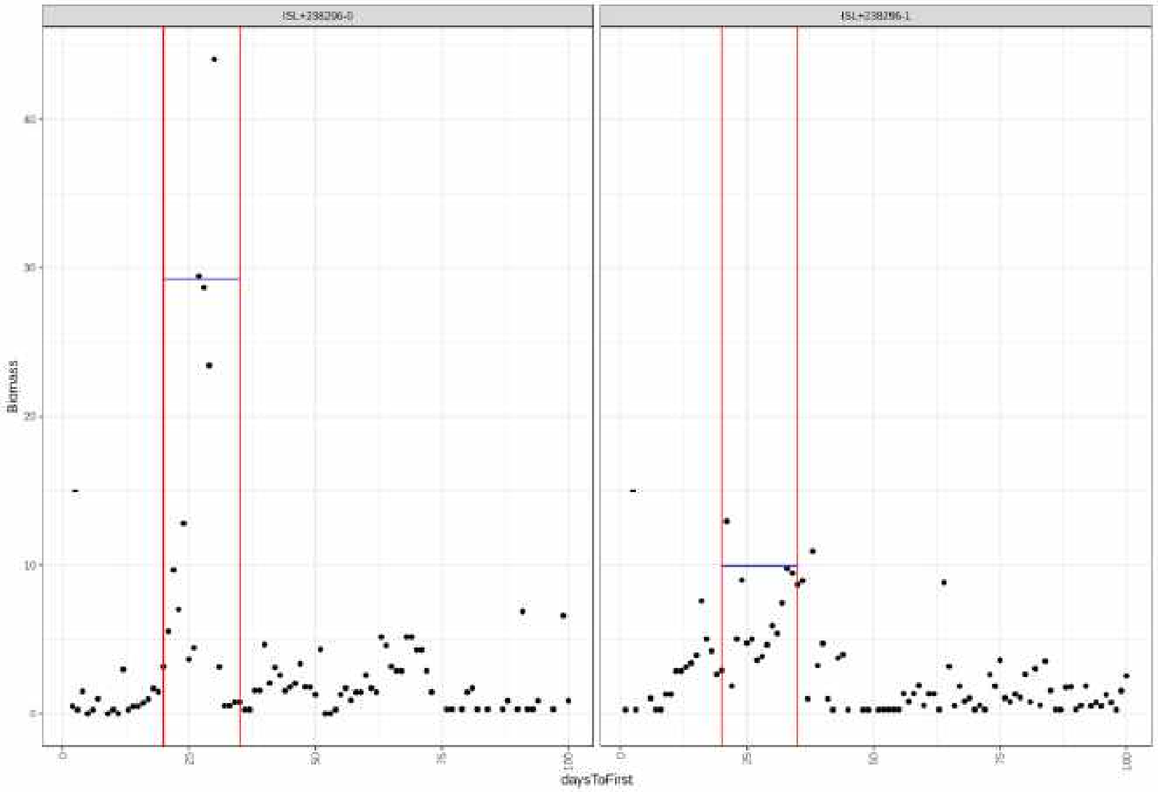



(*) 90% percentile (4-8am)

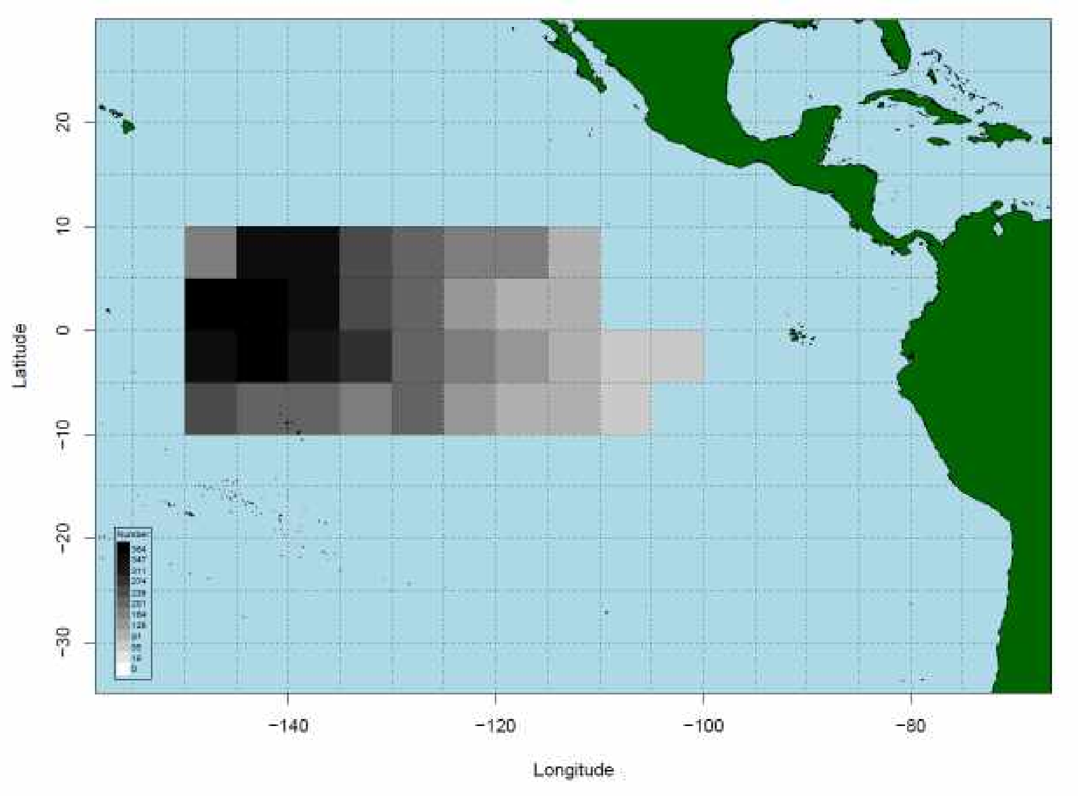
(1 buoy – 2 trajectories – 2 sections)

