CPUE standardization and spatio-temporal distribution modelling of dorado (*Coryphaena hippurus*) in the Pacific Ocean off Peru

Josymar Torrejón – Magallanes[1]; Wencheng Lau – Medrano[1]; Daniel Grados[1]

[1]Instituto del Mar del Perú

Development of spatio-temporal models of fishery catch-per-unit-effort data to derive indices of relative abundance

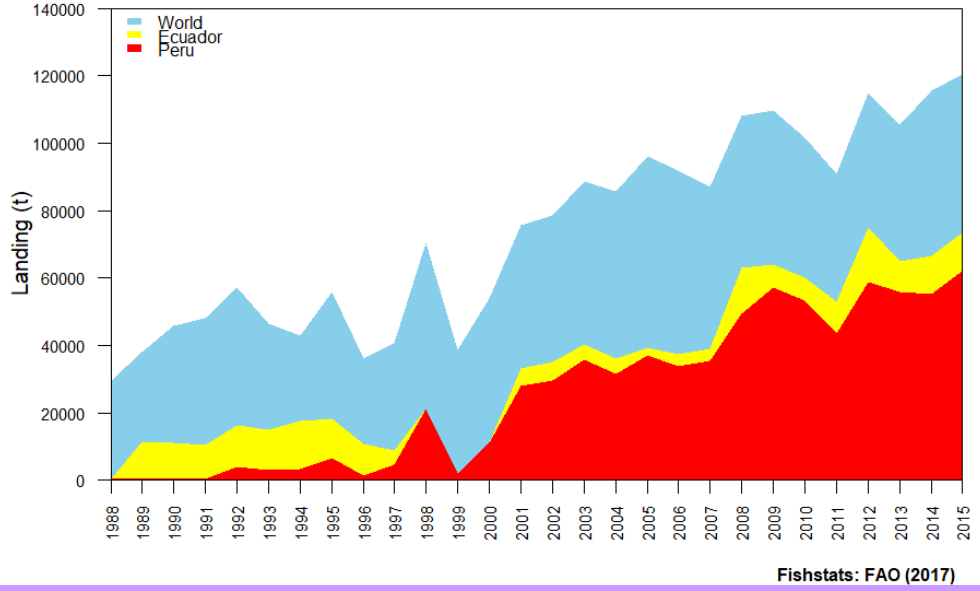
Outline

- Dorado– Peruvian artisanal fishery
- Data description
- Data processing – Models
- Results: CPUE time series - Spatial distribution
- Conclusions
- Issues for further discussion

Dorado: Peruvian artisanal fishery

- The dorado/perico/dolphinfish/mahi mahi is a (epi)pelagic species, with a wide distribution throughout the tropical and subtropical waters of the world's oceans. Top predator, fast growing (~ 3 years).
- The fishing in Peru started in the late 80's.
- Landings: ~ 400 – 61 909 tons (FAO 2017).
- Peru/World: ~ 50% of the total landing.

IMARPE (2015)

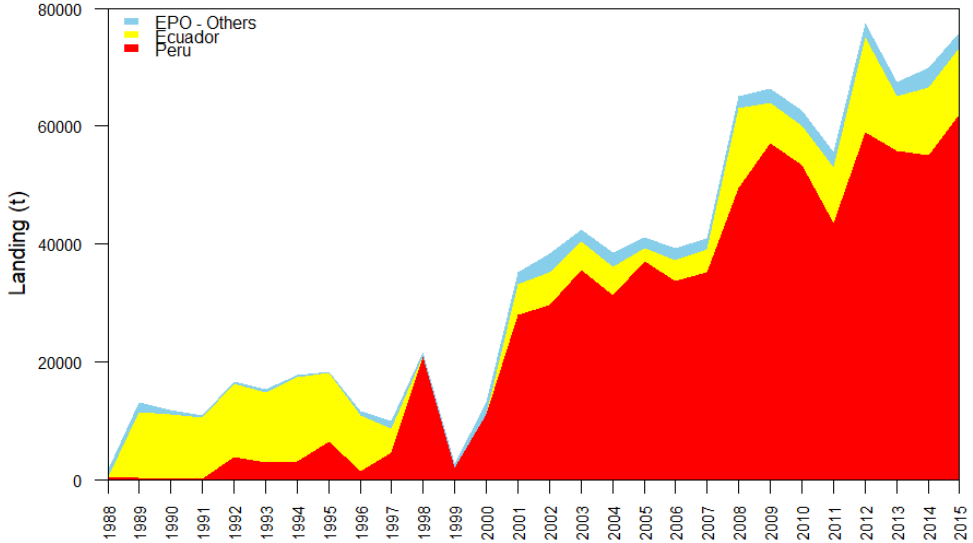


Fishstats: FAO (2017)

Dorado: Peruvian artisanal fishery

- The dorado/perico/dolphinfish/mahi mahi is a (epi)pelagic species, with a wide distribution throughout the tropical and subtropical waters of the world's oceans. Top predator, fast growing (~ 3 years).
- The fishing in Peru started in the late 80's.
- Landings: ~ 400 – 61 909 tons (FAO 2017).
- Peru/World: ~ 50% of the total landing.
- Peru/EPO: ~ 80% of the total landing.

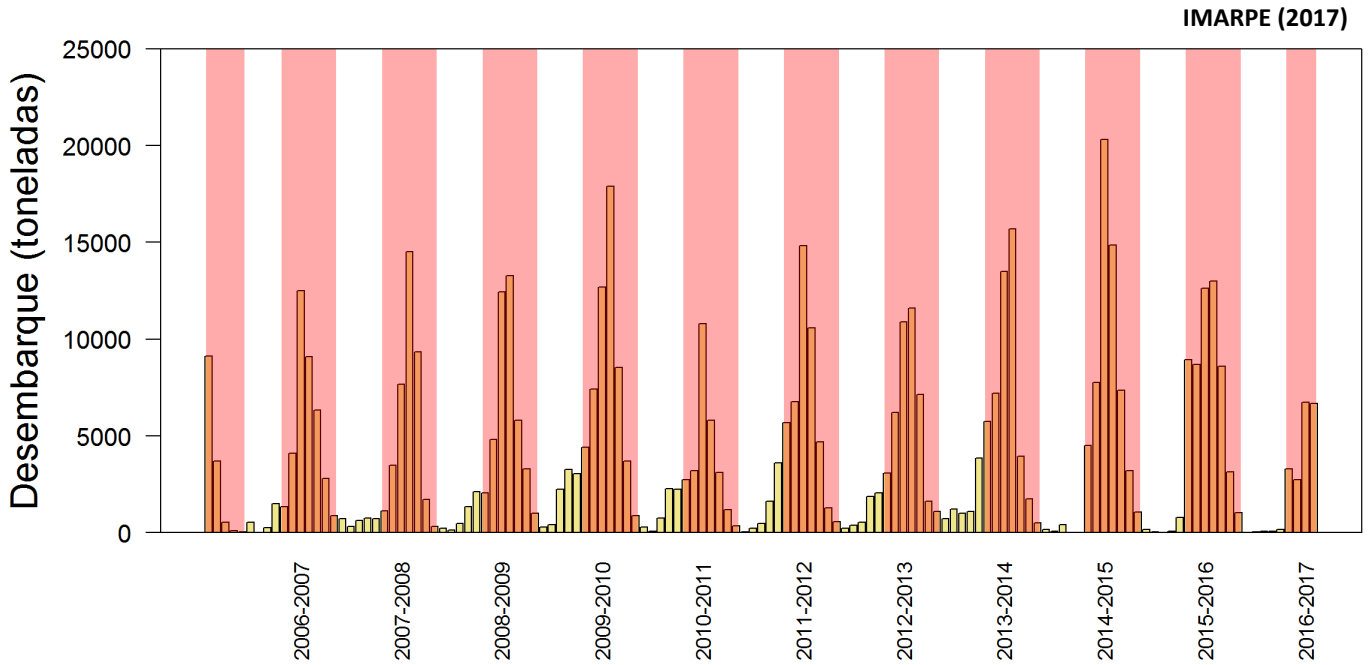
IMARPE (2015)



Fishstats: FAO (2017)

Dorado: Peruvian artisanal fishery

- Seasonal fishery: Mainly in spring and summer (austral), when the Surface Subtropical Waters approach to the coast.
- Fishery season: 01 October – 30 April (Since oct. 2014).
- Fishing areas: Mainly > 30 nautical miles.
- Legal minimum landing size: 70 cm fork length.



