Quantifying the increase in fishing efficiency due to the use of drifting FADs equipped with echo-sounders in tropical tuna purse seine fisheries

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Wain G, Guéry L, Kaplan DM, Gaertner D (*accepted*) Quantifying the increase in fishing efficiency due to the use of drifting FADs equipped with echo-sounders in tropical tuna purse seine fisheries. *ICES Journal of Marine Science*

Echosounder impacts on PS fishing

Fishing on a vessel's floating objects (FOBs) equipped with echosounder buoys can impact fishing in a number of ways:

- Reduce search time

- Increase catch

- Change catch composition

- Change fishing strategy

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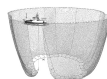
- Reduce search time

- **Increase catch**

- **Change catch composition**

- Change fishing strategy

Challenge → Understanding FOB (≈ buoy) ownership
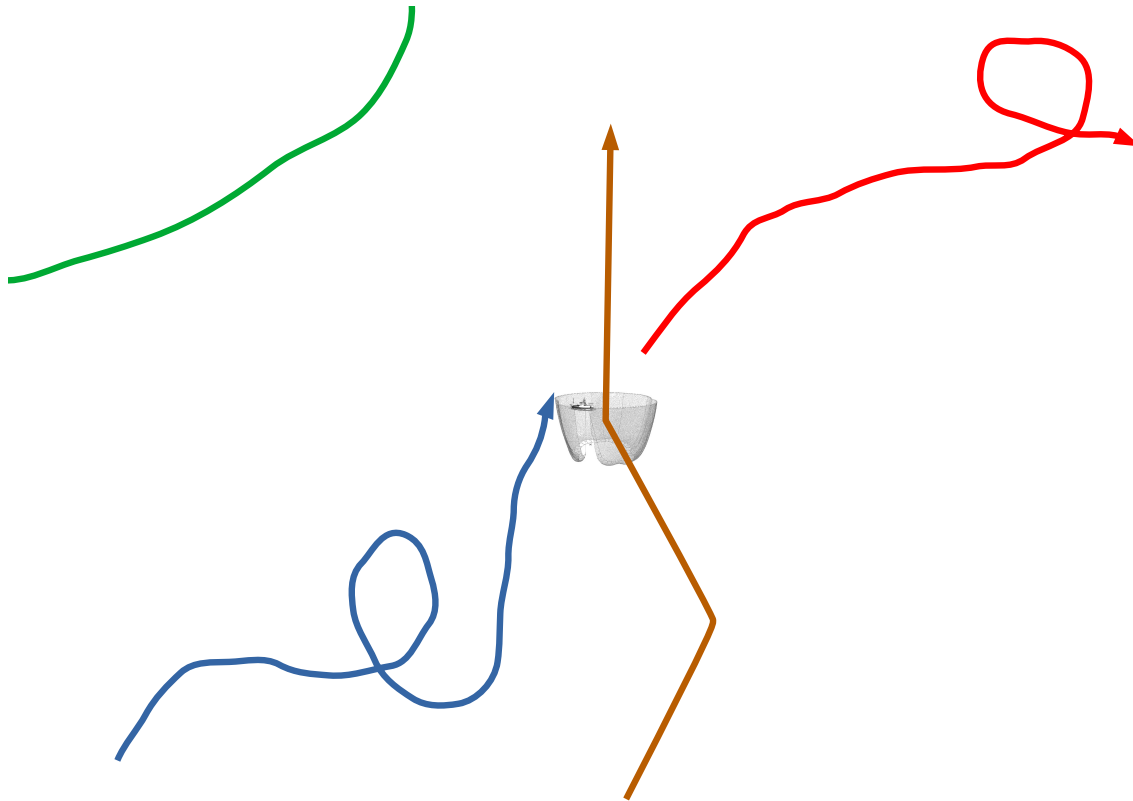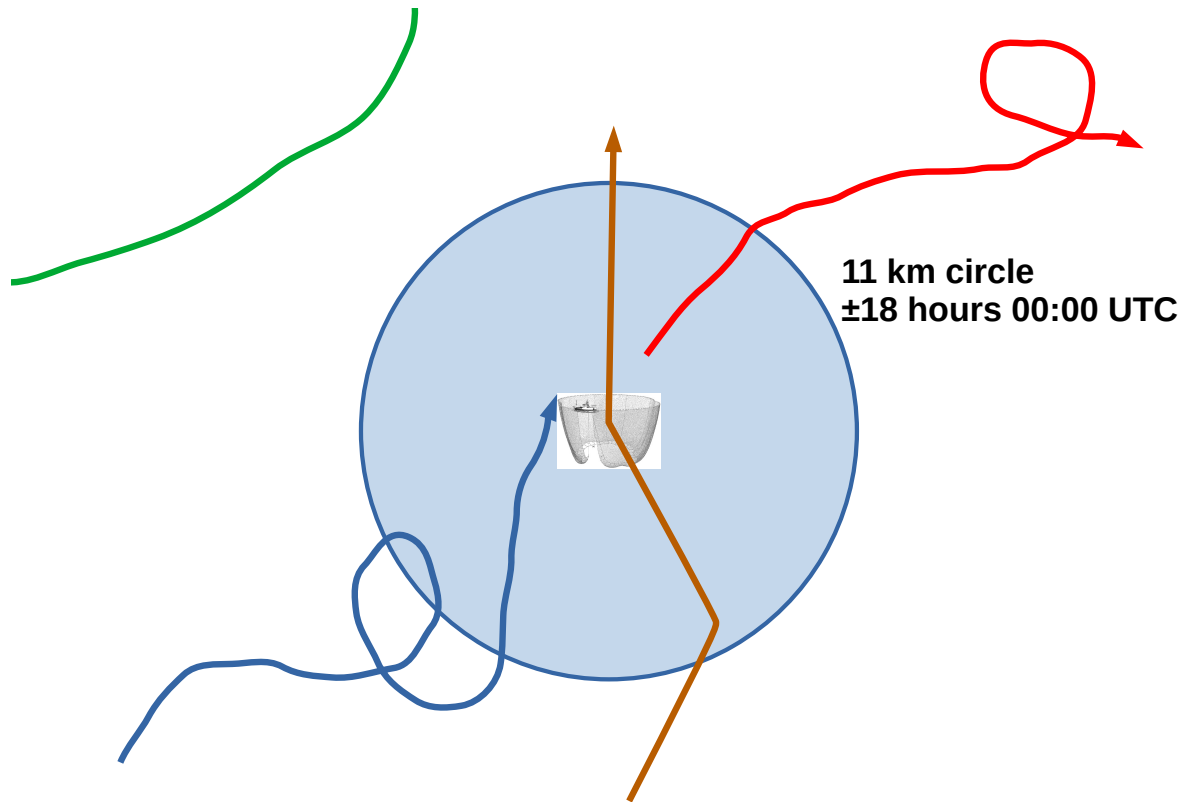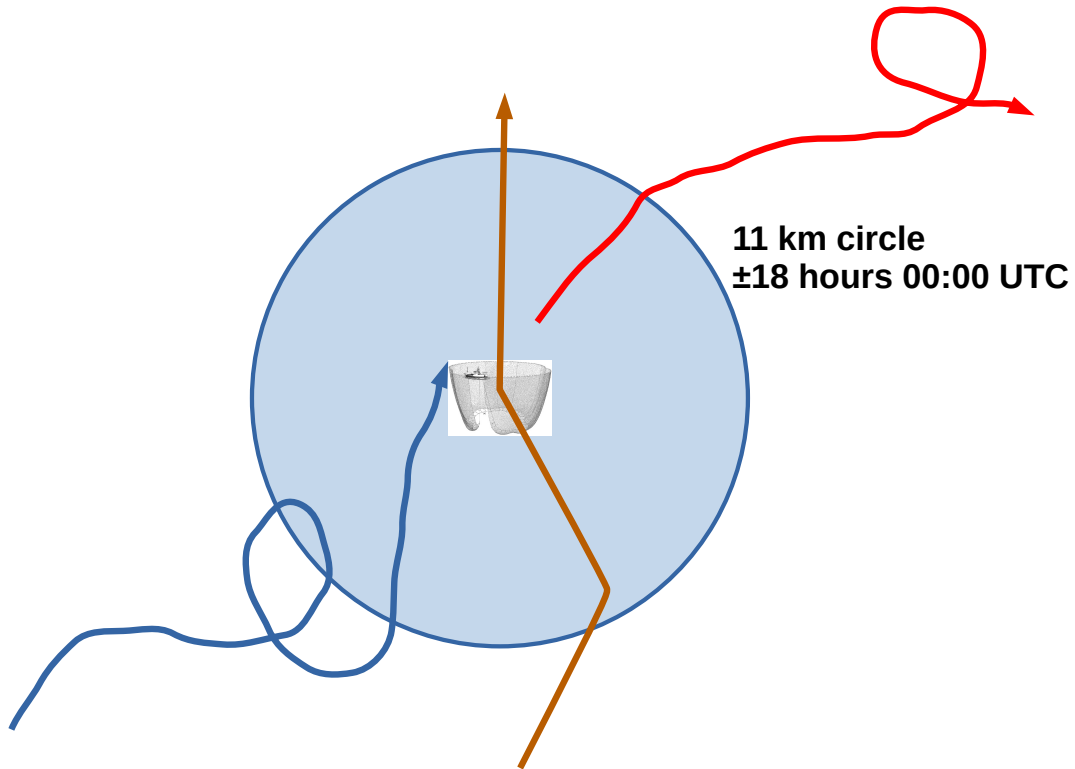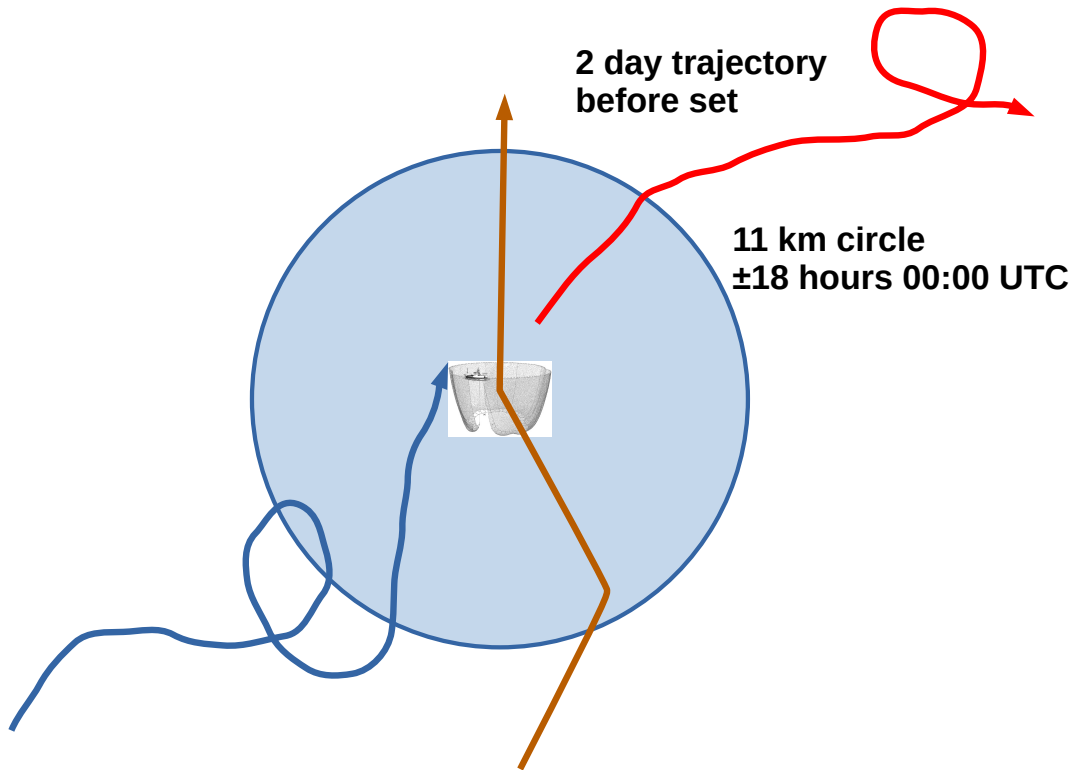
Determining FOB ownership

