

Spatial behavior analysis of fishers by means of trajectory data: stories from faraway seas

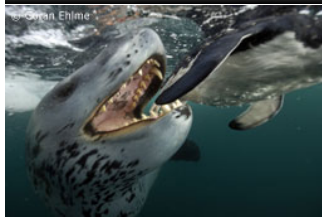
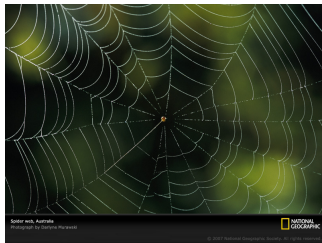
Rocío Joo

Amédée

April 6, 2017

Introduction: movement ecology

Behavior ← expressed through movement



Introduction: movement ecology

Behavior ← expressed through movement



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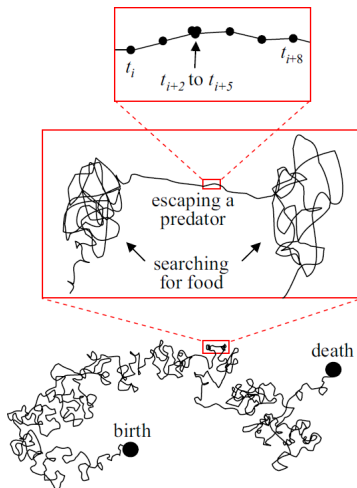


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Introduction: movement ecology

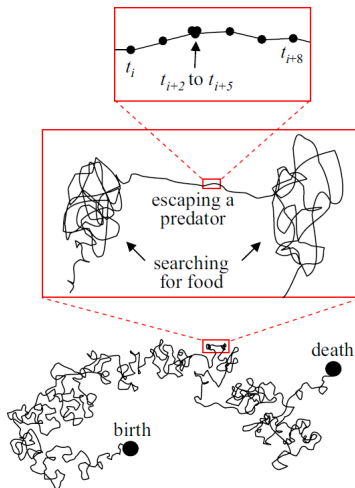
- Behavior \leftarrow expressed through movement
- Movement path \rightarrow behavioral units



(Nathan et al. 2008)

Introduction: movement ecology

- Behavior ← expressed through movement
- Movement path → behavioral units
- What internal and external factors condition individuals' behavior?
- Multiple scales



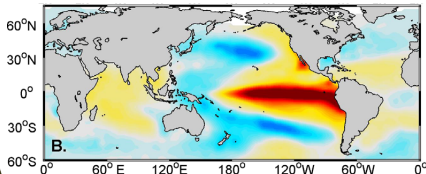
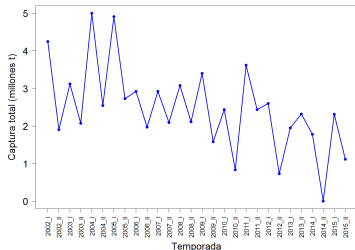
How to decompose trajectories in sequences of behavioral mode units?

Field: Northern Humboldt Current System

- Available trajectories
- Data on main ecosystem components (CHL, SST, fish...)
- World's largest monospecific fishery
- Intense regional climatic variability at multiple spatio-temporal scales (seasonal, interannual, multidecadal,...)

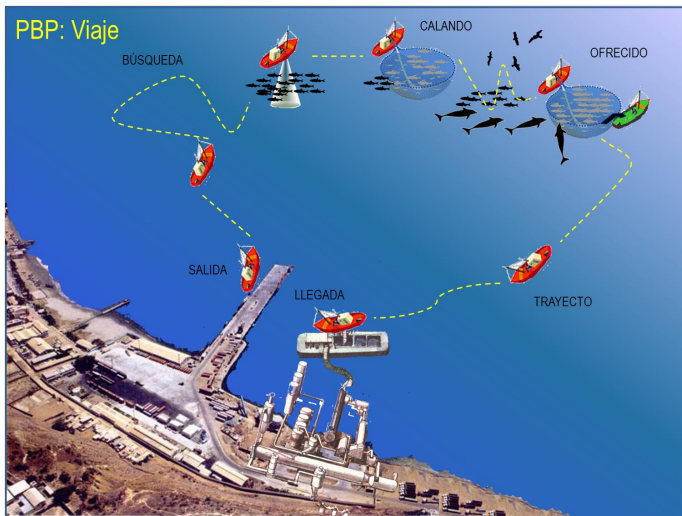


(1970s: collapsed!)