Dorado: Peruvian artisanal fishery

- Seasonal fishery: Mainly in spring and summer (austral), when the Surface Subtropical Waters approach to the coast.
- Fishery season: 01 October – 30 April (Since oct. 2014).
- Fishing areas: Mainly > 30 nautical miles.
- Legal minimum landing size: 70 cm fork length.
- Fleet: Hold capacity range between 2 and 32.5 mt.
- Gear: Longline – Hook "J".

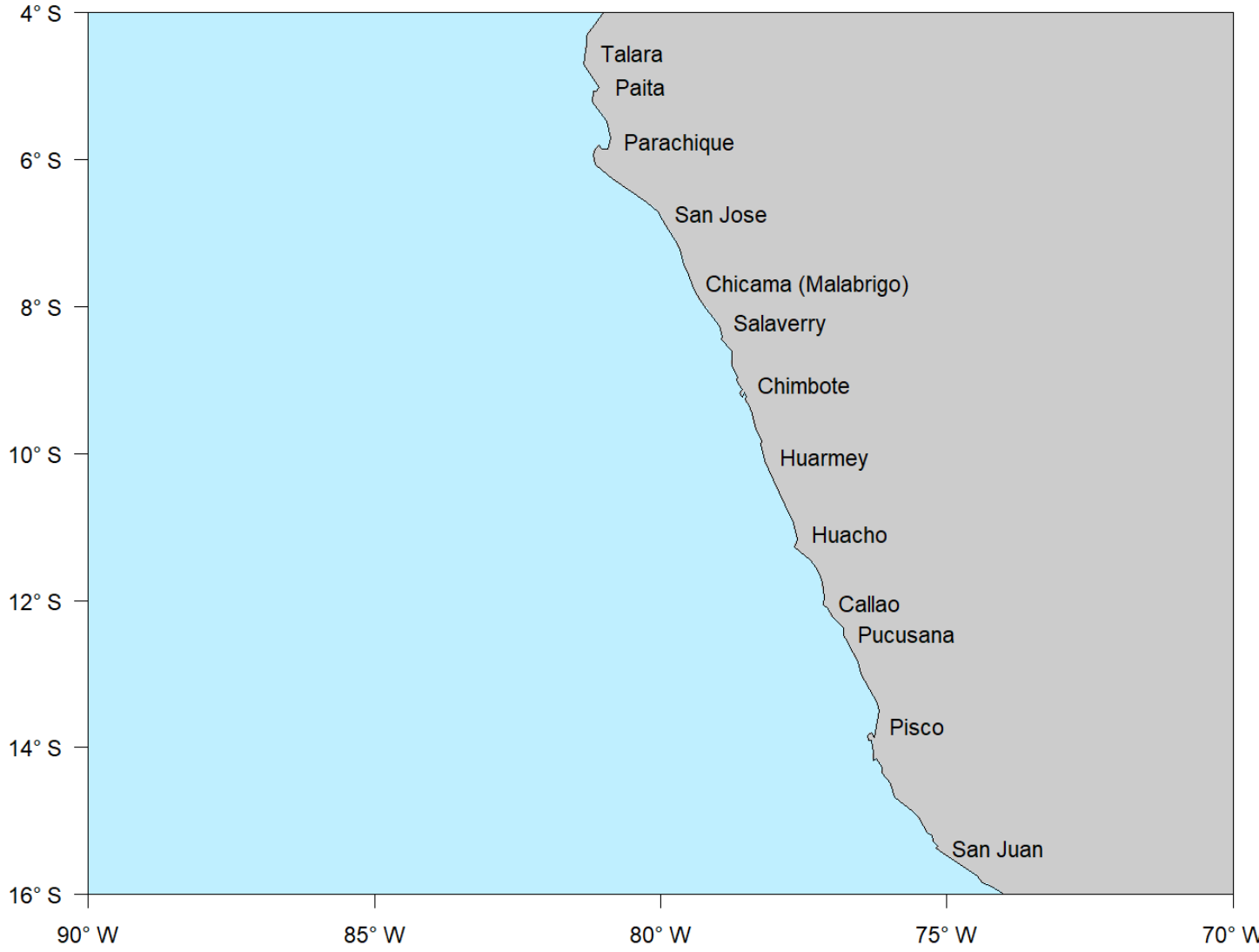
WWF (2017)

Data description

A) Study area:
- 4°S – 16°S | 75°W – 90°W

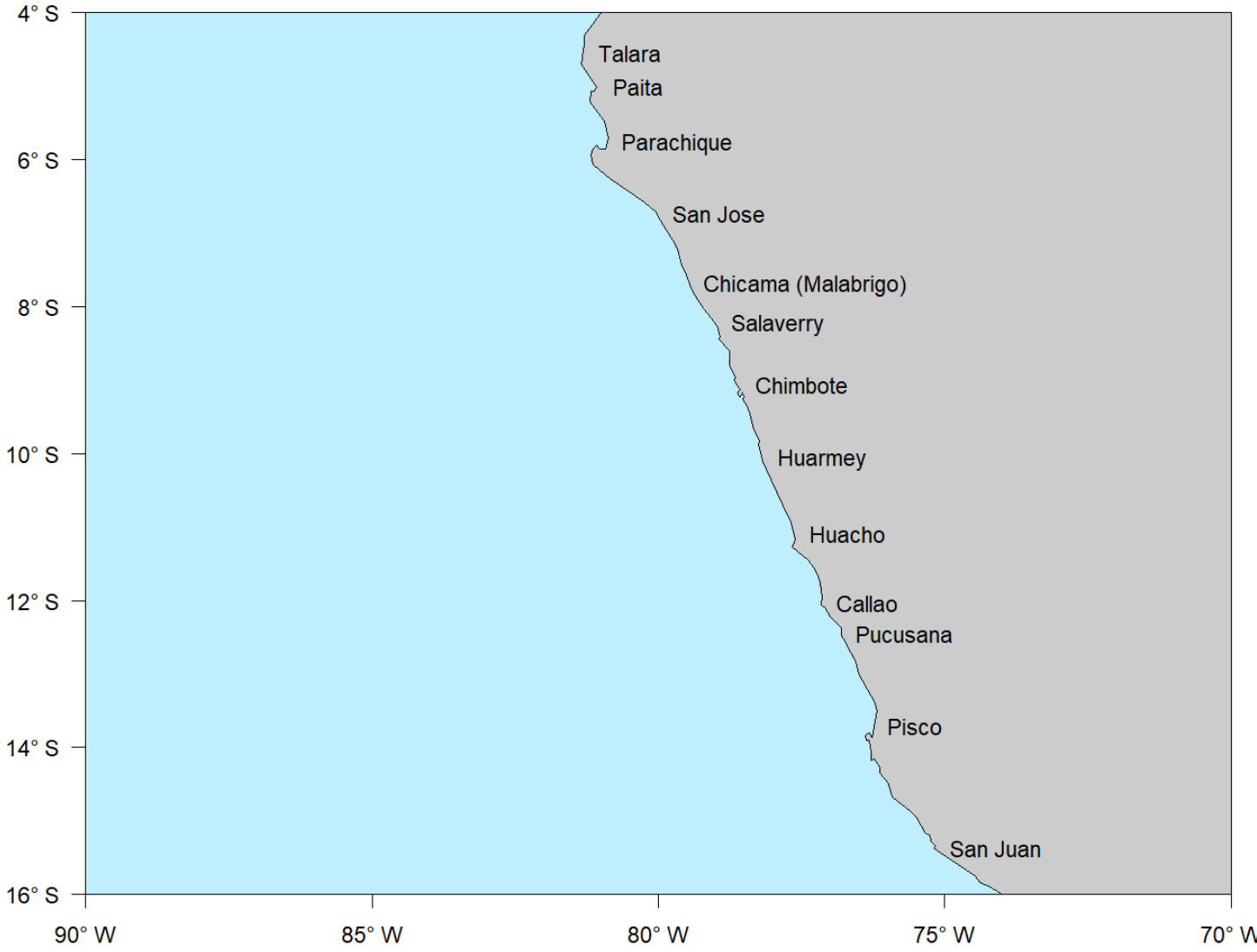
B) Fishery data from artisanal fleet:
- Period: October 2010 – March 2017
- Date (Sail and Arrival)
- Catch per trip (ton)
- Number of hooks
- Hold capacity (ton)
- **Longitude, Latitude**