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- Logbooks + FOB trajectories

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11 km circle
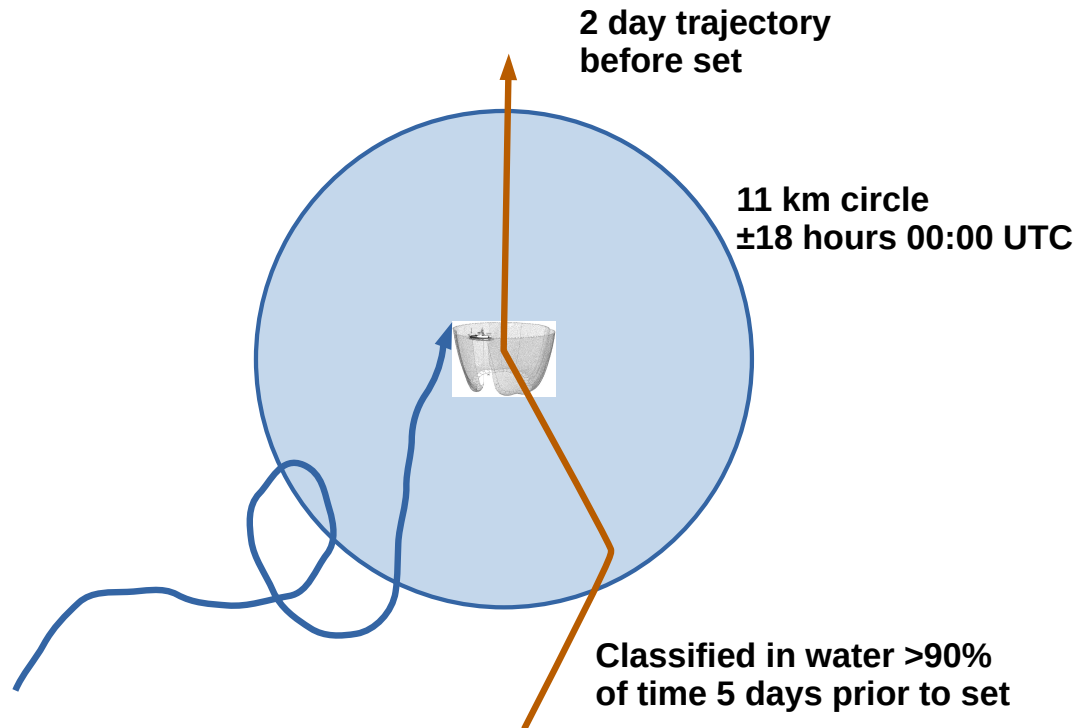**±18 hours 00:00 UTC**

Determining FOB ownership

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**11 km circle
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Determining FOB ownership