# Data and methods

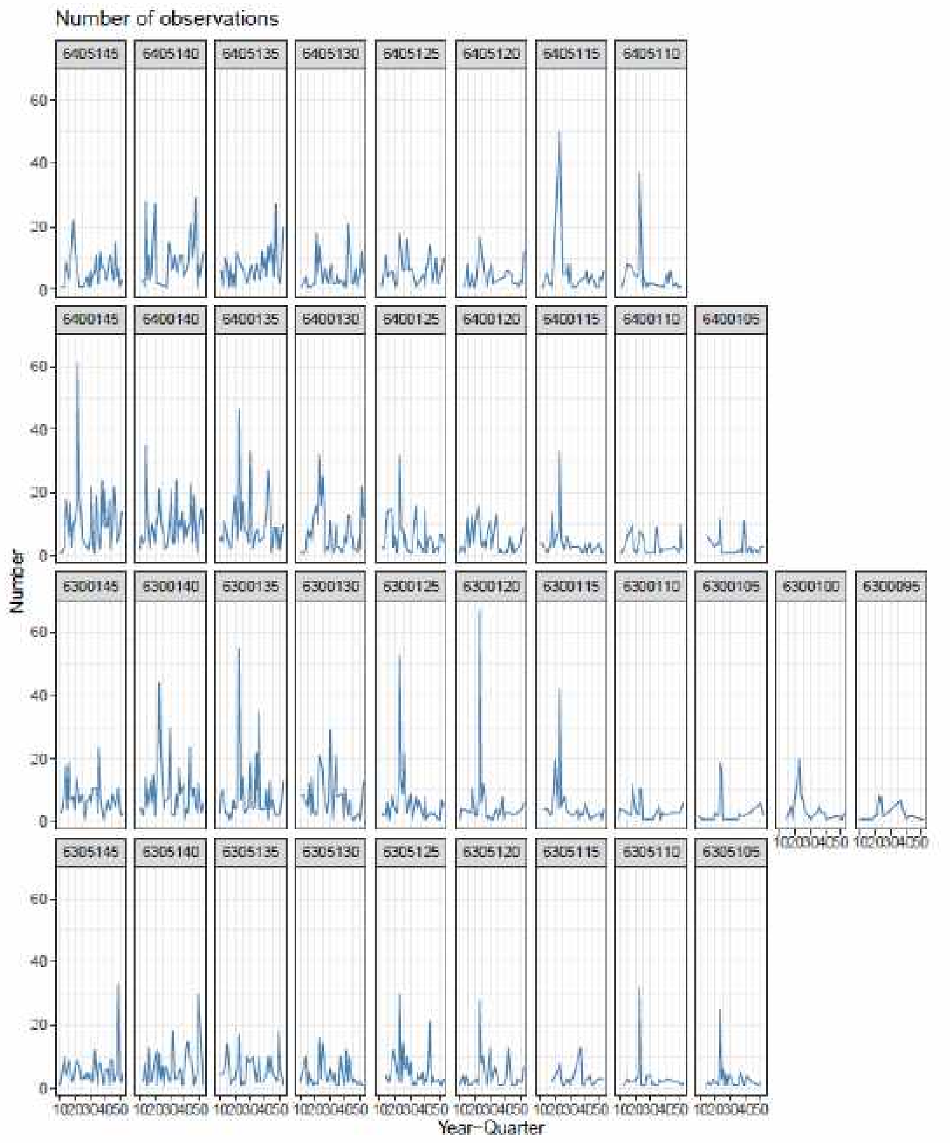


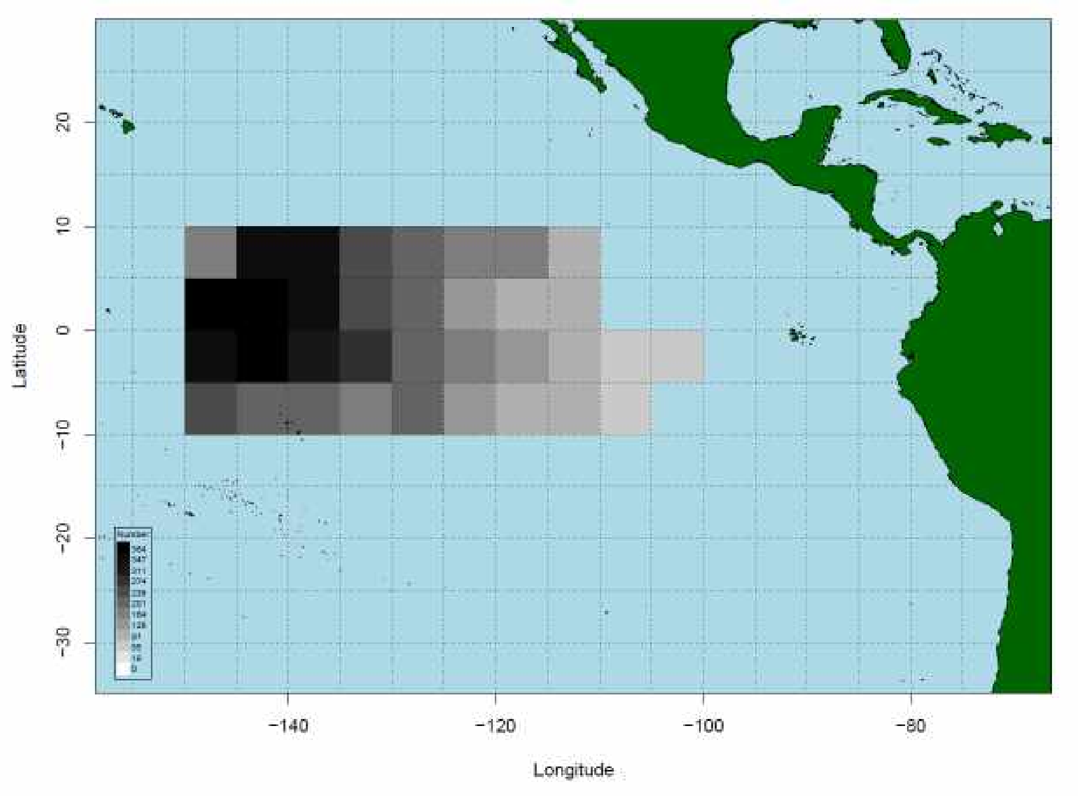
# Data and methods



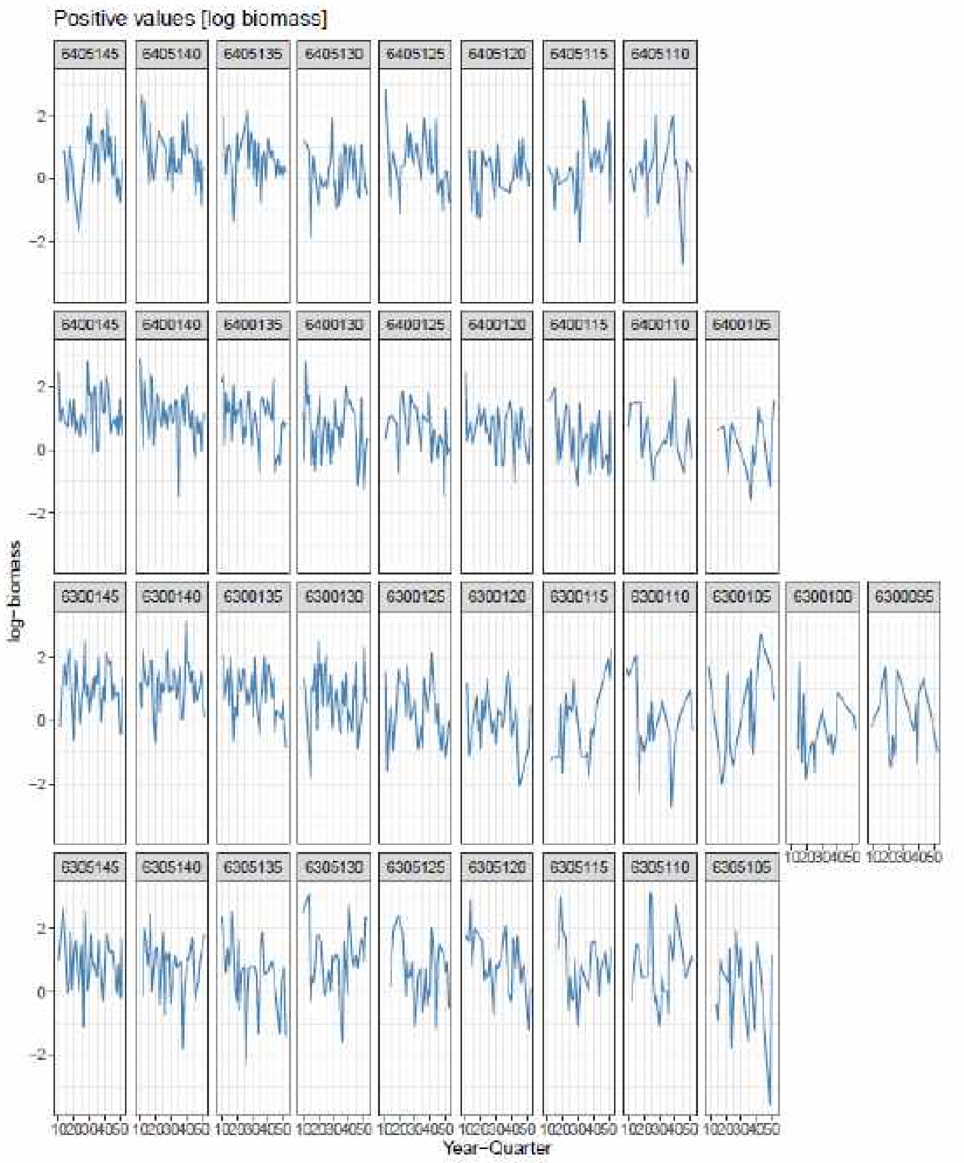

*Number of observations by quarter [5ºx5º]*
*~44,000 buoys; ~8500 observations*



# Data and methods




*Nominal values by quarter [5ºx5º]*



# Data and methods

**The BAI index (Buoy-derived Abundance Index) :**

- Covariates used in the standardization process were:
  - Categorical: year- quarter, 5x5º area and buoy model.
  - Continuous: A proxy of 1ºx1º and monthly FAD densities (average number of unique buoys over each month in a 1x1 area), velocity of the buoy and environmental variables (Ocean mixed layer thickness, Chlorophyll and Chlorophyll front, SST and SST front)
- The signal from the echosounder is proportional to the abundance of fish: $\mathbf{BAI_t = \boldsymbol{\lambda} \, . \, B_t}$
- In standardization analysis is performed. order to ensure that λ can be assumed to be constant a