C) Oceanography:
- *SST* from NOAA/GOES (month)
- *SSS* from HYCOM (day)
- *Chl-a* from NOAA/MODIS (month)



Data processing

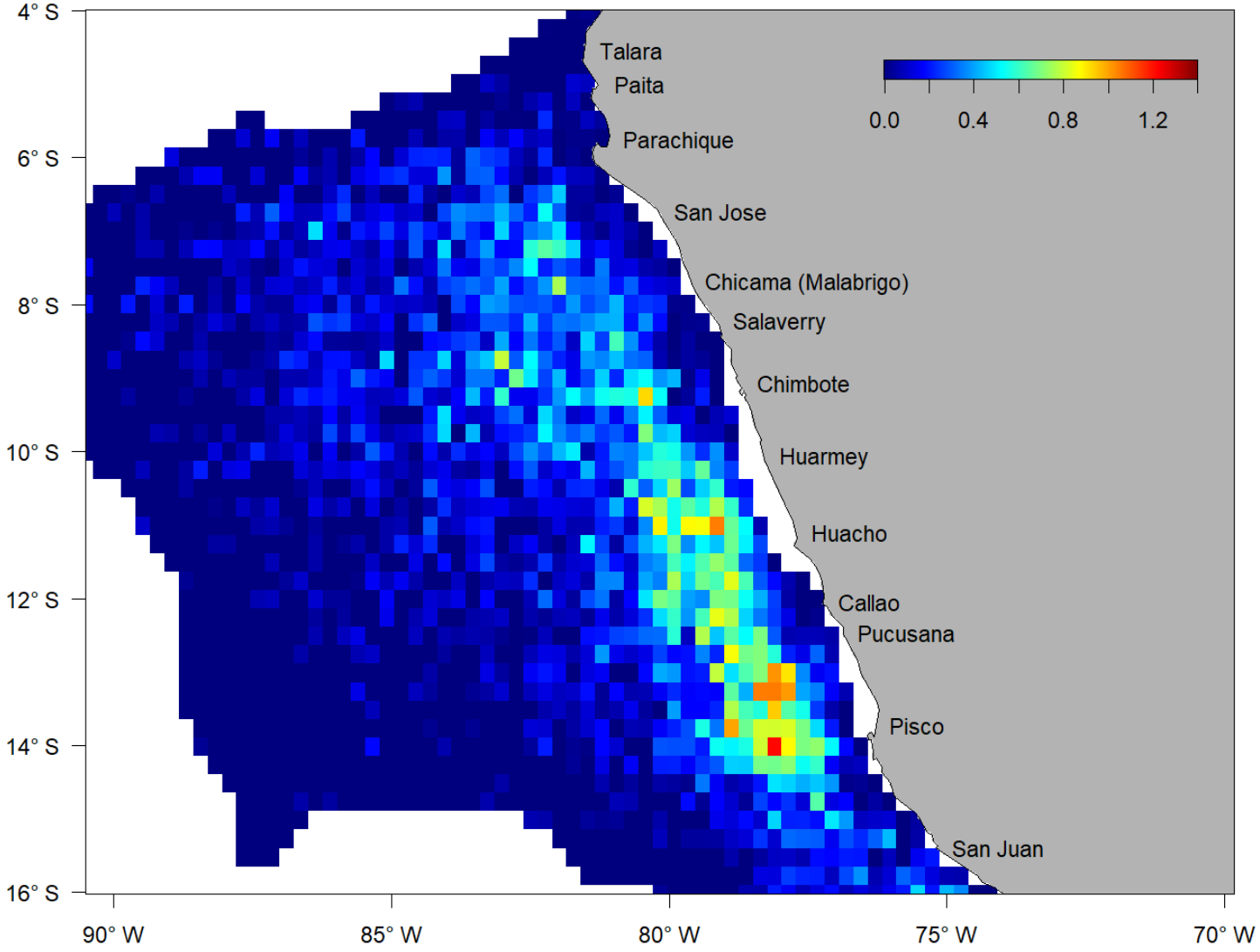
$$CPUE_{ijkl} = \frac{C_{ijkl}\ (ton)}{f_{ijkl}(N°hooks) * 1000}$$



Data processing

$$CPUE_{ijkl} = \frac{C_{ijkl}\ (ton)}{f_{ijkl}(N°hooks) * 1000}$$

- The dataset included a total of 16 108 trips, aggregated in a total of 4 127 x 0.25° grid.
- Satellite remote sensing oceanographic data were averaged to 0.25° grid for each month to match the spatial-temporal resolution of fishery data.



Models

1) Delta log normal model

2) Delta gamma model

gam - mgcv (v. 1.8-22) package in R (Wood)

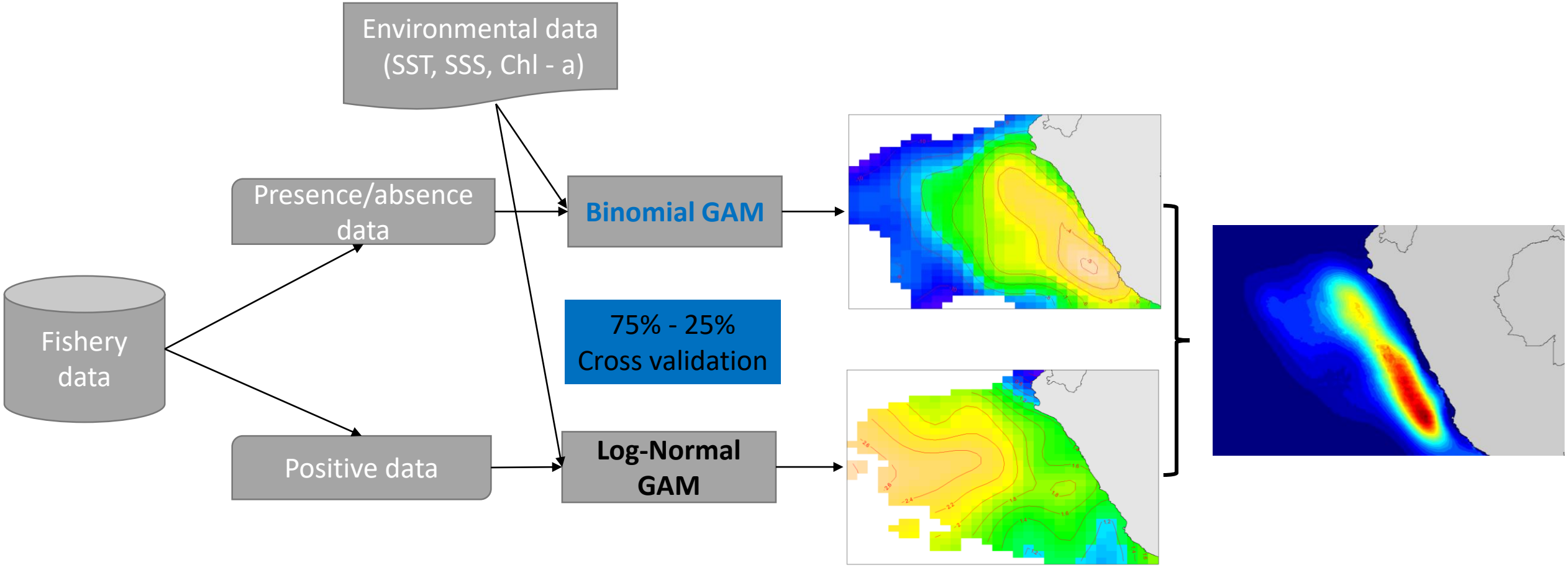
Models

1) **Delta log normal model**

2) Delta gamma model

gam - mgcv (v. 1.8-22) package in R (Wood)