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2 day trajectory before set

11 km circle ±18 hours 00:00 UTC

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2 day trajectory before set

11 km circle ±18 hours 00:00 UTC

Classified in water >90% of time 5 days prior to set

Determining FOB ownership

- Logbooks + FOB trajectories

High emission rate (<=1 hour) at some point during 5 days prior to set

2 day trajectory before set

11 km circle ±18 hours 00:00 UTC

Classified in water >90% of time 5 days prior to set
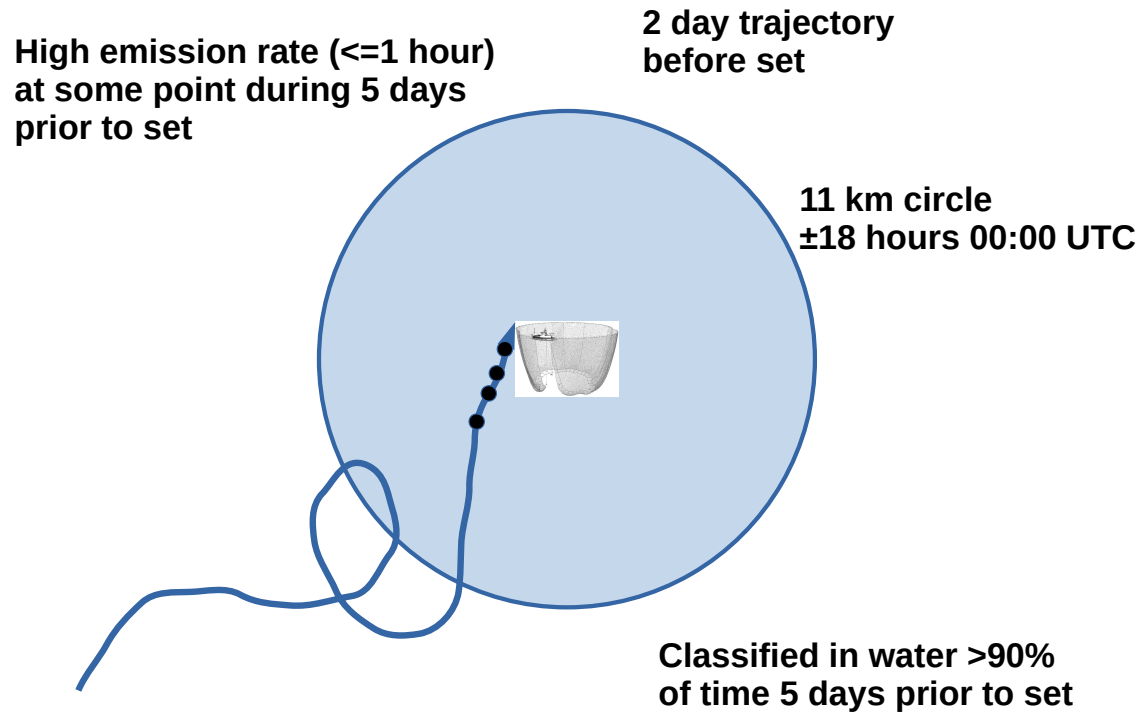
Determining FOB ownership

- Logbooks + FOB trajectories

- Base conditions of water trajectory, high emission rate, etc.

- **One of two additional conditions:**

    1. Matching logbook & FOB vessel names

    2. < 4 km spatial separation

- Vessel names only works for recent Marine Instruments buoys

- 4 km condition based on separation distance for FOBs meeting vessel name condition

- Error rate of $\approx 5\%$ based on free school sets

Set categories

Ownership methodology + tracking buoy model allowed us to place each **French PS FOB set in the Indian Ocean between 2010 & 2017** into one of three categories:

- **Foreign (*F*):** Fishing vessel had no access to buoy tracking information

- **Owned-echosounder (*O-E*):** Fishing vessel had access to the buoy tracking data, but the buoy model was not echosounder equipped

- **Owned+echosounder (*O+E*):** Fishing vessel had access to tracking and echosounder data

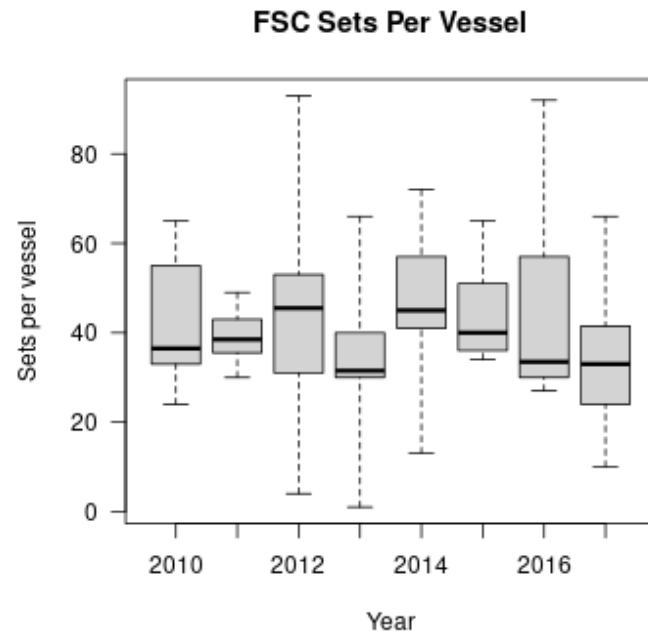→ **Examine catch of *F* versus *O+E* sets**
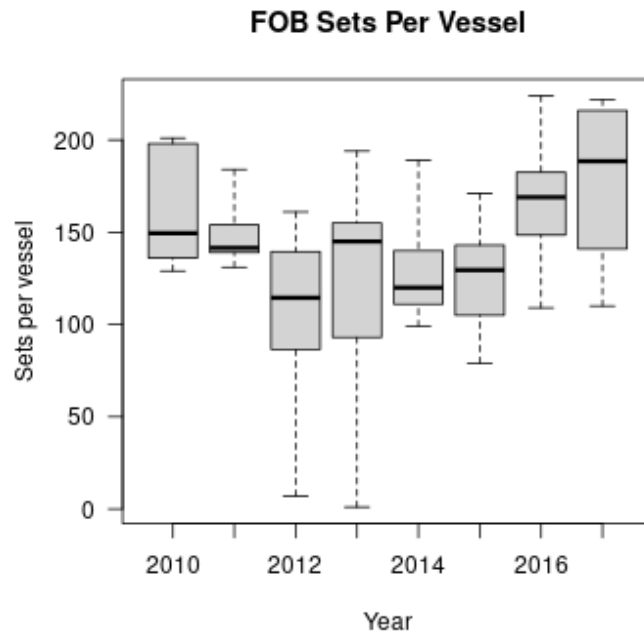
Analyses: Raw data