- Considering the low proportion of zero values (1.58%) a GLMM log-normal error structured model was applied to standardize the acoustic observations

# Results

# Results

## Analysis of deviance table (SKJ model):

| Variable | Df | Deviance | Resid_Df | Resid_Dev | F | Pr_F | Dev_Exp |
|---|---|---|---|---|---|---|---|
| NULL | NA | NA | 22789 | 31673 | NA | NA | NA |
| yyqq | 43 | 2192 | 22746 | 29481 | 66 | 0 | 6.92 |
| area | 33 | 2845 | 22713 | 26636 | 112 | 0 | 8.98 |
| model | 3 | 166 | 22710 | 26470 | 72 | 0 | 0.52 |
| den | 1 | 34 | 22709 | 26436 | 44 | 0 | 0.11 |
| chlfront | 1 | 64 | 22708 | 26372 | 83 | 0 | 0.2 |
| sst | 1 | 0 | 22707 | 26372 | 0 | 0.8921 | 0 |
| sstfront | 1 | 36 | 22706 | 26336 | 46 | 0 | 0.11 |
| mld | 1 | 5 | 22705 | 26331 | 6 | 0.0154 | 0.01 |
| yyqq:area | 996 | 8645 | 21709 | 17687 | 11 | 0 | 27.29 |
| yyqq:model | 33 | 276 | 21676 | 17411 | 11 | 0 | 0.87 |
| yyqq:den | 39 | 487 | 21637 | 16923 | 16 | 0 | 1.54 |
| yyqq:sst | 43 | 145 | 21594 | 16779 | 4 | 0 | 0.46 |
| yyqq:mld | 42 | 131 | 21552 | 16648 | 4 | 0 | 0.41 |

The proportion of deviance explained by the model was 47%.