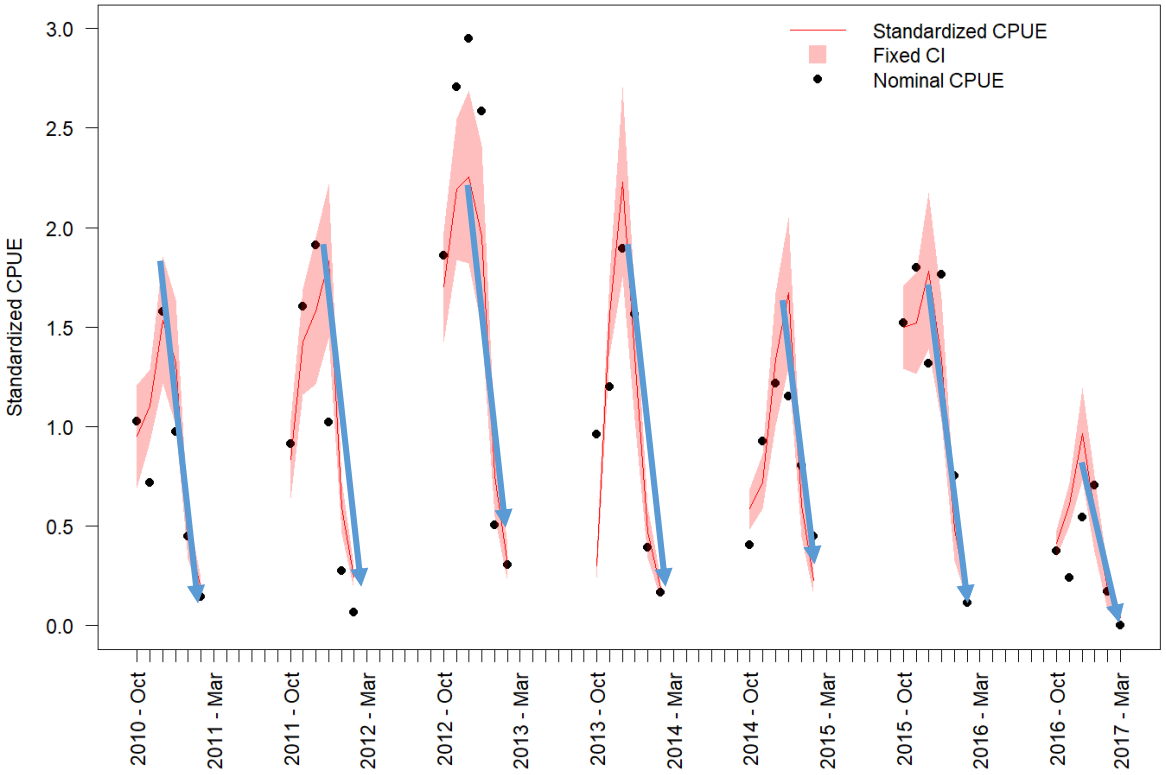
Getting temporal index and spatial distribution



$$P/A \sim year + month + s(SST) + s(SSS) + s(lon) + s(lat) + s(lon, lat) + te(lon, lat, month) + te(lon, lat, year) + \varepsilon$$

$$CPUE \sim year + month + s(SST) + s(SSS) + s(lon) + s(lat) + s(lon, lat) + te(lon, lat, month) + te(lon, lat, year) + \varepsilon$$