Temporal evolution
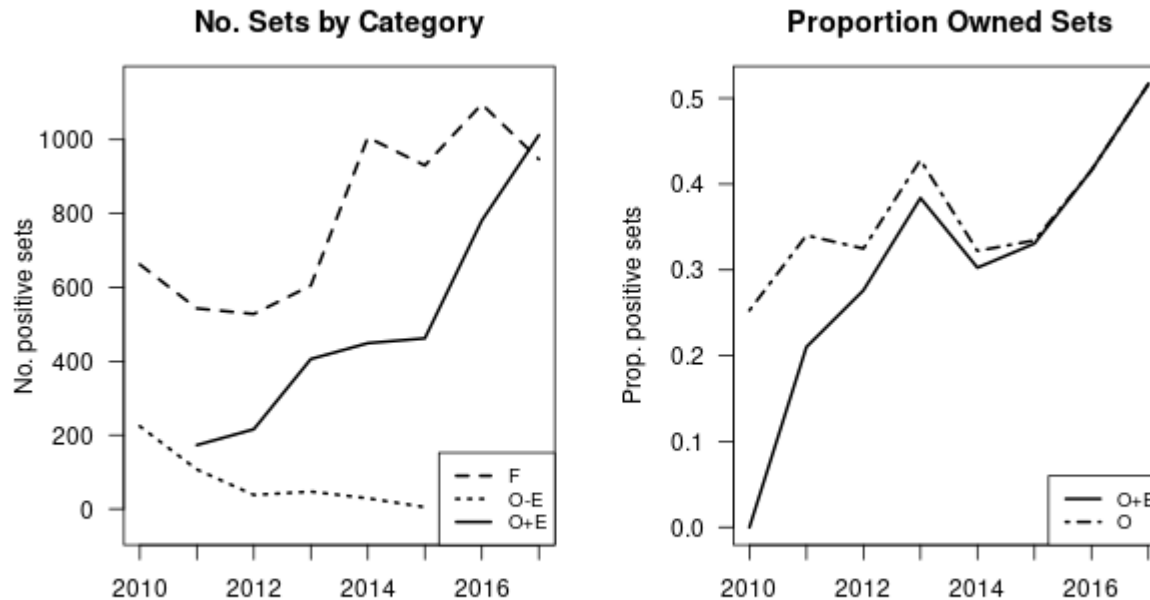
→ **Recent increase in number of FOB sets**
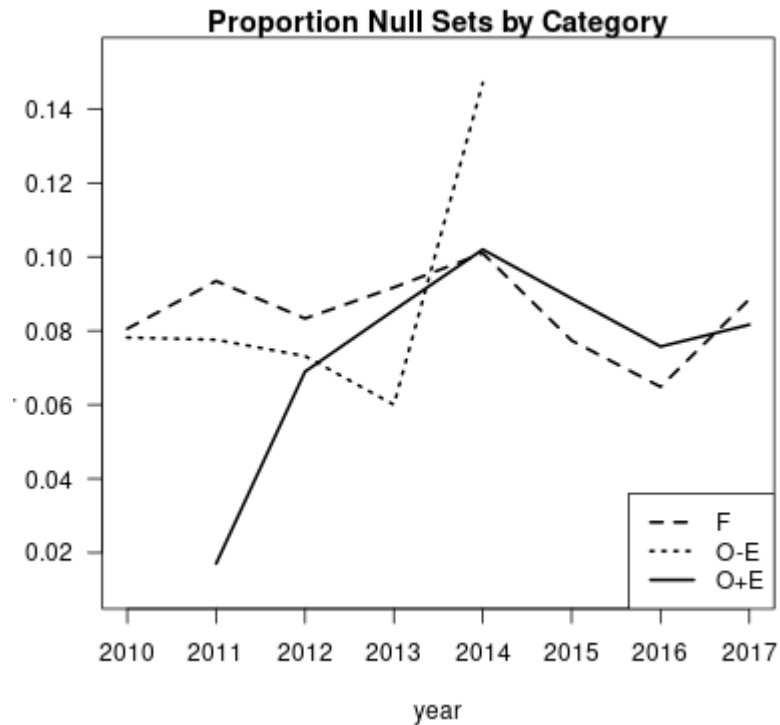
→ **Increase in fraction of sets on owned FOBs**