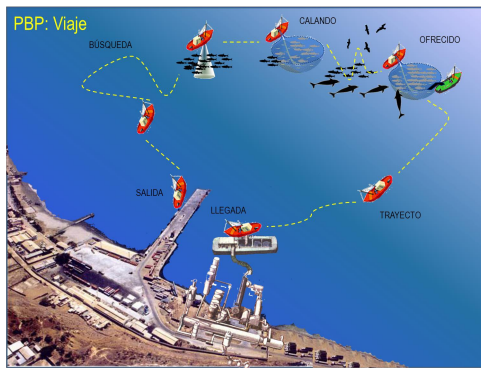


(SST variability; Chavez et al 2008)

A fisher track and its behavioral modes

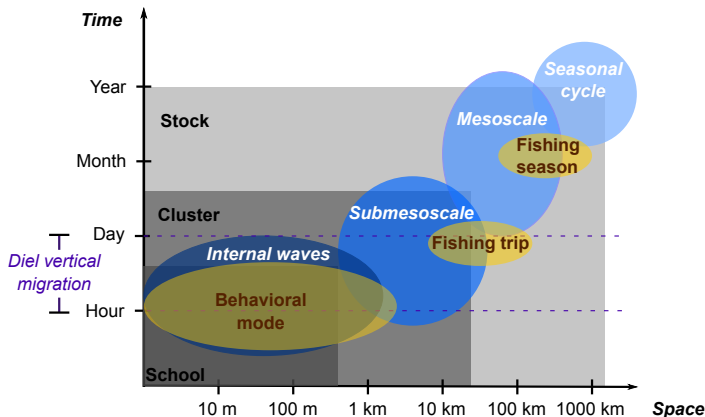


A fisher track and its behavioral modes



tracks	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
obs (post)	132	109	356	193	265	309	155	127	242	182
vms (10^3)	28.8	26.2	44.4	30.8	43.6	41.5	31.0	30.6	36.1	39.6

Fisher movement ecology



Main drivers
of fishermen
behavior

Internal state

Management rules
Personality
Fleet segment

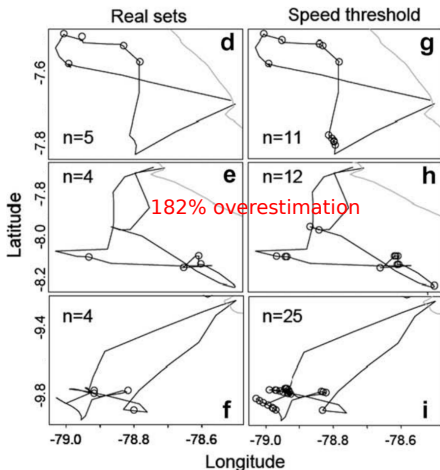
Fish and
environment
conditions

Behavior within trips: fishing

- Speed thresholds

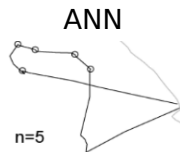
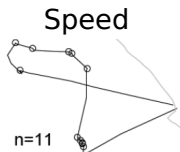
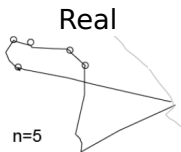
(Rijnsdorp *et al.* 1998, Dinmore *et al.* 2003, Deng *et al.* 2005, Murawski *et al.* 2005, Eastwood *et al.* 2007, Piet *et al.* 2007, Walter *et al.* 2007, Witt & Godley 2007, Fock 2008, Mullowney & Dawe 2009, Piet & Quirijns 2009, Lee *et al.* 2010, ...)

- Problems: false positives and overestimation! (Palmer & Wigley 2009, Bertrand *et al.* 2008)

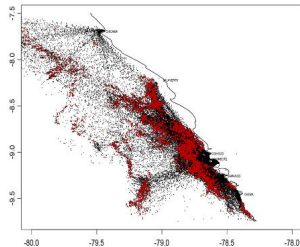
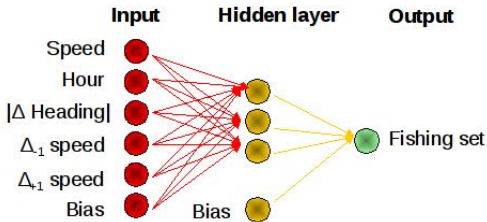


Behavior within trips: fishing

- VMS + observers data (2000-2007)