Results



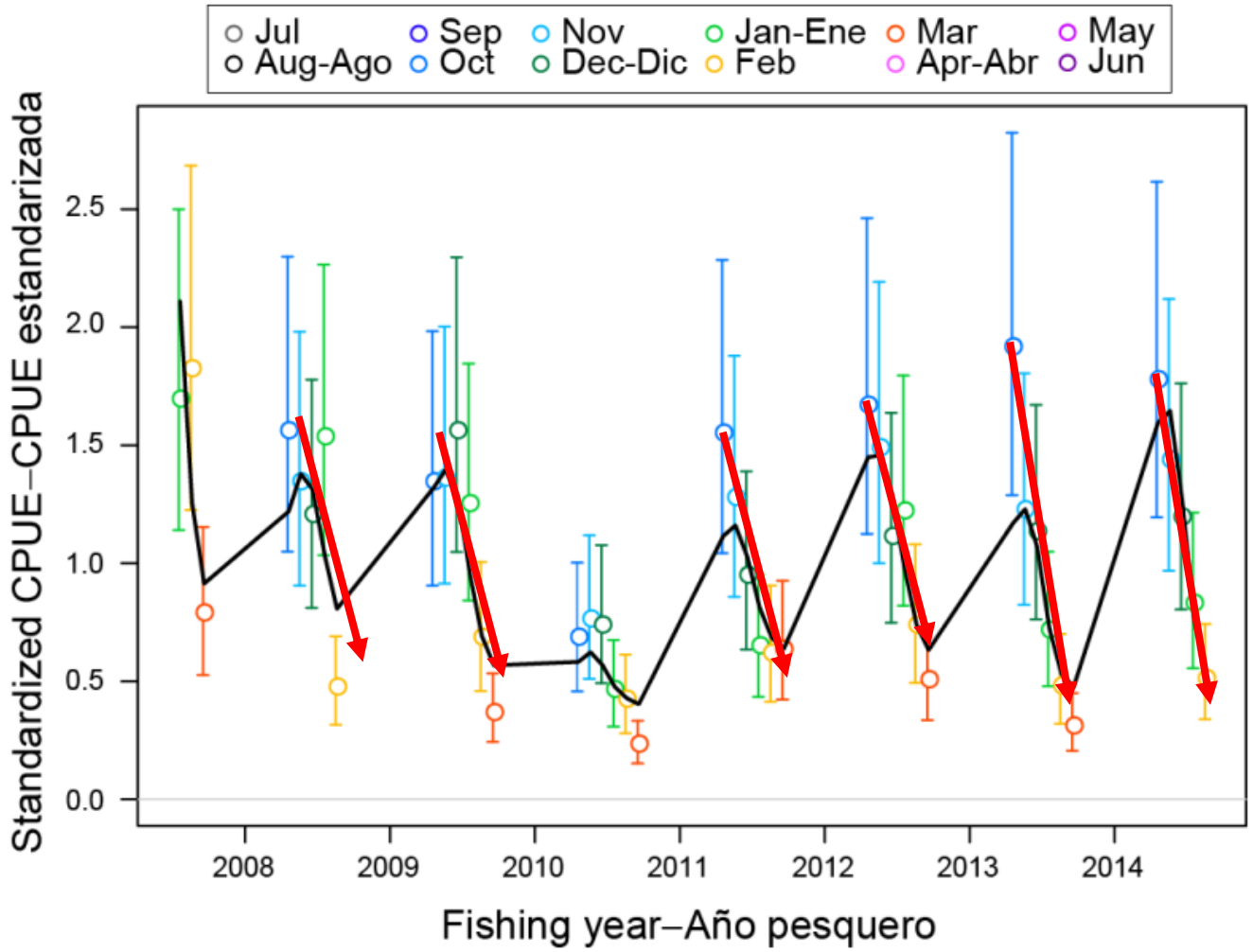
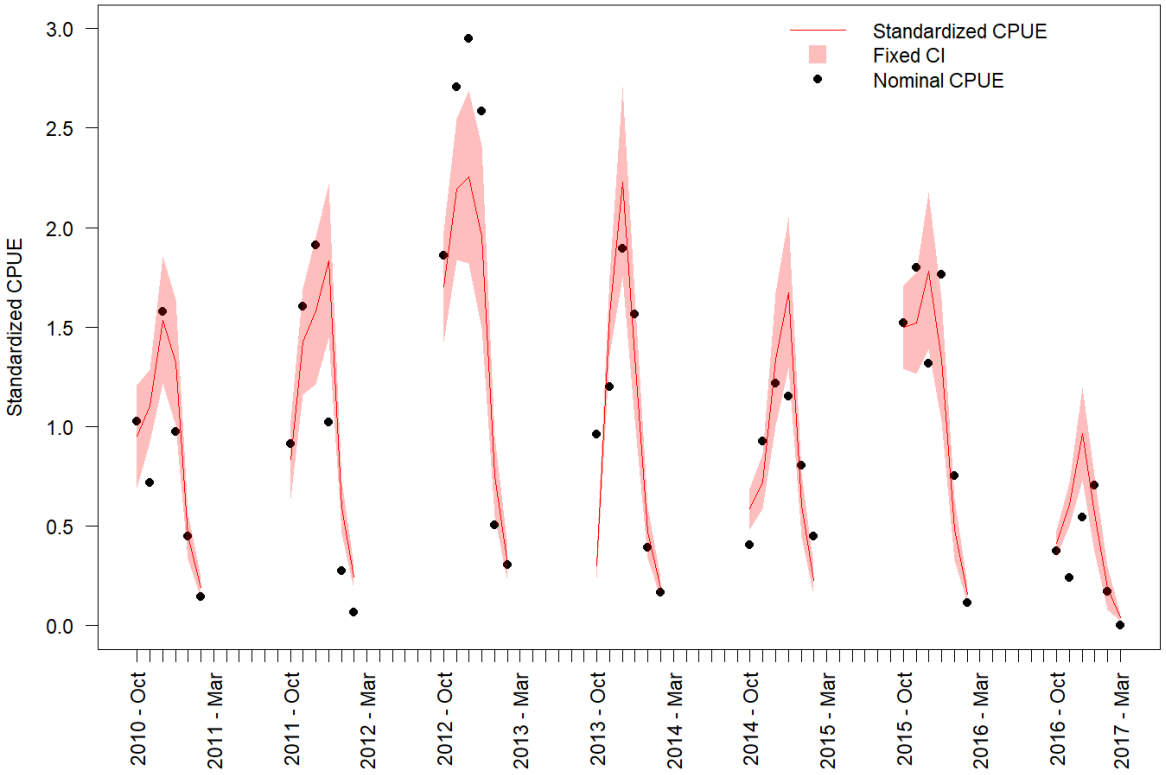
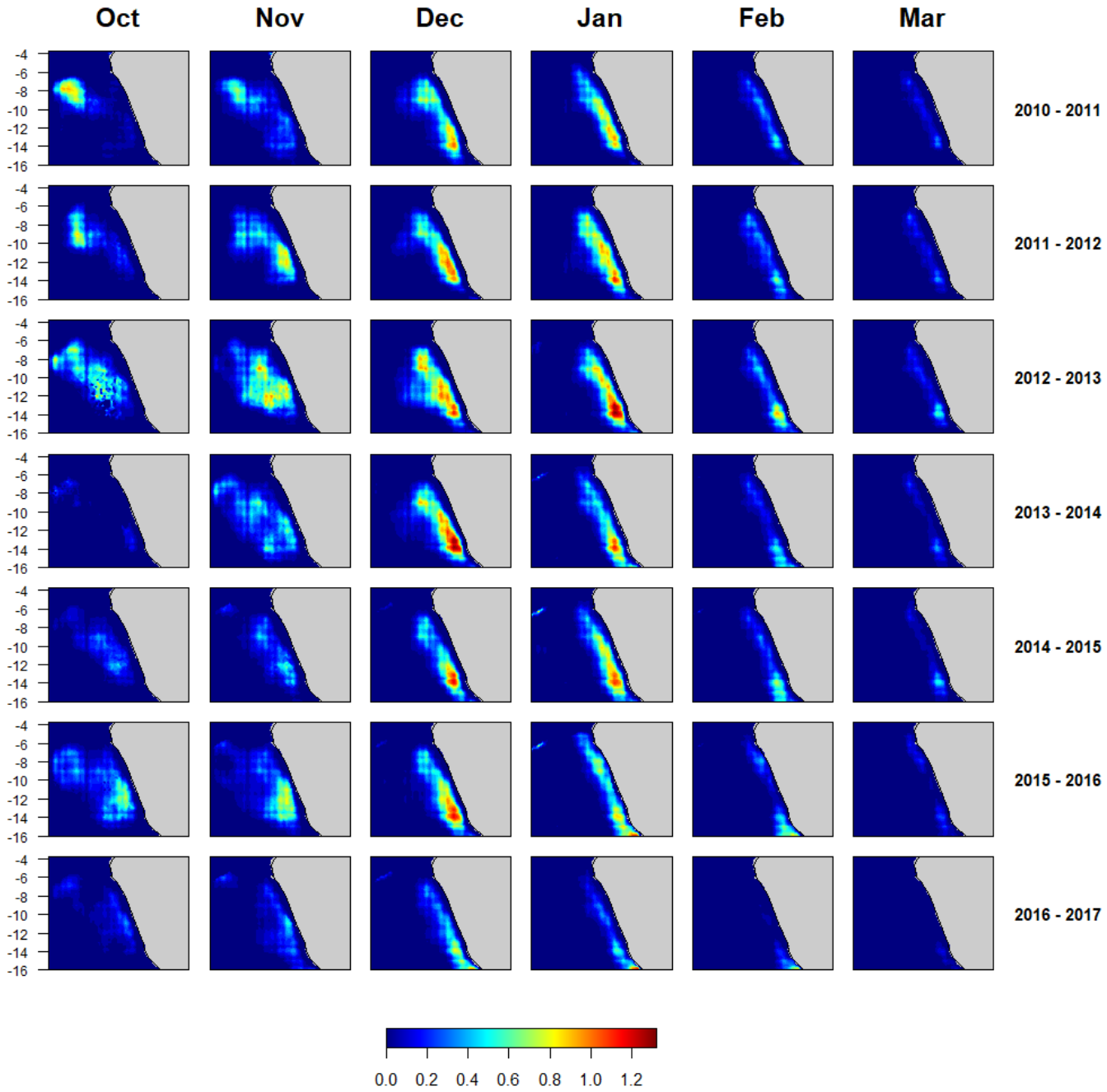


FIGURE 11a. Base-case model fit to the standardized CPUE data from the Ecuadorian artisanal fishery. The vertical lines represent the fixed confidence intervals (±2 standard deviations) around the CPUE values.

Aires-da-Silva et al. 2018

Results


Standardized CPUE
Fixed CI
Nominal CPUE
Standardized CPUE
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010 - Oct
2011 - Mar
2011 - Oct
2012 - Mar
2012 - Oct
2013 - Mar
2013 - Oct
2014 - Mar
2014 - Oct
2015 - Mar
2015 - Oct
2016 - Mar
2016 - Oct
2017 - Mar


Oct
Nov
Dec
Jan
Feb
Mar
2010 - 2011
2011 - 2012
2012 - 2013
2013 - 2014
2014 - 2015
2015 - 2016
2016 - 2017
-4
-6
-8
-10
-12
-14
-16
0.0
0.2
0.4
0.6
0.8
1.0
1.2