Sets per vessel

→ **FOB** *increase* 2014-2017: **51 sets/yr**
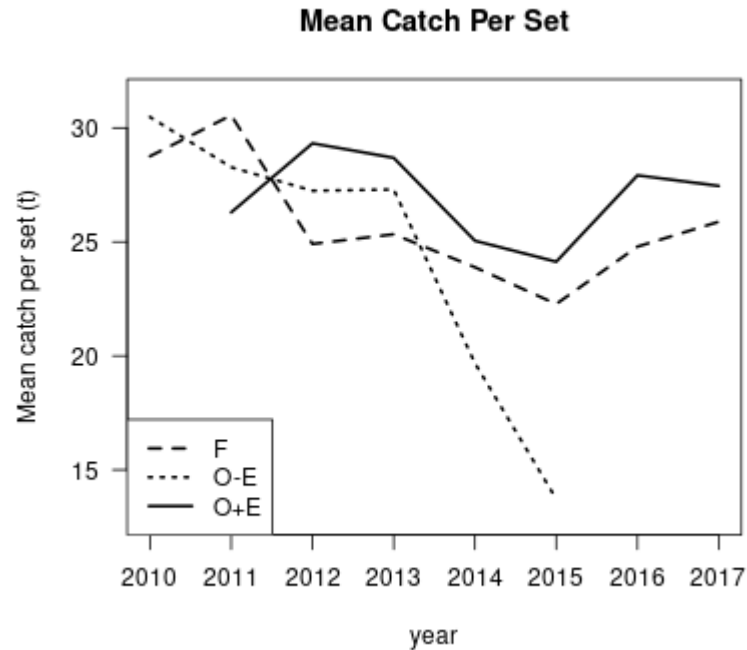
→ **FSC** *decrease* 2014-2017: **13 sets/yr**

Null set reduction?

Proportion Null Sets by Category

→ **Sample size outliers: 2011:O+E & 2014:O-E**

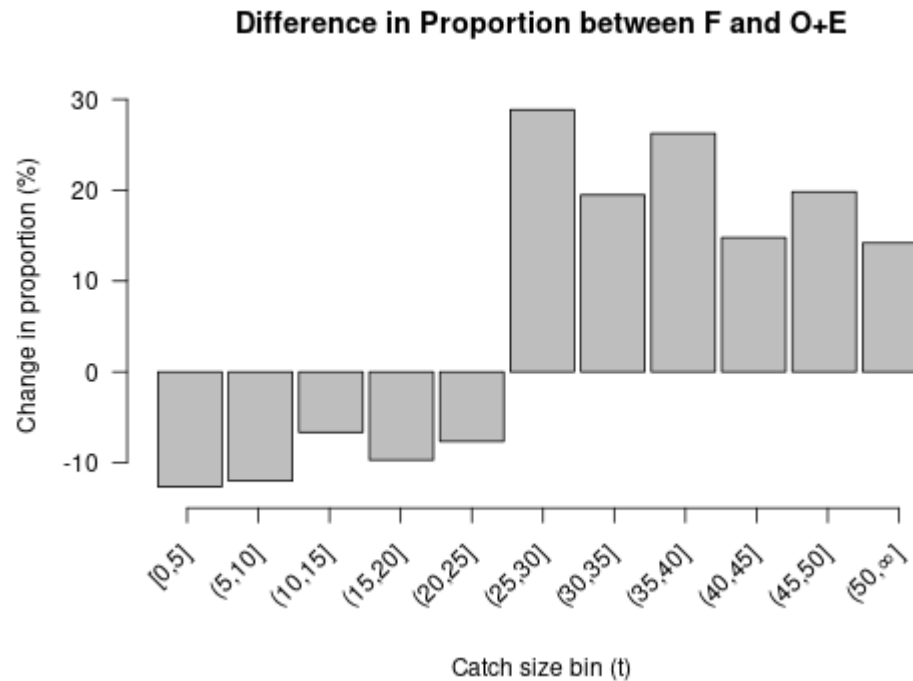→ **No apparent difference in null sets by category**

Catch per positive set?