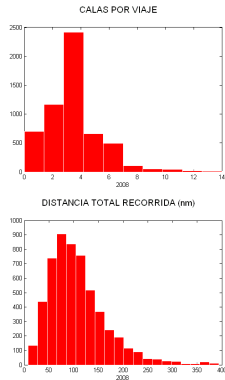
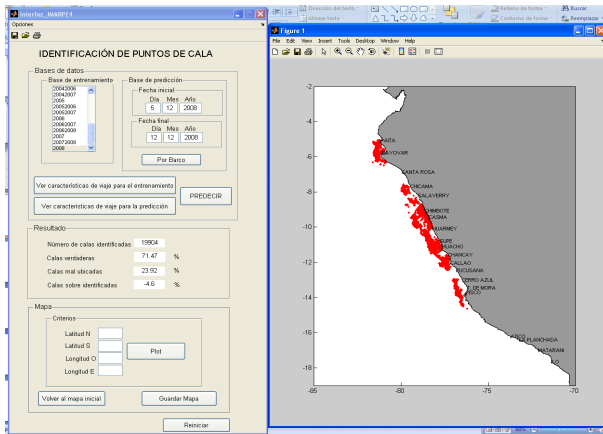


+1% overestimation
76% true fishing sets
(Bertrand *et al.* 2008,
Joo *et al.* 2011)



Behavior within trips: fishing

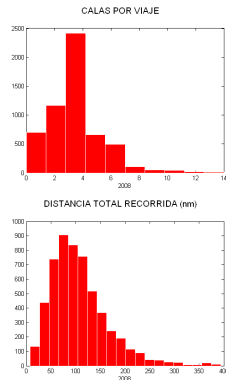
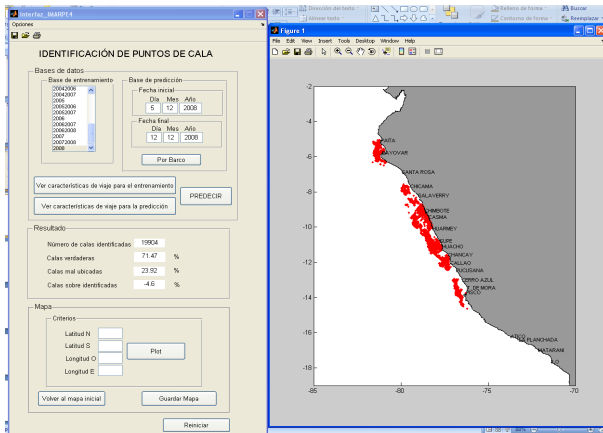
Graphic interface



Matlab \rightarrow R

Behavior within trips: fishing

Graphic interface



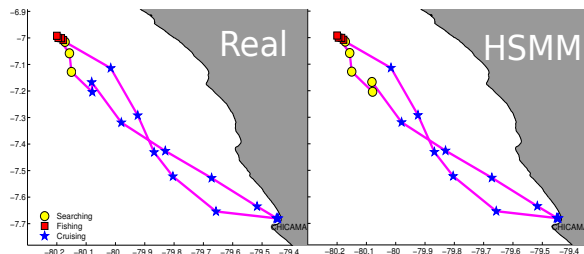
Matlab \rightarrow R



(packages: fenix, VMSkit, SISESATools)

Behavior within trips: all modes

Fishing, searching and cruising segments



Fishing 81%
Searching 58%
Cruising 87%
Global 79%
(Joo *et al.* 2013)

- VMS + observers data (2000-2009)

Behavior within trips: all modes

Model	Markovian		Discriminative			
	HSMM	HMM	ANN	SVM	RF	PDF
Set of variables	$sp, \Delta sp_{+1}$	$sp, \Delta sp_{+1}$	$sp, \Delta sp_{-1}, \Delta sp_{+1}$	$sp, \Delta sp_{-1}, \Delta sp_{+1}$	$sp, \Delta sp_{-1}, \Delta sp_{+1}, \theta, \Delta \theta_{+1}$	$sp, \Delta sp_{-1}, \Delta sp_{+1}, \Delta \theta_{+1}$
Global	80%	79%	79%	79%	76%	76%
Fishing	86%	76%	75%	75%	74%	72%
Searching	60%	60%	57%	57%	54%	51%
Cruising	88%	87%	82%	80%	74%	77%