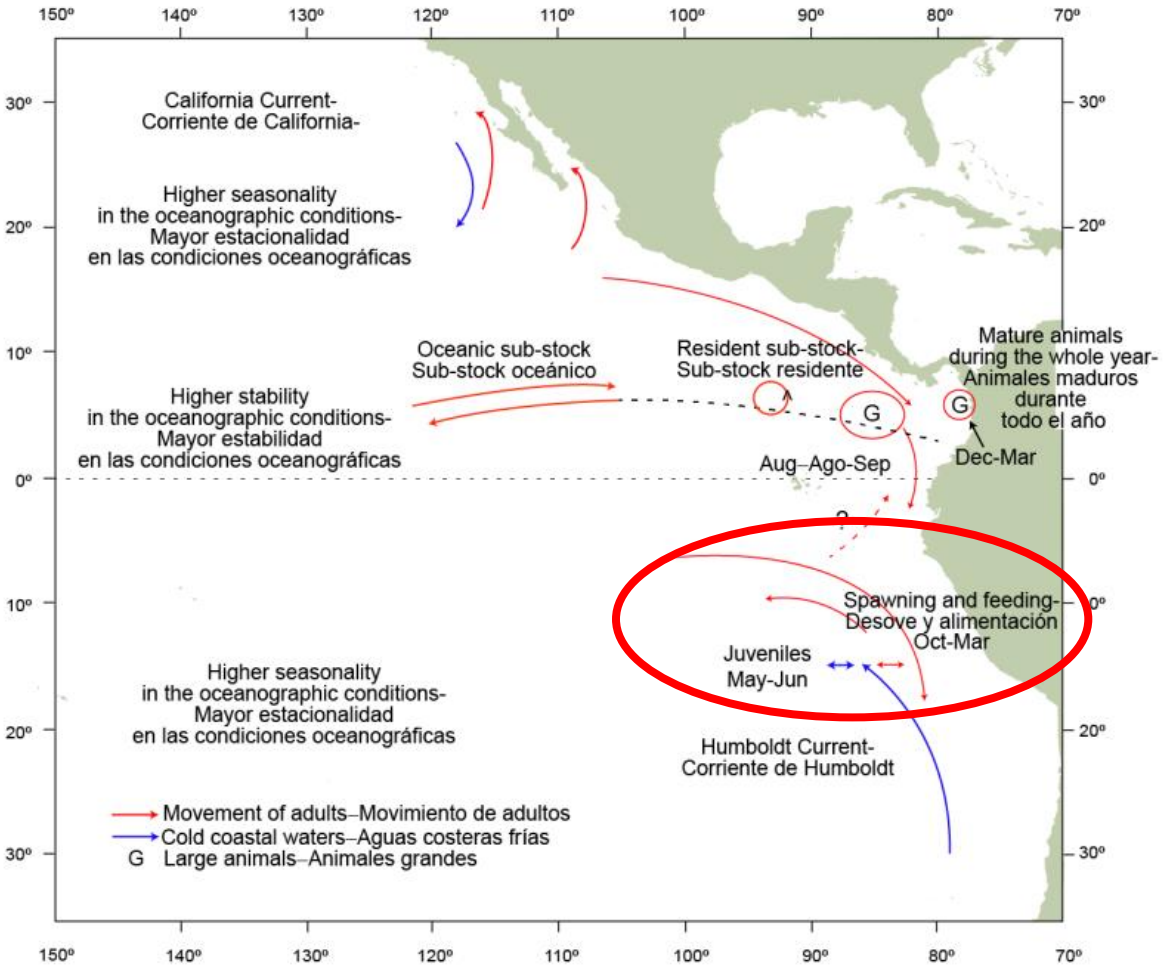
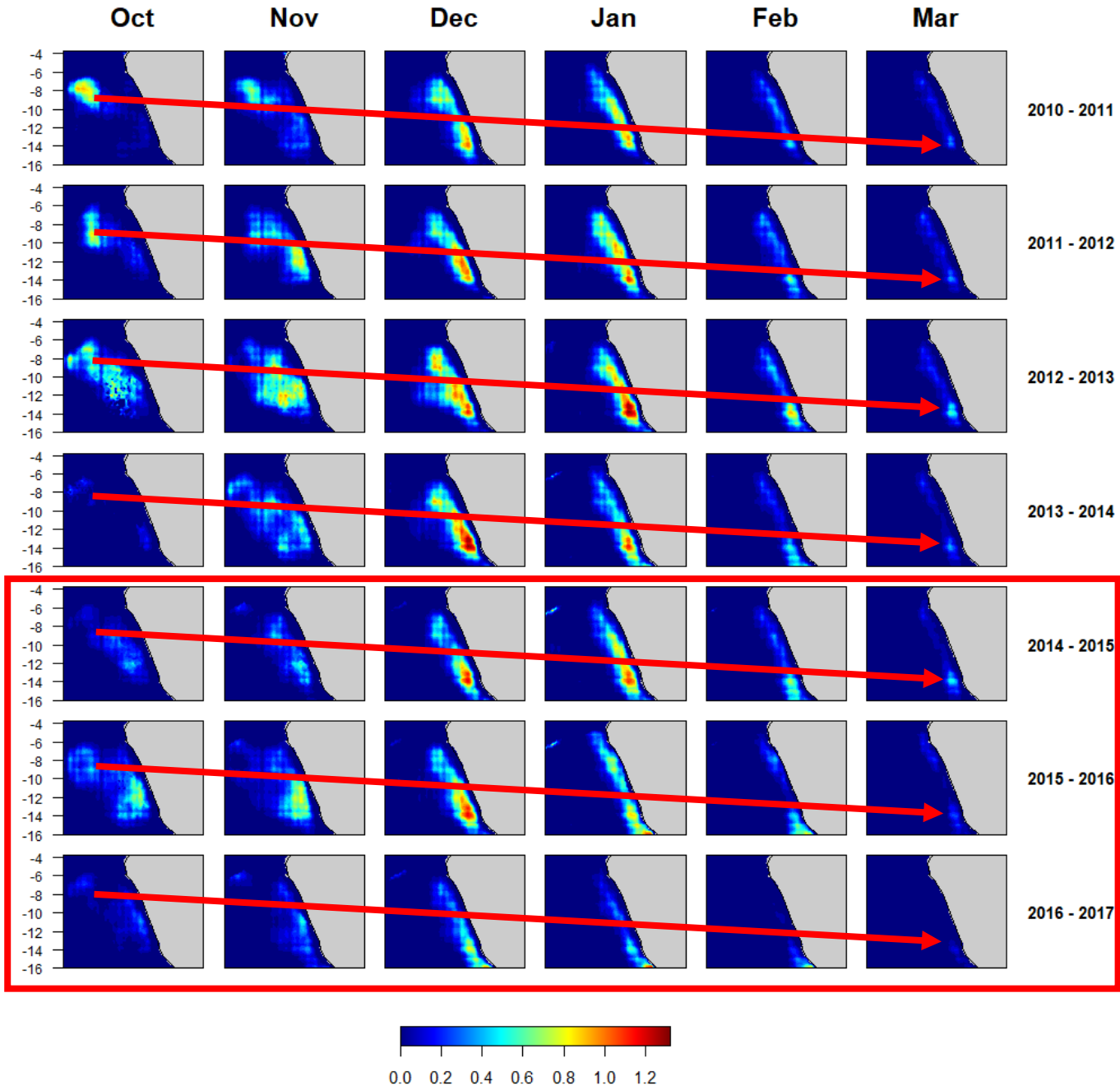
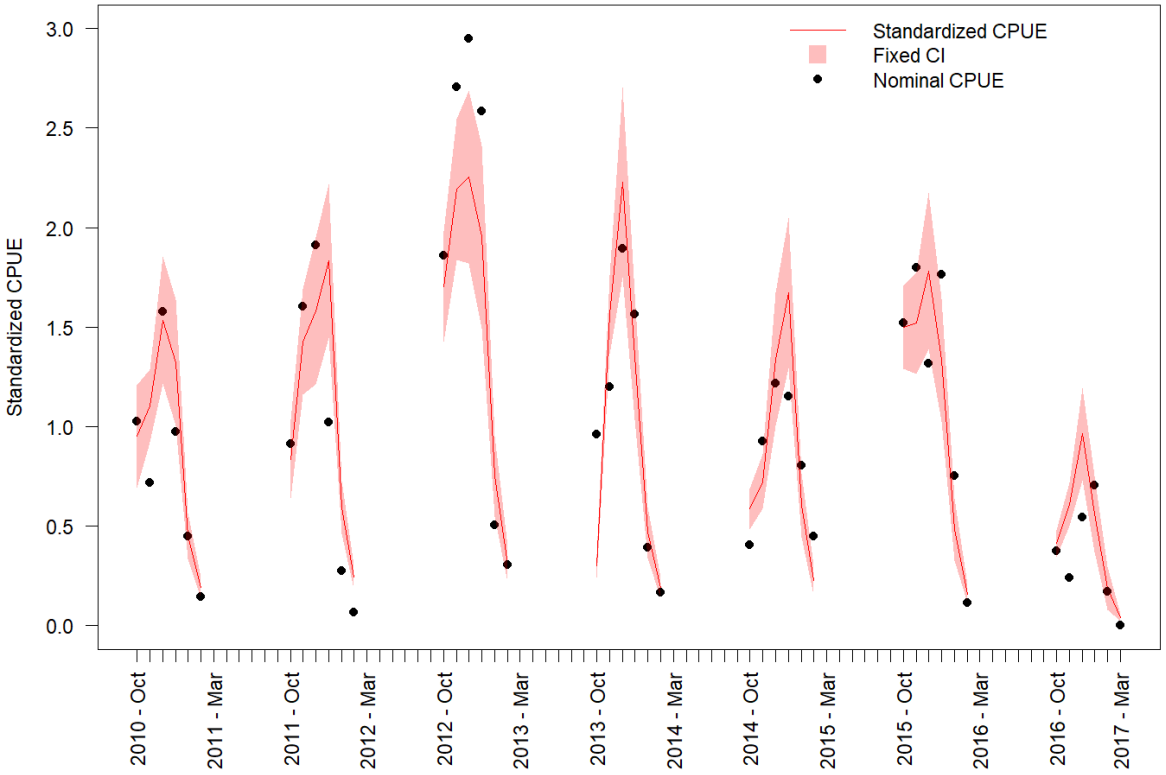


FIGURE 2a. Conceptual model of the movements and spatial distribution of dorado (2nd Technical Meeting on Dorado, 2015).