log(index)~yyqq + area + yyqq:area

# Results

## Analysis of deviance table (BET model):

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NULL | NA | NA | 22457 | 46316 | NA | NA | NA |
| yyqq | 43 | 3402 | 22414 | 42914 | 73.1057 | 0 | 7.35 |
| area | 33 | 5615 | 22381 | 37298 | 157.243 | 0 | 12.12 |
| model | 3 | 286 | 22378 | 37012 | 88.2148 | 0 | 0.62 |
| den | 1 | 107 | 22377 | 36905 | 98.8709 | 0 | 0.23 |
| chlfront | 1 | 30 | 22376 | 36875 | 27.6809 | 0 | 0.06 |
| sst | 1 | 80 | 22375 | 36794 | 74.2552 | 0 | 0.17 |
| sstfront | 1 | 33 | 22374 | 36761 | 30.8957 | 0 | 0.07 |
| mld | 1 | 0 | 22373 | 36761 | 0.1948 | 0.66 | 0 |
| yyqq:area | 988 | 12186 | 21385 | 24575 | 11.3974 | 0 | 26.31 |
| yyqq:model | 32 | 414 | 21353 | 24161 | 11.9587 | 0 | 0.89 |
| yyqq:den | 39 | 745 | 21314 | 23415 | 17.6541 | 0 | 1.61 |
| yyqq:sst | 43 | 187 | 21271 | 23229 | 4.0168 | 0 | 0.4 |
| yyqq:mld | 42 | 255 | 21229 | 22974 | 5.6048 | 0 | 0.55 |

The proportion of deviance explained by the model was 50%.