Behavior within trips: all modes

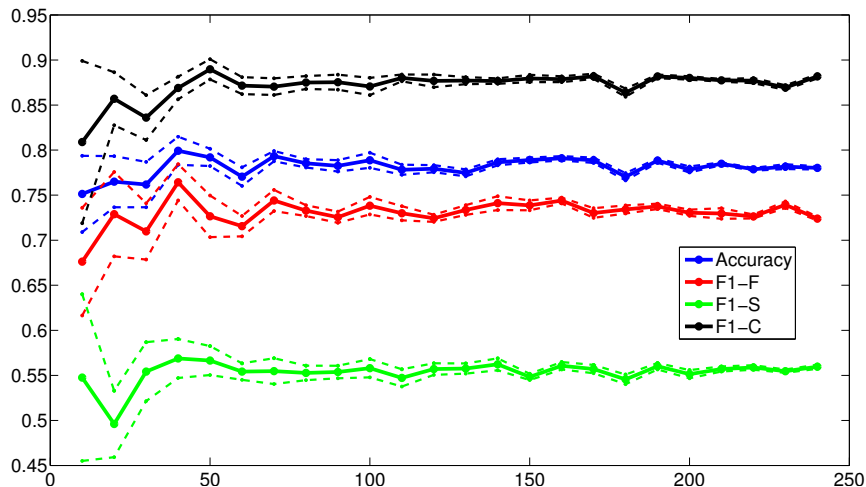
Supervised vs. Non-Supervised (EM) approaches

State	Indicator	NS-HMM	S-HMM	S-HSMM
	Accuracy	68%	78%	80%
F	F1	64%	72%	81%
S	F1	29%	56%	60%
C	F1	74%	88%	89%

Under NS, Searching state is highly confused with Fishing (30%) and Cruising (40%).

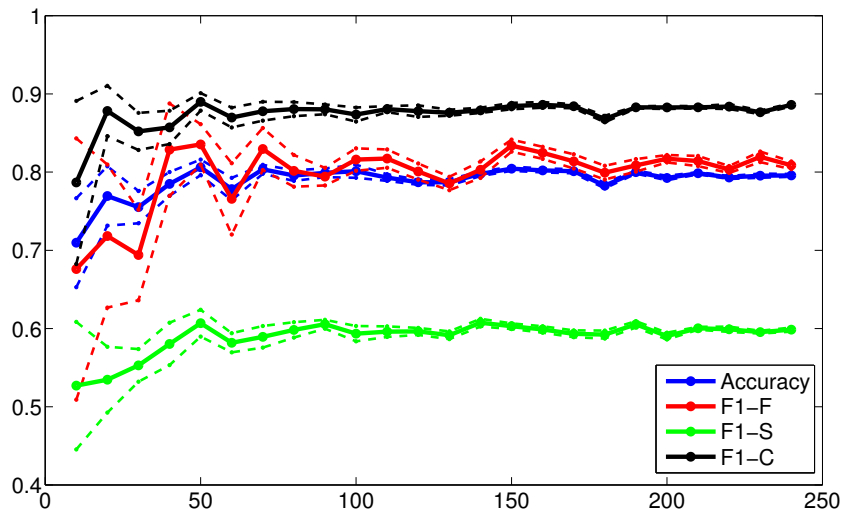
Under S, Searching is less confused with Fishing (21%) and Cruising (28%).

Behavior within trips: sample size effect?



- Mean stabilizes at $n \approx 50$.
- Confidence bands are narrower while sample size increases.

Behavior within trips: sample size effect?



- Mean stabilizes at $n \approx 80$.
- Confidence bands are narrower while sample size increases.

Spatial patterns of behavioral units

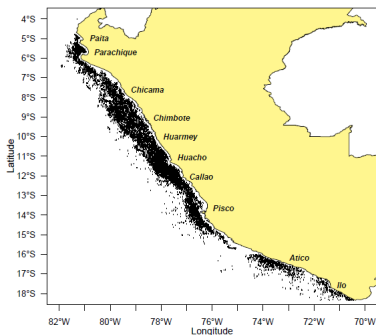
What can they tell us?



Spatial patterns of behavioral units

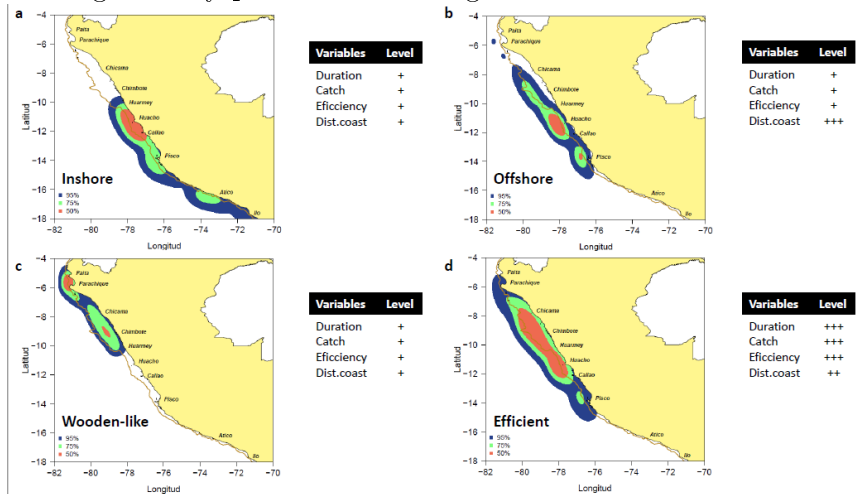
Fishing activity patterns → fishing tactics?