→ **Mean for O+E consistently higher than for F after 2011**

→ **Approximately 2.6 tonnes per set ≈ 10%**

Set size composition

Difference in Proportion between F and O+E

→ **Non-linear transition around ≈25 tonnes ≈mean set size**

Species composition?
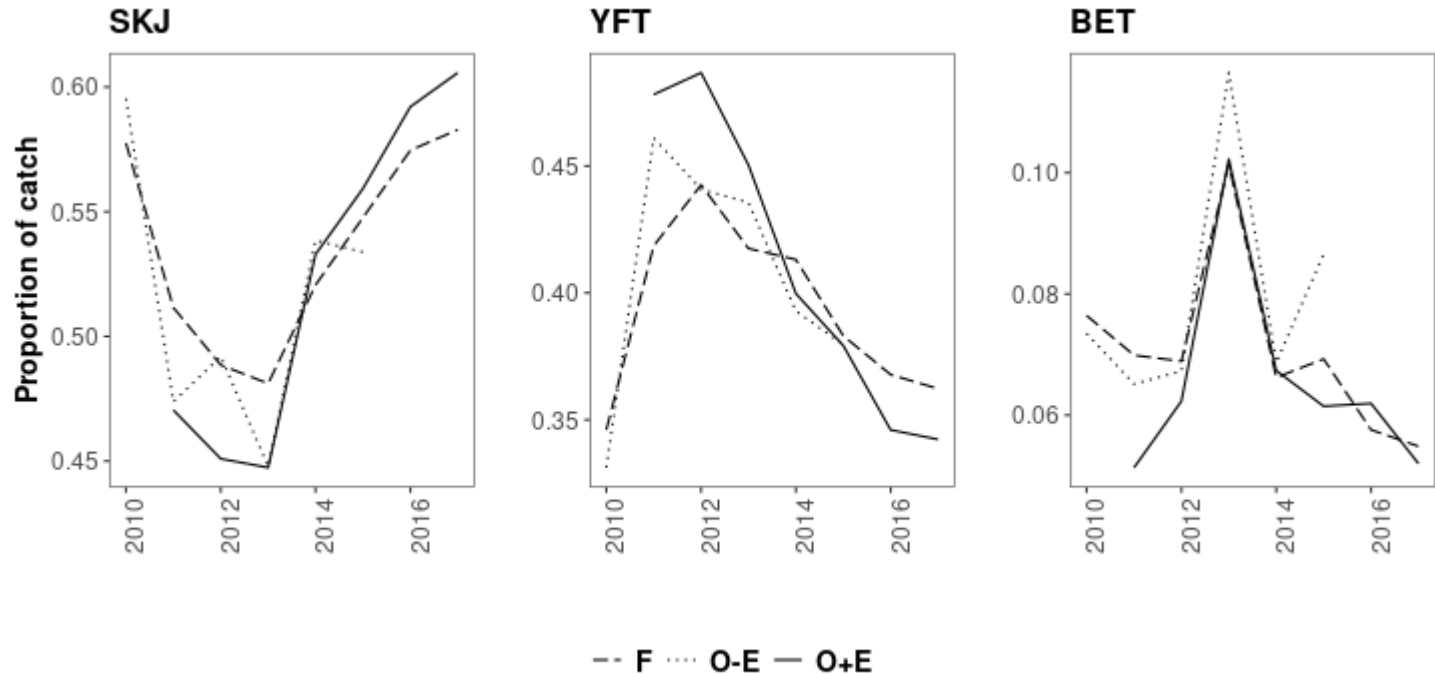
→ **Small, but consistent, shift over time to >SKJ for O+E**

→ **Learning process?**

Analyses: Model outputs

Model motivation

- Raw data could have spatial, temporal or vessel biases

- Standardize data to remove biases and extract echosounder effect

- Mostly GAM models (total catch, set category)

- Also Beta regression (species composition) & GLM (robustness of results)

- Focus primarily on 2012-2017

    - Avoid 2011: small sample size / learning period

Full model list

ID	Depend. var.	Data distribution	Type	Time period	Model equation
A1	Total catch	Gamma	GAM	2010-2017	te(lon,lat,by=season)+vessel+s(year,by=category)
A2	Total catch	Gamma	GAM	2012-2017	te(lon,lat,by=season)+vessel+s(year)+category
L1	Total catch	Gamma	GLM	2012-2017	cwp55+vessel+season+year+category
A3	Total catch	Gamma	GAM	2012-2017	te(lon,lat,by=category:season)+vessel+s(year)
B1	Proportion of SKJ	Beta	Beta regr.	2010-2017	cwp55+vessel+season+category*year+year^2+year^3+year^4
N1	Category F or E	Binomial	GAM	2012-2017	te(lon,lat,by=season)+vessel+s(year)+size class

Catch per set

	GAM Model A2			GLM Model L1		
	Estimate	**Pr(>|t|)**		**Estimate**	**Pr(>|t|)**	
Intercept (Cat. F)	22.00	0.0000	***	21.7	0.0000	***
Category O-E	-2.26	0.2241		0.2	0.9253	
Category O+E	**1.98**	**0.0001**	***	**2.5**	**0.0000**	***

Model A2: total catch ~ te(lon,lat,by=season)+vessel+s(year)+category

Model L1: total catch ~ cwp55+vessel+season+year+category

→ **Both GAM & GLM: 2.0-2.5 tonnes per set increase**

→ **GAM more sophisticated, "better" standardization**

Proportion SKJ

Beta Model B1			
	Estimate	**Pr(>z)**	
Intercept (Cat. F)	0.05	0.5701	
Year	7.14	0.0000	***
Year^2	6.59	0.0000	***
Year^3	-7.76	0.0000	***
Year^4	-1.52	0.0935	.
Category O-E	0.08	0.4796	
Category O+E	0.00	0.8112	
Year : Category O-E	2.82	0.7120	
Year : Category O+E	**15.39**	**0.0000**	*******

Model B1: Prop. SKJ ~ cwp55 + vessel + season + category*year + year^2 + year^3 + year^4