log(index)~yyqq + area + yyqq:area

# Results

## Analysis of deviance table (YFT model):

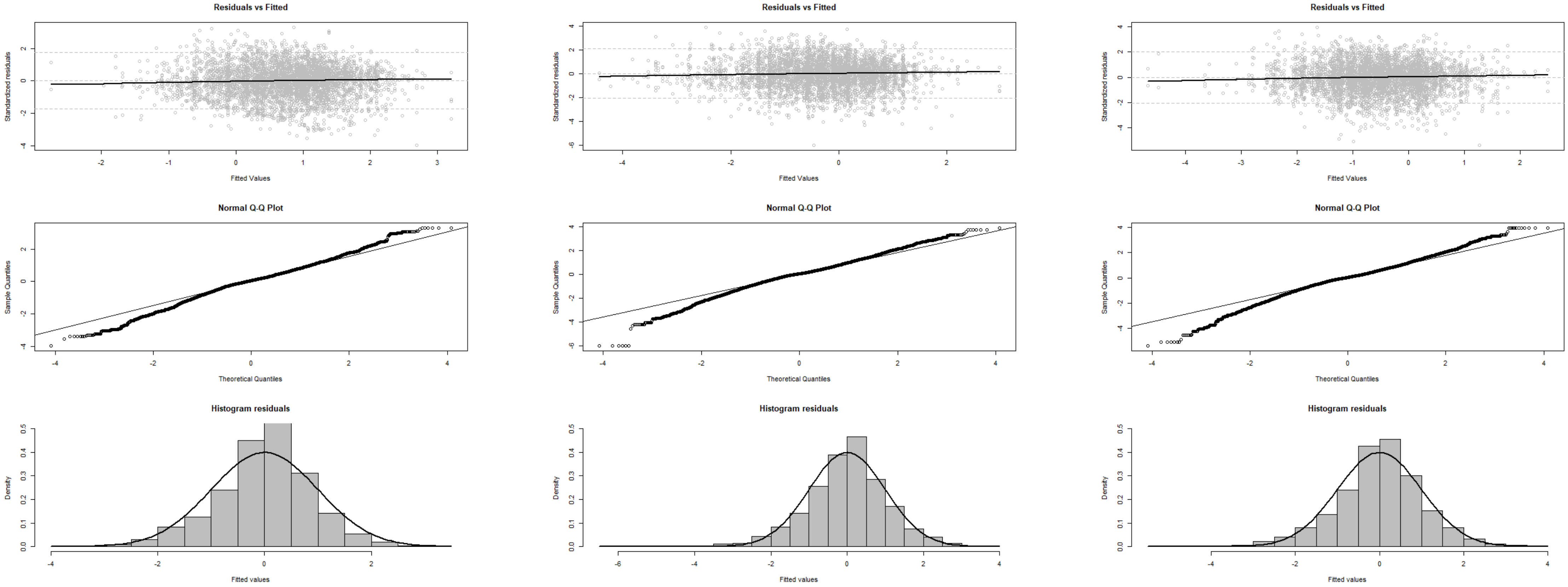
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NULL | NA | NA | 22663 | 41844 | NA | NA | NA |
| yyqq | 43 | 2881 | 22620 | 38963 | 63 | 0 | 6.88 |
| area | 33 | 2963 | 22587 | 36000 | 85 | 0 | 7.08 |
| model | 3 | 177 | 22584 | 35823 | 56 | 0 | 0.42 |
| den | 1 | 436 | 22583 | 35387 | 413 | 0 | 1.04 |
| chlfront | 1 | 66 | 22582 | 35321 | 62 | 0 | 0.16 |
| sst | 1 | 23 | 22581 | 35298 | 22 | 0 | 0.06 |
| sstfront | 1 | 25 | 22580 | 35273 | 24 | 0 | 0.06 |
| mld | 1 | 0 | 22579 | 35273 | 0 | 0.8898 | 0 |
| yyqq:area | 994 | 11477 | 21585 | 23796 | 11 | 0 | 27.43 |
| yyqq:model | 32 | 302 | 21553 | 23494 | 9 | 0 | 0.72 |
| yyqq:den | 39 | 472 | 21514 | 23021 | 11 | 0 | 1.13 |
| yyqq:sst | 43 | 145 | 21471 | 22876 | 3 | 0 | 0.35 |
| yyqq:mld | 42 | 228 | 21429 | 22648 | 5 | 0 | 0.55 |

The proportion of deviance explained by the model was 45%.