- Observers data (2005-2014)
 - 15067 fishing sets
 - 359 vessels
- Variables
 - Duration
 - Catch
 - "Efficiency" =
Catch / Fish-hold
capacity
 - Distance to shelf break
 - Distance to coast
 - Location (lon,lat)
- Exploratory univariate and multivariate analyses



Spatial patterns of behavioral units

Fishing activity patterns → fishing tactics?

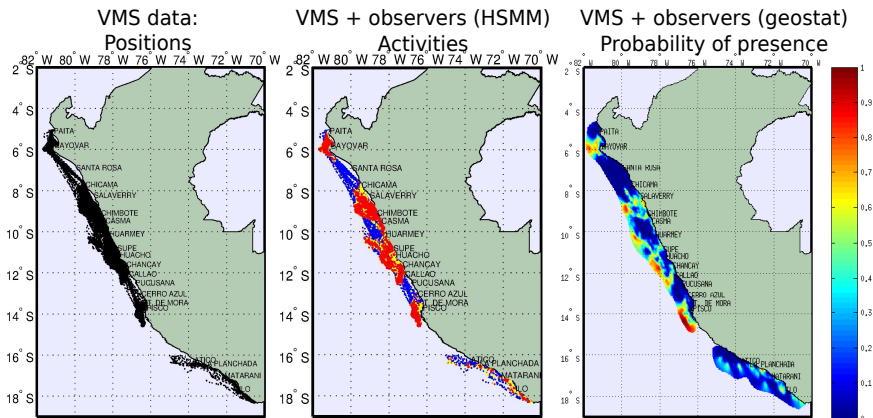


* 1 & 2 related to el Niño / la Niña

* cluster sizes: 32%, 31%, 27%, 10%.

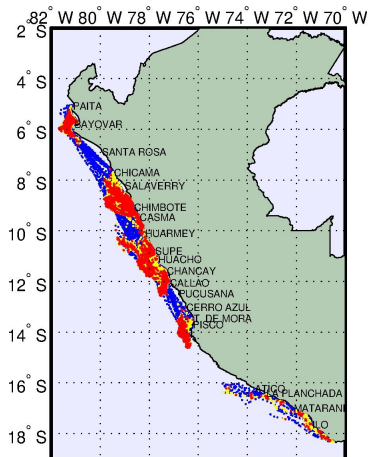
Spatial patterns of behavioral units

Spatial behavior as a proxy of fish presence?



- 1) Build VMS-based presence proxy
- 2) Compare it with acoustic-based presence proxy from same period

Spatial patterns of behavioral units



- Grid cells of 5 km x 5 km

- For each cell: $P = \frac{(\#F \times 1) + (\#S \times 0.75) + (\#C \times 0.3)}{\#F + \#S + \#C}$

$\#F$: number of **fishing** locations;

$\#S$: number of **searching** locations;

$\#C$: number of **cruising** locations

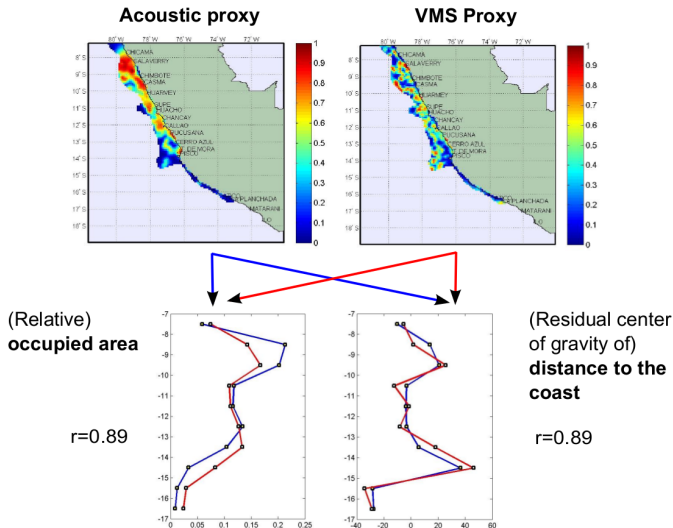
- $Z_V = \frac{(P - P_{min})}{P_{max} - P_{min}}$; $Z_V \in [0, 1]$

- Variogram model and ordinary kriging



Spatial patterns of behavioral units

Similar spatial patterns?



