Spatiotemporal tagging model for skipjack tuna in the EPO

SCIENTIFIC ADVISORY COMMITTEE
13^{th} MEETING
(Agenda item 6dii)

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16-20 May 2022

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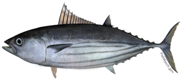
Motivation



- SKJ in the EPO is an important fisheries resource (300 TMT SKJ caught in EPO in 2020)
- Historically, problematic to assess:
  - No reliable index of relative abundance
  - No age-composition data
  - Possibility of dome-shape selectivity
- On the other hand, tagging data available
  - Spatiotemporal population model that can estimate abundance and sustainable harvest levels
  - First step: Estimate movement with spatiotemporal tagging model

Maunder and Harley, 2005; SAC-12–03; SAC-12-06

Tagging data

- Four tagging events :
  - 1955 - 1964
  - 1979 - 1981
  - 2000 - 2006
  - 2019 - ongoing
- 9625 conventional tags
- 49 unique release locations
- 2007 (21%) recaptured
- EPO:
  - $150°$W - coastline
  - $30°$S - $35°$N
- Grid: $5°/2.5°$ grid cell

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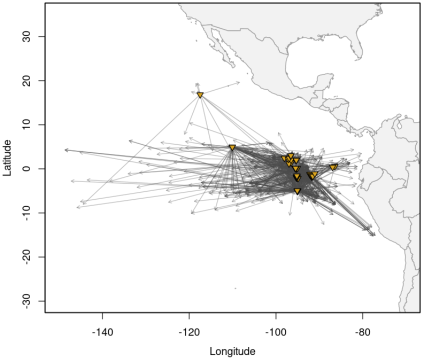

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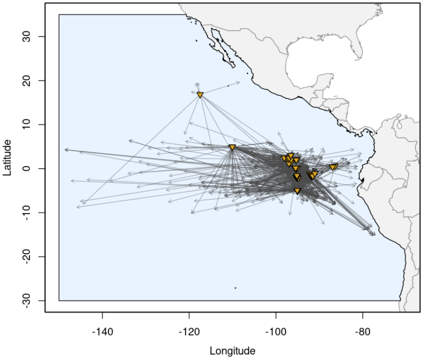

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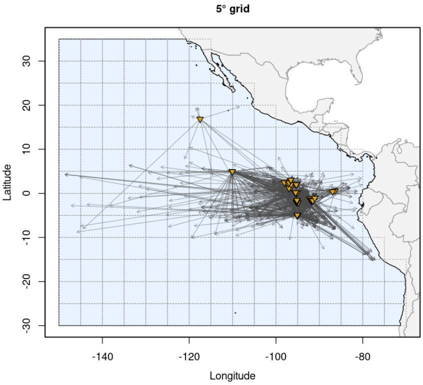

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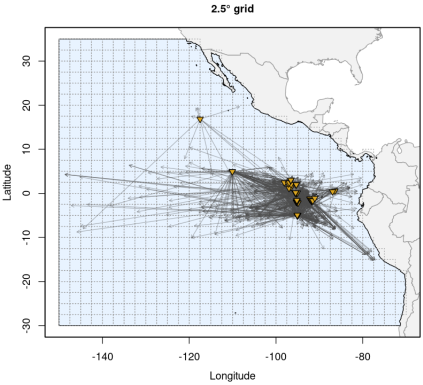


Spatiotemporal tagging model

Movement M defined as the matrix exponential of instantaneous the advection A^* and diffusion D^* rates (Thorson *et al.* 2021).

$$\boldsymbol{M} = e^{(\boldsymbol{A}^* + \boldsymbol{D}^*)\Delta t}$$

Thorson *et al.* 2021

Instantaneous advection rate

The habitat preference function is defined as the sum of smooth functions f_i of the ith environmental layer $x(g,t)$ with knot vector k_i and corresponding parameter values α_i:

$$h(g,t) = \sum_{i=1}^{n} f_i(x_i(g,t), k_i)$$

where g and t correspond to the the grid cell and time step, respectively.