log(index)~yyqq + area + yyqq:area

# Results

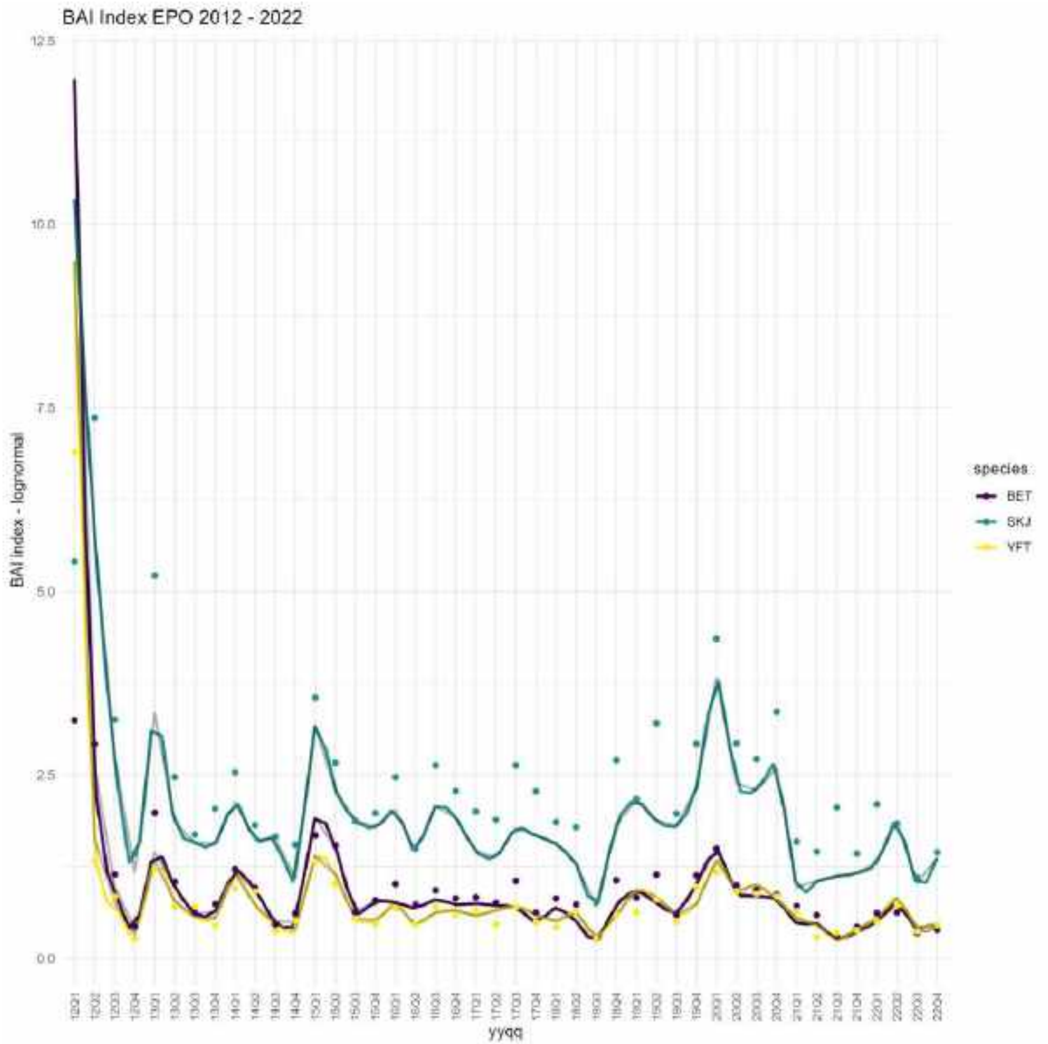
Diagnostics of the lognormal model selected for the period 2012-2022: residuals vs fitted, Normal Q-Q plot and frequency distributions of the residuals. No residual patterns found.