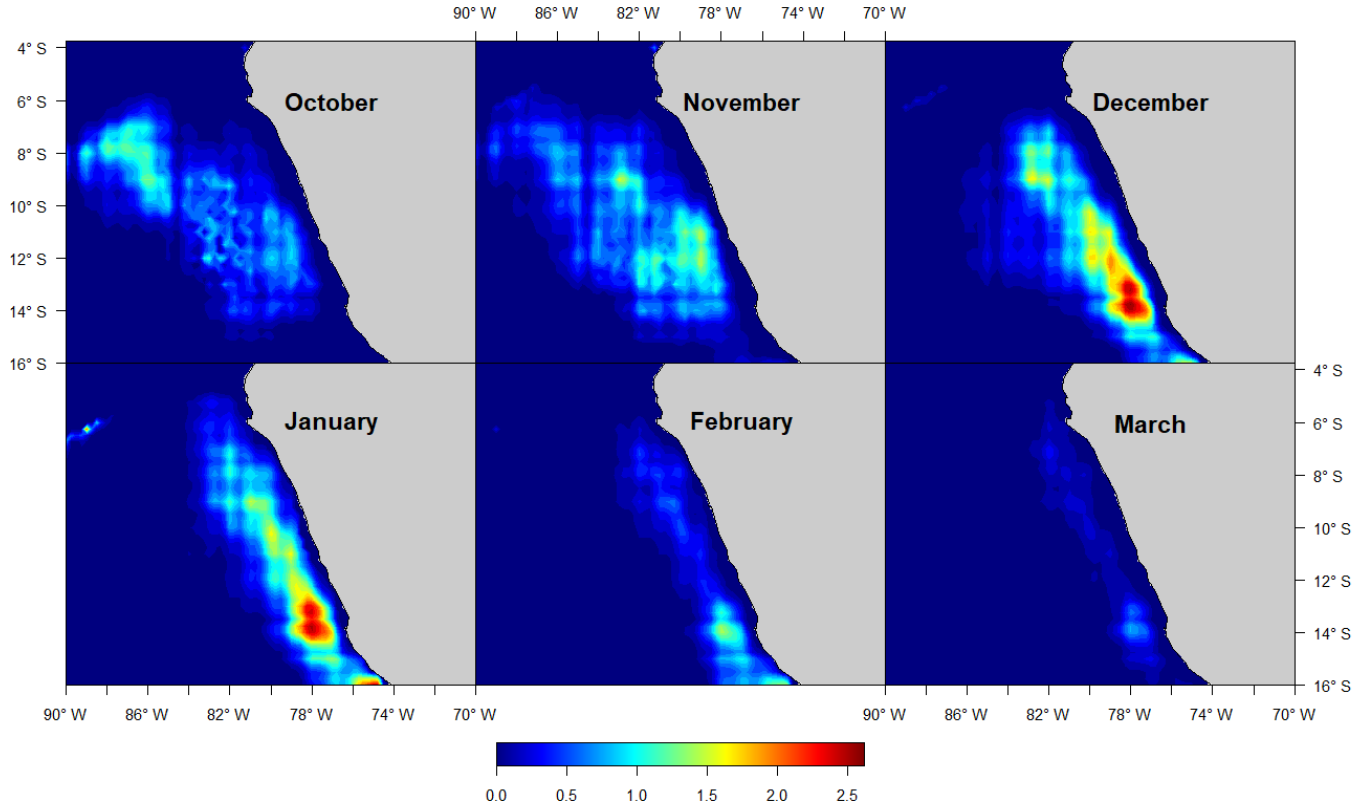
Aires-da-Silva et al. 2018



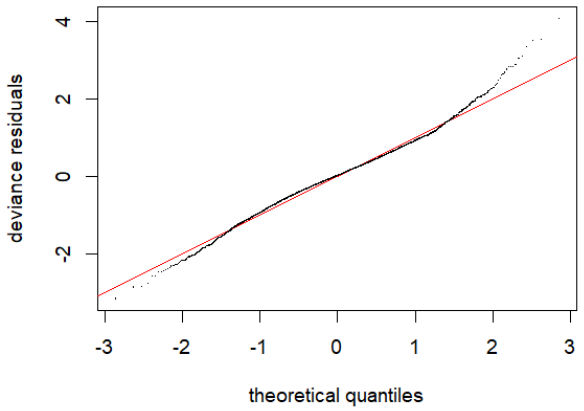
Results

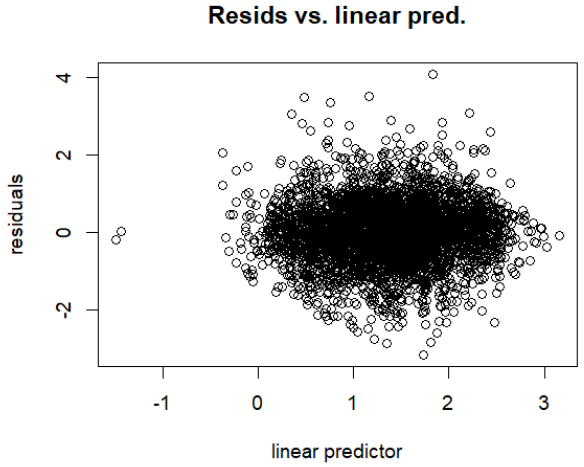


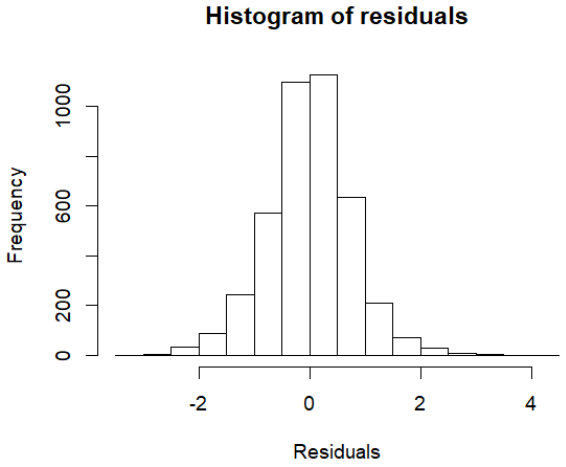
HOT SPOT

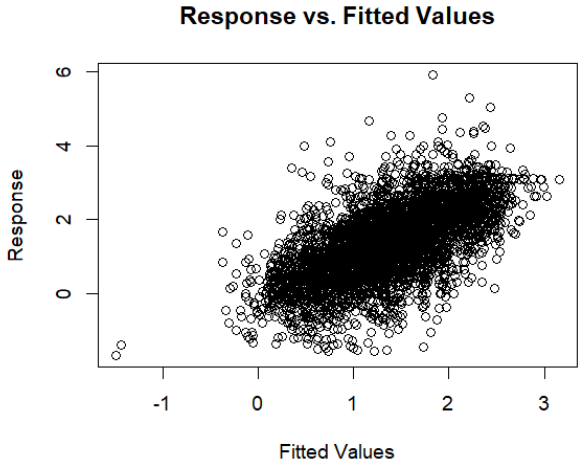


Results









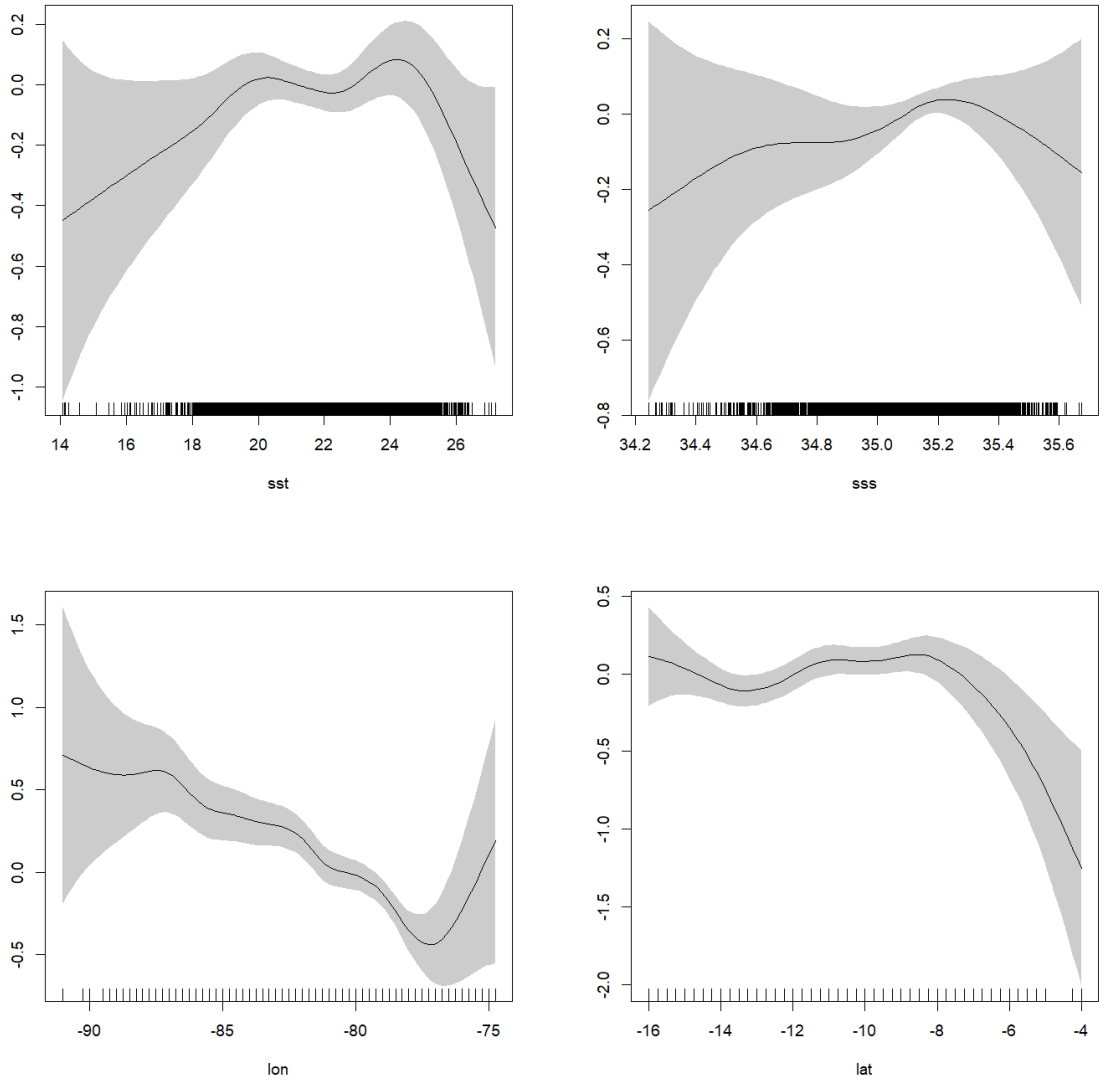
Diagnostic plots for the error distribution when fitting the non-zero catch

Analysis of deviance tables

	Residual deviance	% of total deviance explained	AIC	Δ AIC	$P(X^2)$
P/A model					
Null	33204.82		33207		
+s(sst)	30967.76	19.35	30996	2211.02	<0.05
+s(sss)	29499.3	12.70	29557	1438.8	<0.05
+s(month)	29340.67	1.37	29408	148.72	<0.05
+s(year)	29004.22	2.91	29088	320.28	<0.05
+s(lon)	26265.4	23.69	26427	2661.04	<0.05
+s(lat)	25420.7	7.31	25421	1006.26	<0.05
+s(lon,lat)	24477.98	8.16	24331	1090	<0.05
+s(lon, lat, month)	23291.75	10.26	23050	1280.7	<0.05
+s(lon,lat, year)	21645.62	14.24	22362	688.44	<0.05
Total deviance explained	**36.5%**				
CPUE model					
<NULL>	3981.313		11568		
+s(sst)	3656.661	20.97	11235	333.08	<0.05
+s(sss)	3515.241	9.13	11088	146.86	<0.05
+ month	3240.461	17.75	10759	328.82	<0.05
+ year	2841.104	25.80	10229	529.55	<0.05
+s(lon)	2730.389	7.15	10085	143.94	<0.05
+s(lat)	2698.493	2.06	10058	27.28	<0.05
+s(lon, lat)	2645.471	3.42	10040	18.37	<0.05
+s(lon, lat, month)	2601.291	2.85	10012	27.25	<0.05
+s(lon, lat, year)	2433.135	10.86	9792	220.673	<0.05
Total deviance explained	**38.9%**				

P, level of significance

Results



Partial effect plots for the CPUE model

Analysis of deviance tables

	Residual deviance	% of total deviance explained	AIC	Δ AIC	$P(X^2)$
P/A model					
Null	33204.82		33207		
+s(sst)	30967.76	19.35	30996	2211.02	<0.05
+s(sss)	29499.3	12.70	29557	1438.8	<0.05
+s(month)	29340.67	1.37	29408	148.72	<0.05
+s(year)	29004.22	2.91	29088	320.28	<0.05
+s(lon)	26265.4	23.69	26427	2661.04	<0.05
+s(lat)	25420.7	7.31	25421	1006.26	<0.05
+s(lon,lat)	24477.98	8.16	24331	1090	<0.05
+s(lon, lat, month)	23291.75	10.26	23050	1280.7	<0.05