The advection rate is defined by local differences in the habitat preference that is based on smoothed functions of any number of environmental layers:

$$\boldsymbol{A}^*(g_2, g_1, t) = \begin{cases} h(g_2,t) - h(g_1,t) & \text{if } g_1 \text{ and } g_2 \text{ are adjacent} \\ -\sum_{g' \neq g_1} \boldsymbol{A}^*(g', g_1, t) & \text{if } g_1 = g_2 \\ 0 & \text{if otherwise,} \end{cases}$$

Thorson *et al.* 2021

Instantaneous diffusion rate

The diffusion rate can assumed to be constant in time and space or similarly dependent on an environmental layer:

$$
\boldsymbol{D}^*(g_2, g_1, t) = \begin{cases} e^{2\beta} & \text{if } g_1 \text{ and } g_2 \text{ are adjacent} \\ -\sum_{g' \neq g_1} \boldsymbol{D}^*(g', g_1, t) & \text{if } g_1 = g_2 \\ 0 & \text{if otherwise,} \end{cases}
$$

where g and t correspond to the the grid cell and time step, respectively

Thorson *et al.* 2021

Instantaneous diffusion rate

The diffusion rate can assumed to be constant in time and space or similarly dependent on an environmental layer:

$$\boldsymbol{D}^*(g_2, g_1, t) = \begin{cases} e^{2d(g_1,t)} & \text{if } g_1 \text{ and } g_2 \text{ are adjacent} \\ -\sum_{g' \neq g_1} \boldsymbol{D}^*(g', g_1, t) & \text{if } g_1 = g_2 \\ 0 & \text{if otherwise,} \end{cases}$$

where g and t correspond to the the grid cell and time step, respectively, and

$$d(g,t) = \sum_{i=1}^{n} f_i(x_i(g,t), k_i)$$

is the sum of smooth functions f_i of the ith environmental layer $x(g,t)$ with knot vector k_i and corresponding parameter values β_i.

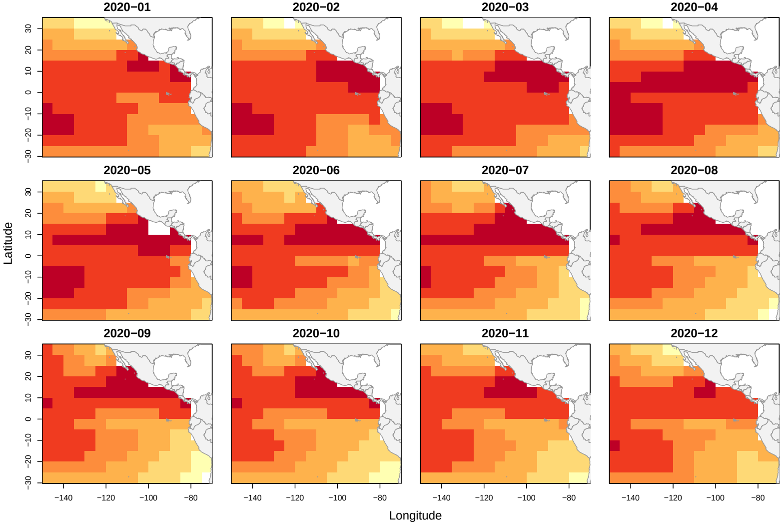
Thorson *et al.* 2021

Model specifications

- Recovered tags from two tagging events: 2000 - 2020
- Spatial resolution: 5° and 2.5° grid
- Temporal resoluton: 12 time steps per year
- Constant instantanoeus diffusion rate
- Instantaneous advection rate:
    - Mixed layer depth (MLD) and Sea Surface Temperature (SST)
    - Natural splines with 3 knots for each environmental variable
- Implemented in R and Template Model Builder (TMB)

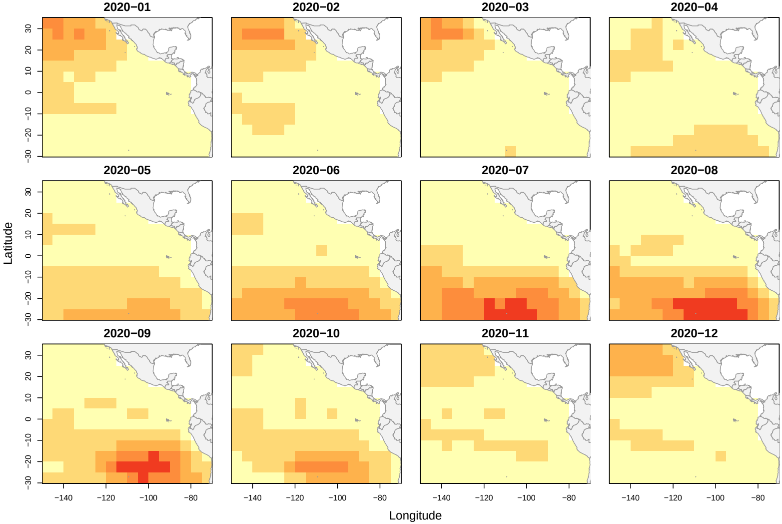
R Core Team 2020; Kristensen et al. 2016