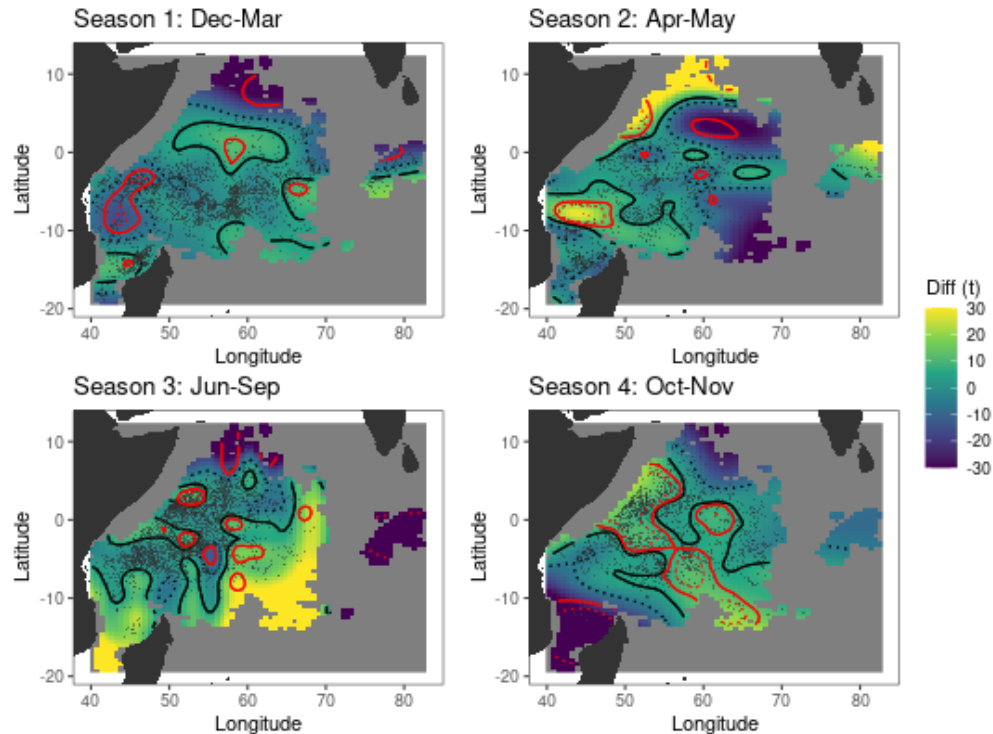→ **Positive interaction between time and proportion SKJ**

Set size composition

Probability O+E relative to F
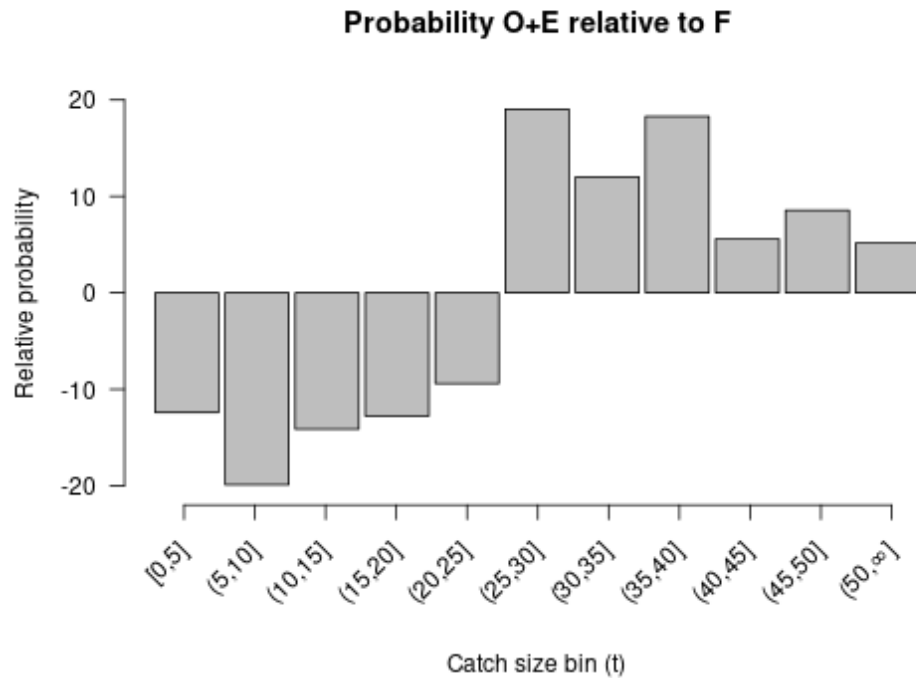
→ **Consistent with, but somewhat less dramatic than, analyses of raw data**

Model N1: Set category ~ te(lon,lat,by=season) + vessel + s(year) + size class

Spatial effects

- **Model A3:**
  te(lon,lat,by=category:season)

- **Green-Yellow:**
  More O+E catch

- **Black contours:**
  > 5 tonnes difference

- **Red contours:**
  Significant difference

- **Dots:**
  Data points

- **Seasons 1 & 3:**
  4 months

- **Seasons 2 & 4:**
  2 months

- **Pretty noisy / no strong patterns**

- **Perhaps off Somalia Season 4 & off Tanzania Season 2**

Conclusions

- Robust methodology for assigning FOB ownership

- Depends on fine scale FOB trajectory data

- Increase in proportion sets on own FOBs

- Recent change from FSC to FOB fishing

- Echosounders increase catch per set ≈2-2.5 tonnes ≈10%

  - Net gain of ≈US$5000-7000 over life of buoy
  - Search time change to be quantified, but net 30% increase in FOB sets/vessel/year

- Accounting for foreign sets, net change in FOB fishing efficiency of 1.7%-4.0%

- Reduce sets < 25 tonnes (Baida *et al.* 2020)

- Temporal shift towards more SKJ?

- Weak spatial patterns?

Stock assessment

- Reduction in PS abundance index since onset of echosounder use
  - 2012 for French Fleet
  - ?? for Spanish Fleet

- Reduction size a function of proportion of sets on owned echosounders

  - Net 2%-4% for French Fleet
  - ?? for Spanish Fleet
  - Expert opinion estimate of proportion on owned echosounders?

- Future PS abundance indexes should also account for increases in search efficiency

  - In the meantime, constant increase in fishing efficiency?

Acknowledgements