+s(lon,lat, year)	21645.62	14.24	22362	688.44	<0.05
Total deviance explained	**36.5%**				
CPUE model					
<NULL>	3981.313		11568		
+s(sst)	3656.661	20.97	11235	333.08	<0.05
+s(sss)	3515.241	9.13	11088	146.86	<0.05
+ month	3240.461	17.75	10759	328.82	<0.05
+ year	2841.104	25.80	10229	529.55	<0.05
+s(lon)	2730.389	7.15	10085	143.94	<0.05
+s(lat)	2698.493	2.06	10058	27.28	<0.05
+s(lon, lat)	2645.471	3.42	10040	18.37	<0.05
+s(lon, lat, month)	2601.291	2.85	10012	27.25	<0.05
+s(lon, lat, year)	2433.135	10.86	9792	220.673	<0.05
Total deviance explained	**38.9%**				

P, level of significance

Conclusions

- The time series of CPUE would be reflecting the monthly decay (year after year) of a single cohort of dorado due to natural mortality and fishery. At the beginning (oct - nov) the cohorts is not fully recruited to the fishery (migration, availability).

- Dorado changed their spatial distribution by month, possibly in accordance with changes in the SST …… ¿SS?.

- Dorado prefers to stay in slightly higher SST around 20 – 24°C and SSS around 35.1 – 35.3 what characterizes the Surface Subtropical Waters (SSW).

- Dorado fundamentally changed their monthly distribution latitudinal direction between north and south and their longitudinally direction between west and east.

Issues? – What to do

- Fishermen have an strategy called: “22° C isotherm strategy” (using color maps).
- Fishermen prefer start to fish in Sep – Oct because before of this period the sizes are smaller than the mínimum legal size, also they have to invest a lot of time (distance) to find big groups of dorados.
- We do not have the date when a set is ocurring (trip resolution)
- Vessel sizes would be included as a random effect to remove the assumption of homogeneity of characteristics among vessels.
- Tweedie distribution - 35 x times (doing something wrong?)
- Try VAST

THANK YOU!

IMARPE

IATTC
Alex Aires da Silva
Juan Valero
Cleridy Lennert-Cody
Carolina Minte-Vera
Mark Maunder