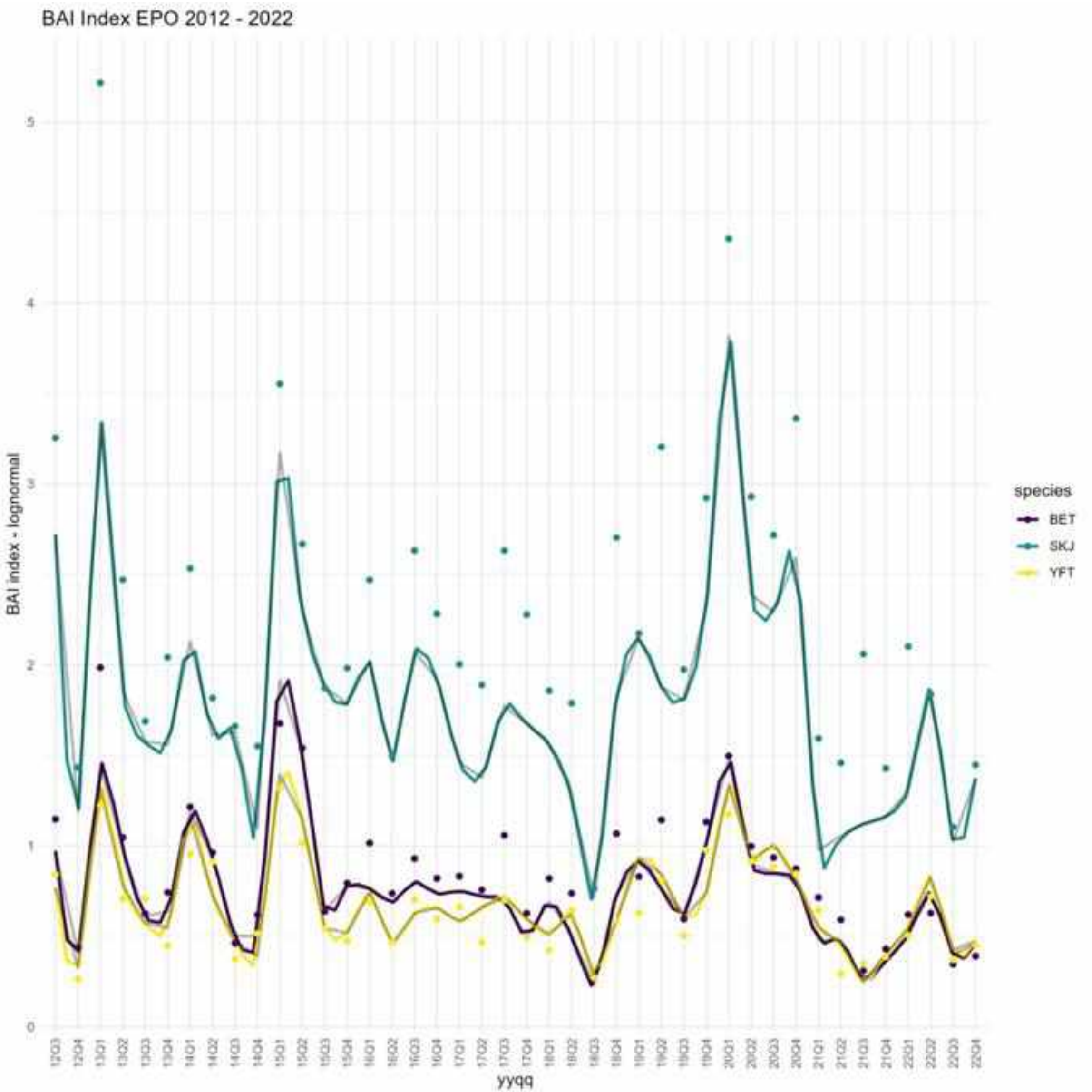



SKJ BET YFT

# Results

## BAI indices



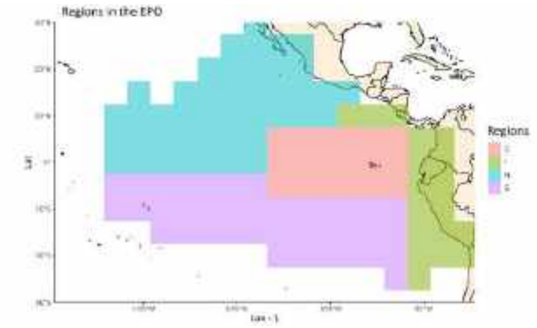

Time series of nominal (circles) and standardized (continuous line) Buoy-derived Abundance Indices for SKJ, BET and YFT for the period 2012-2022 in the EPO. The 95% upper and lower confidence intervals of the standardized BAI index are shown.

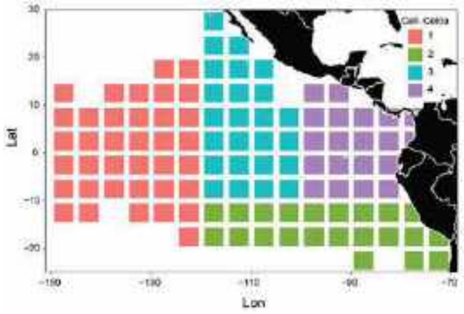
# Conclusions and Discussion

- Retrieve new **historical acoustic data** from other companies or associations and integrate them into latest BAI index. **(SAC, FAD WG and Staff Recommendation)**

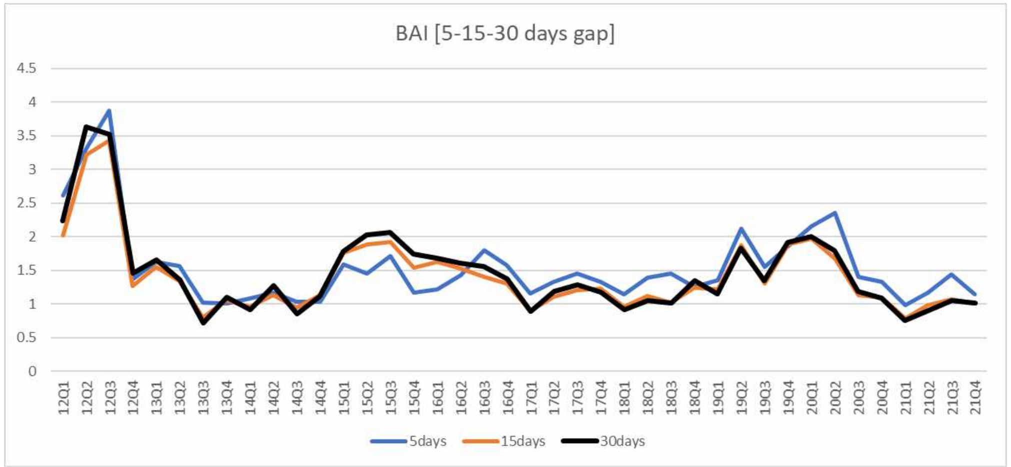
- The contribution of data from other areas could produce/update the index in the same area or generate two different indices: **offshore vs coastal**.