Environmental data: Sea Surface Temperature



https://www.copernicus.eu/en

Environmental data: Mixed layer depth

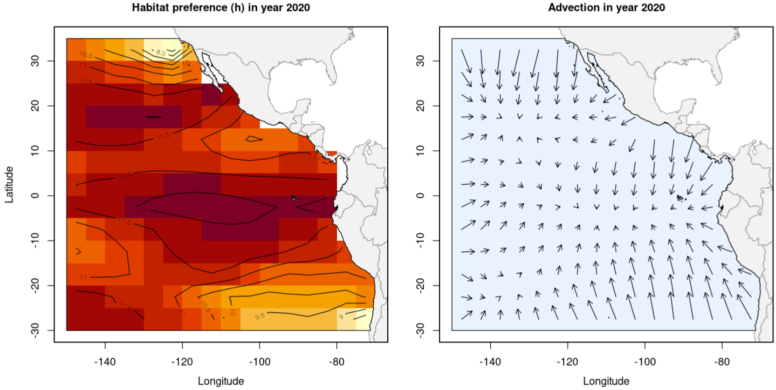


https://www.copernicus.eu/en

Estimated habitat preference and advection

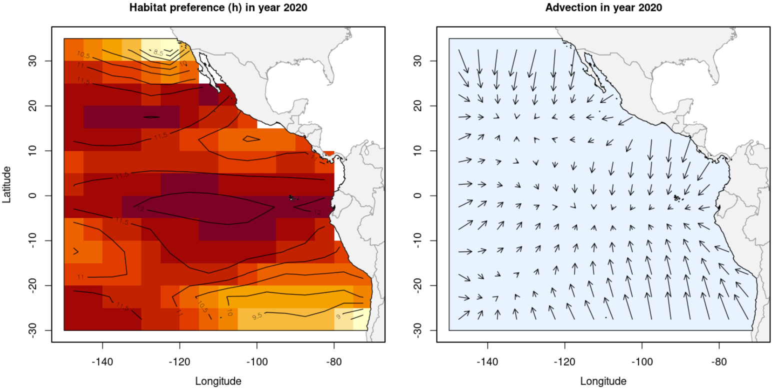
$\rightarrow$ Convergence and meaningful estimates

Estimated habitat preference and advection



→ Convergence and meaningful estimates

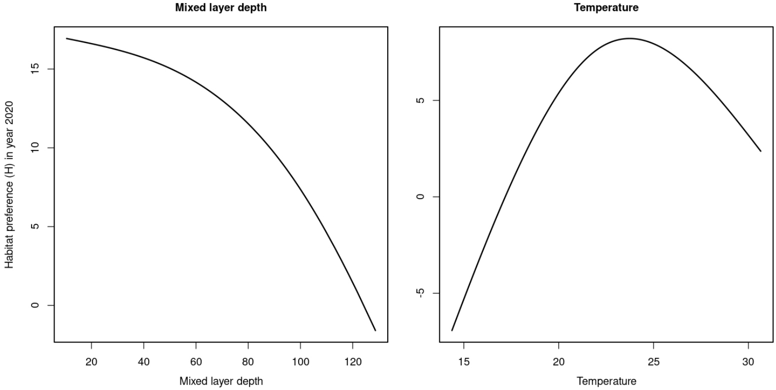
Estimated habitat preference and advection



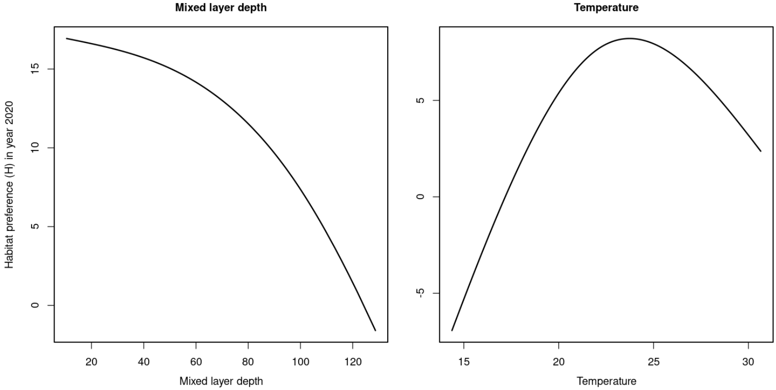
→ Convergence and meaningful estimates

→ Indicate high habitat preference around equator (130° to 80° W), around 20° N, around 30° S and 145° W