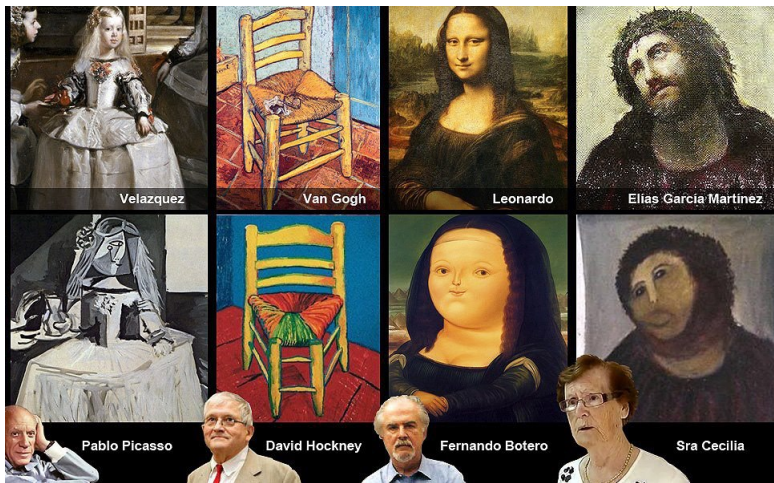
Spatial patterns of behavioral units

Two sides of the same coin?



Spatial patterns of behavioral units

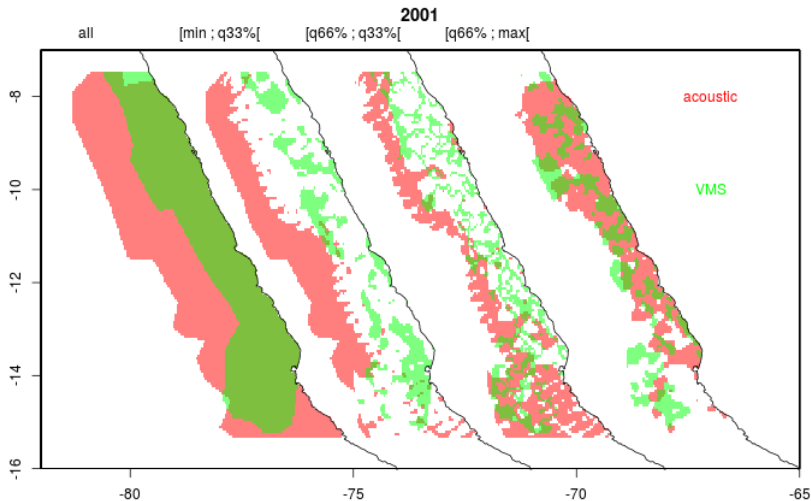
Two sides of the same coin? Or not?



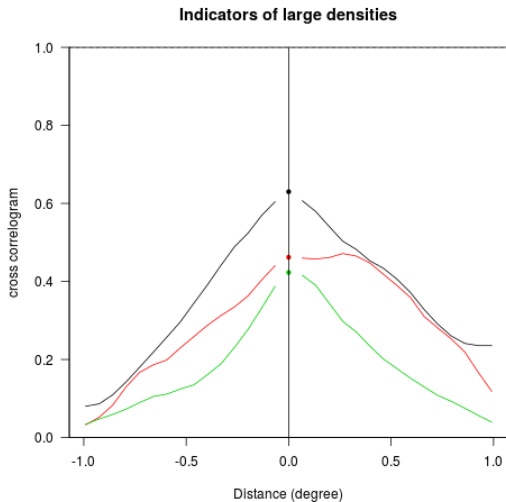
Spatial patterns of behavioral units



Differences in sampling effort



Spatial patterns of behavioral units

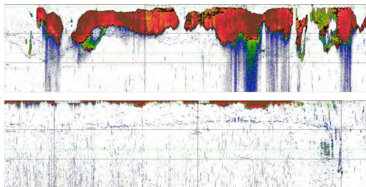
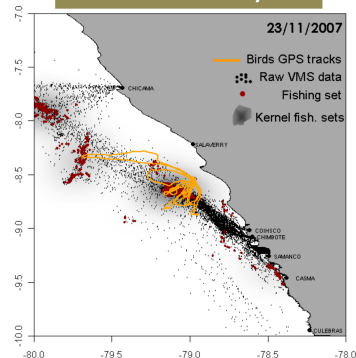


- 2001: > 60% coherence between dense VMS and acoustic zones.
- 2008 and 2009: > 40% coherence.

to be continued...