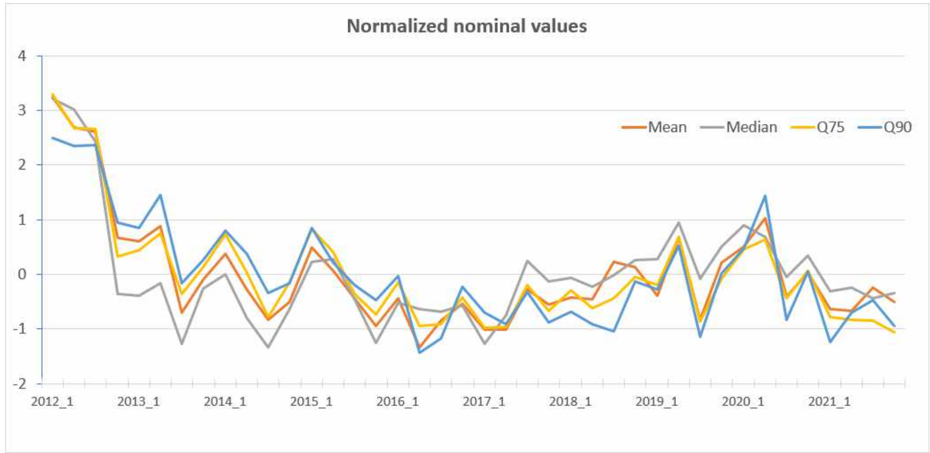
- Integrate data from different brands to determine if acoustic data can be standardized or brand-specific indices should be generated. (**Contacts with other manufactures ongoing**)



- **Review and (re)evaluate database filters** for producing virgin segments.
- **Update the process for assigning species and size composition to acoustic data**. Better understand the effect of different species and size composition resolutions on the final index and develop a protocol for assigning values hierarchically.
- **Reconsider the assumption that days 20-35 after new deployments are the best measure for colonization models**. Find an adaptive solution suitable for different regions and seasons of the Eastern Pacific Ocean, even at the buoy level.
- **Try to Integrate Marine Instruments and Zunibal buoys into the study**, carefully considering the need for independent indices or standardized data.
- **Conduct additional sensitivity tests on the model for exploring alternative biomass values:**

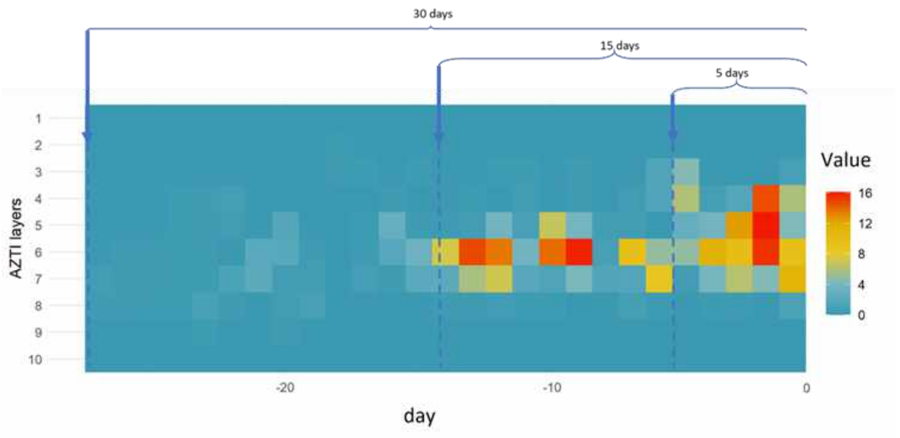


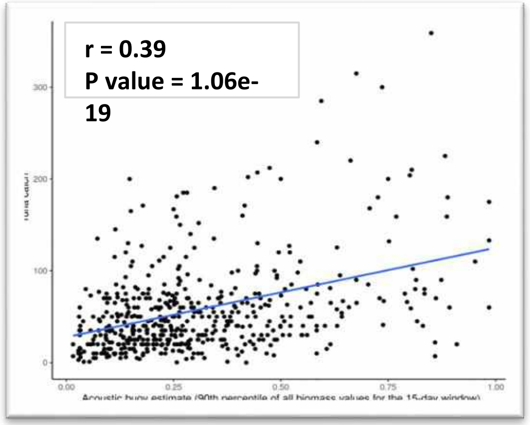



- **Cross-referencing acoustic data with capture data** linked to buoys is crucial for improving the methodology and ensuring robustness of the data used in this proposal.

- Switching to complete echograms of the virgin segment as input for new models and increasing the number of samples for comparison can lead to a significant qualitative improvement in species discrimination and pattern recognition. **Develop a ML model to determine Species and Sizes composition based on echograms.**

- Further research is needed to generate relative abundance indices based on buoy acoustics, addressing the noise in the data and exploring the potential of **collaborative projects with fishing vessels to collect complementary acoustic data (e.g., vessels echo-sounder, sonar)**.



# Acknowledgements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**Gracias!** **Thank you!**