Estimated splines

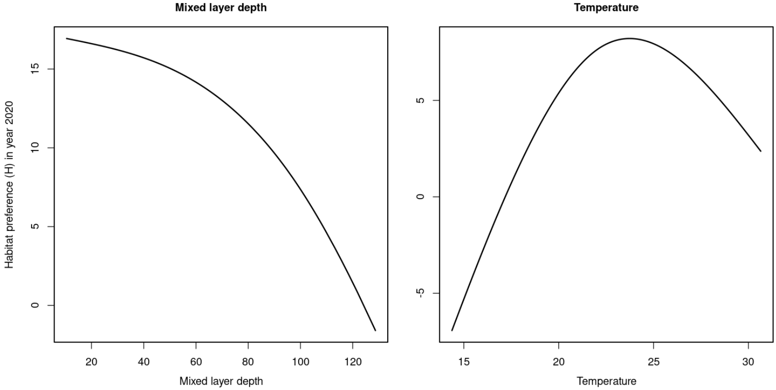


Estimated splines



→ Indicate that SKJ preferred a low MLD and intermediate SST around 24 °C

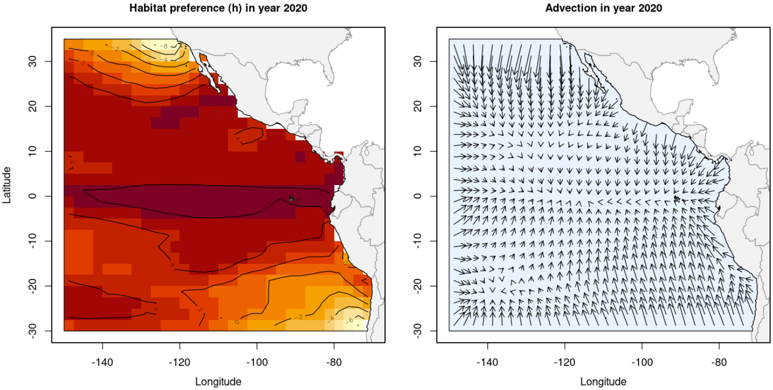
Estimated splines



→ Indicate that SKJ preferred a low MLD and intermediate SST around 24 ℃

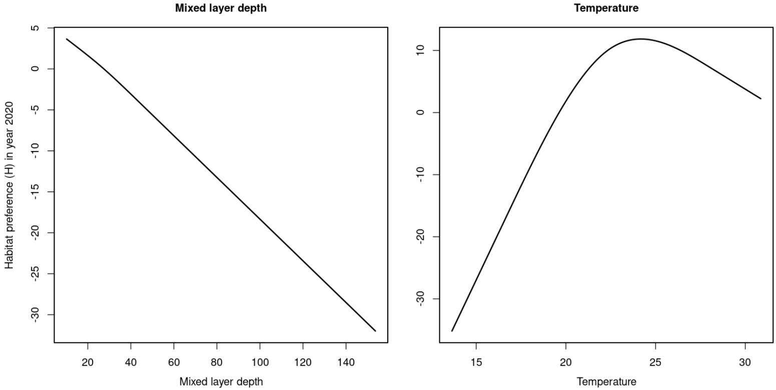
→ MLD and SST similar weighting in terms of contribution to the habitat preference function

Estimated habitat preference and advection (2.5° grid)



→ Consistent results for quarterly model and finer grid (2.5° grid)

Estimated splines (2.5° grid)



→ Same trends, but MLD function declining more linearly

Next steps

Short-term

- Exploring and comparing different environmental layers and spline types and implementations
- Including non-recovered conventional tags
- Utilizing archival tags to further inform the movement of SKJ

Long-term

- Utilizing spatiotemporal catch and effort data to estimate fishing and natural mortality rates
- Setting up a spatially-explicit abundance model informed by the estimated movement matrices
- Estimating reference levels for sustainable harvest
- Determining how the results can be integrated into the interim assessment (SAC-13-07)

Acknowledgements

- Funding from IATTC
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- Everyone involved in the tagging and the recovery of tags

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