Spatial patterns of behavioral units

Humboldt Current System



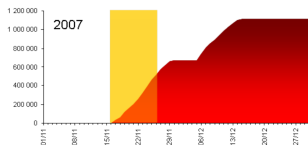
Bertrand et al. (2012) JAE

Tracking at the opening of fishing season

Seabird foraging effort increase day after day, seabirds forage farther from vessels

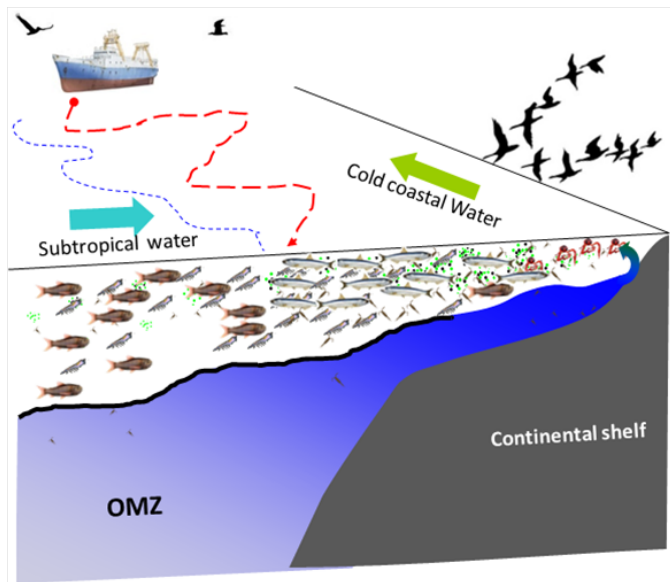
Mixed effect models:
Main effect from the local depletion generated by the fishery removals

Seabird needs: $\sim 200 \text{ t.d}^{-1}$
Fishery removals: $\sim 50\,000 \text{ t.d}^{-1}$



Competition seabirds / fishery
Localized depletions

Behavior at fishing season scale



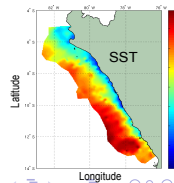
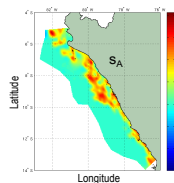
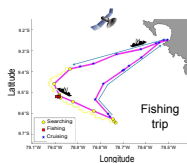
Behavior at fishing season scale

Ecosystem conditioning fisher spatial behavior?

- Fishermen:
 - [800, 16000] trips per season: fishing, searching, cruising, duration, distance, maximum distance to coast, diffusion
- Anchovy:
 - 1 value per season: global and local biomass, spatial occupation, distance to coast
- Environment:
 - weekly/monthly data: SST, CHL, oxycline

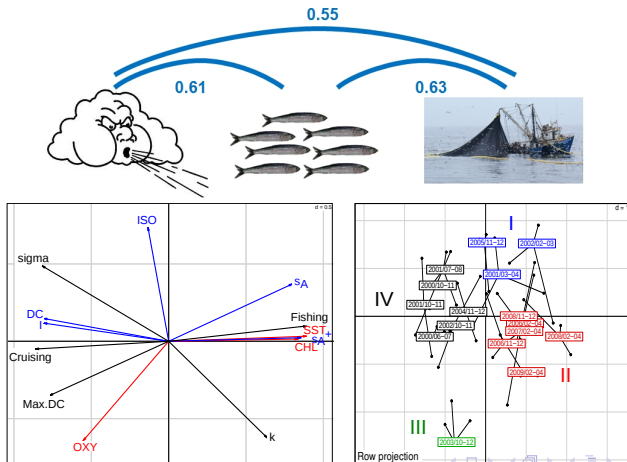
Challenges: **data** (nature & resolution)

Strategy: averaging, grouping, multivariate exploration

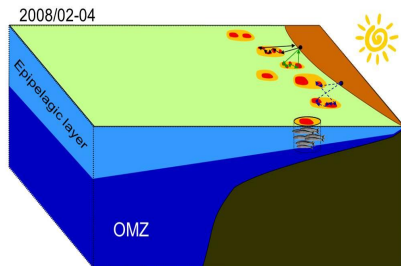


Behavior at fishing season scale

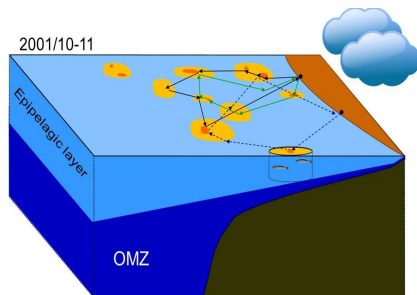
- Associations → environment and anchovy condition
- fisher behavior
- Stronger associations for direct links



Behavior at fishing season scale



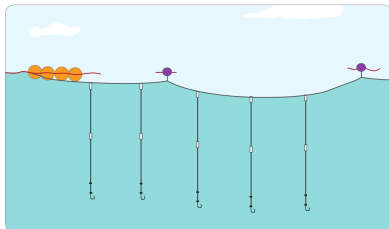
- Warm, productivity, superficial oxycline
- Abundant, concentrated, coastal
- Coastal, fishing, diffusive



- Cold, low productivity, deep oxycline
- Scarce, sparse, far
- Far, cruising, low diffusion

Behavior at annual scale

Did **small-scale** fishers change strategies?



Fuente: IMARPE

Figura 03-04 - Espinel de superficie

- Drifting longline
- ~ 10 tonnes

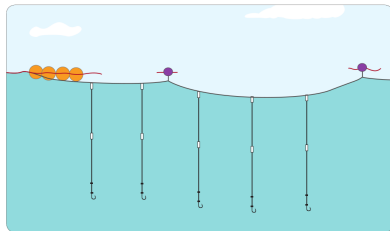


Foto 03-11 - Cortina costera

- Coastal gillnet
- ~ 2 tonnes

Behavior at annual scale

Did **small-scale** fishers change strategies?



Fuente: IMARPE

Figura 03-04 - Espinel de superficie



Foto 03-11 - Cortina costera

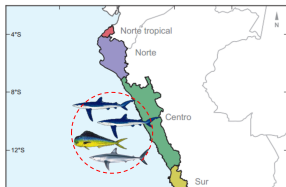
- Drifting longline
- ~ 10 tonnes
- Landing declarations (1997-2001)
- Following vessels (~ 10 per gear/region)
- Fishing area and species composition
- Descriptive stats, spatial density kernels
- Coastal gillnet
- ~ 2 tonnes



Behavior at annual scale

Drifting longline

1998



Especie	Nivel Captura	
Tiburón azul	++	<i>Prionace glauca</i>
Perico	+	<i>Coryphaena hippurus</i>
Tiburón diamante	+	<i>Isurus oxyrinchus</i>
Tiburón martillo		<i>Sphyrna zygaena</i>

Característica	Zona de pesca
Área	-
Distancia a la costa	-
Amplitud latitudinal	-
Amplitud longitudinal	-

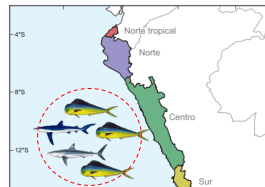
1999



Especie	Nivel Captura	
Tiburón azul	++	
Perico	+	
Tiburón diamante	+	
Tiburón martillo		

Característica	Zona de pesca
Área	+
Distancia a la costa	+
Amplitud latitudinal	+
Amplitud longitudinal	+

2000-2001



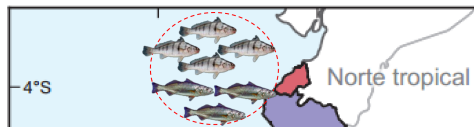
Especie	Nivel Captura	
Tiburón azul	+	
Perico	+++	
Tiburón diamante	+	
Tiburón martillo		

Característica	Zona de pesca
Área	+
Distancia a la costa	+
Amplitud latitudinal	+
Amplitud longitudinal	+

Behavior at annual scale

Coastal gillnet

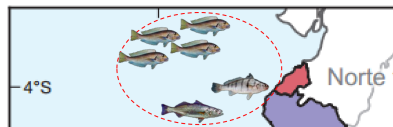
1997-2000



Especie	Nivel Captura
Coco	+
Cachema	+
Otros	+
Peje blanco	-

Característica	Zona de pesca
Área	+
Distancia a la costa	-
Amplitud latitudinal	+
Amplitud longitudinal	+

2001



Especie	Nivel Captura
Coco	-
Cachema	-
Otros	-
Peje blanco	+++

Característica	Zona de pesca
Área	+
Distancia a la costa	+
Amplitud latitudinal	+
Amplitud longitudinal	+

Paralanchurus peruanus

Cynoscion analis

Caulolatilus affinis

More?

Collective behavior:

More?

Collective behavior:



If there's time for a teaser...