Methods for integrating data from fisheries and acoustic surveys in a spatial predator-prey approach to fisheries

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ICES Joint session FAST / FTFB - Roma, 21st April 2005

IRD

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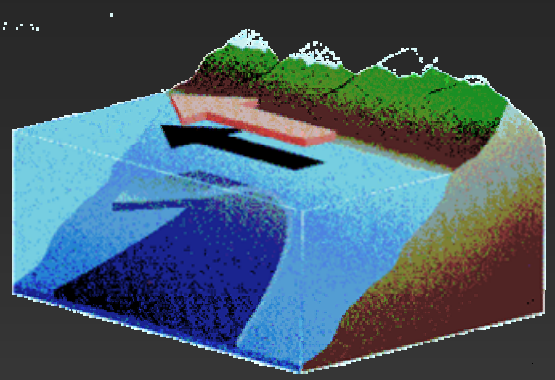
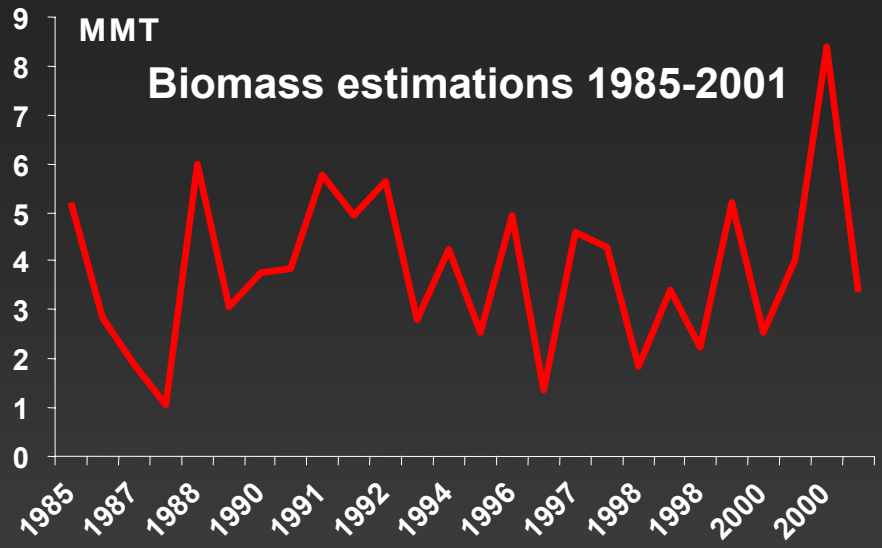
Outline

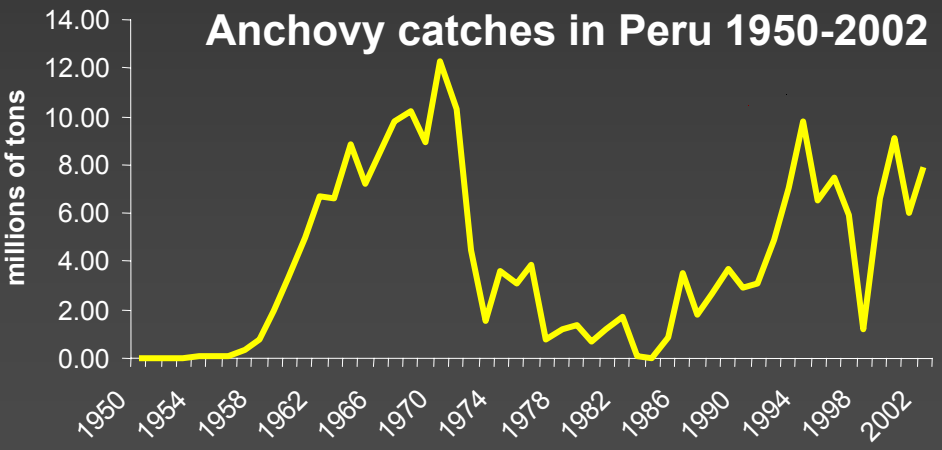
- Context and available data
- Indicators for
  - Fish spatial distribution
  - Fishers' spatial behaviour
- Integration through
  - Statistical multivariate approach
  - Multi-scale approach
  - Spatial point process approach
- What did we learn from this integration?

Peruvian anchovy fishery

Coastal upwelling ecosystem





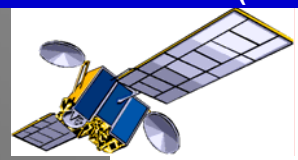


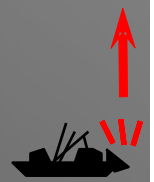
Fishing fleet:

- 800 purse seiners
- Homogeneous (80% between 100 and 400 m3 hold capacity)
- Searching for fish: plane prospecting, bird sonar and echosounding
- Fishing regulations: quotas + fishing closures
- In real time management

Available data

ARGOS : georeferenced position for the whole fleet (800 vessels) in real time since 1999



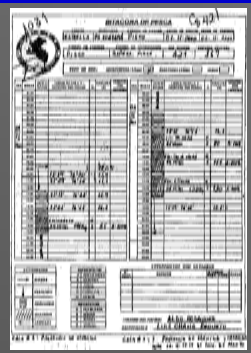


- 1position/vessel/hour
- Probable fishing sets
- Typology of fishing trips trajectories

Fishery statistics

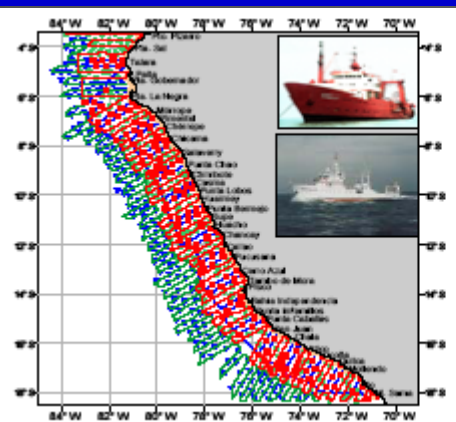
- Vessel characteristics
- Landings (/day; /port; /vessel) from Imarpe and fish meal factories

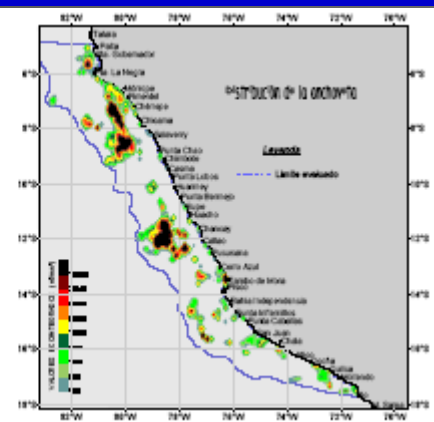
Observers at sea : 25 vessels by day, all along the coast



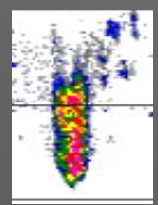
- Vessel/port
- Travelling and searching durations
- Position, number and composition of net sets
- Type and depth of blanked schools
- Size structure of catches

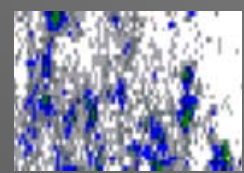
Acoustic surveys: 1 to 4 per year





- Horizontal distribution
- School typology
- Vertical distribution





INDICATORS FOR FISH DISTRIBUTION

Fish spatial distribution from acoustic surveys

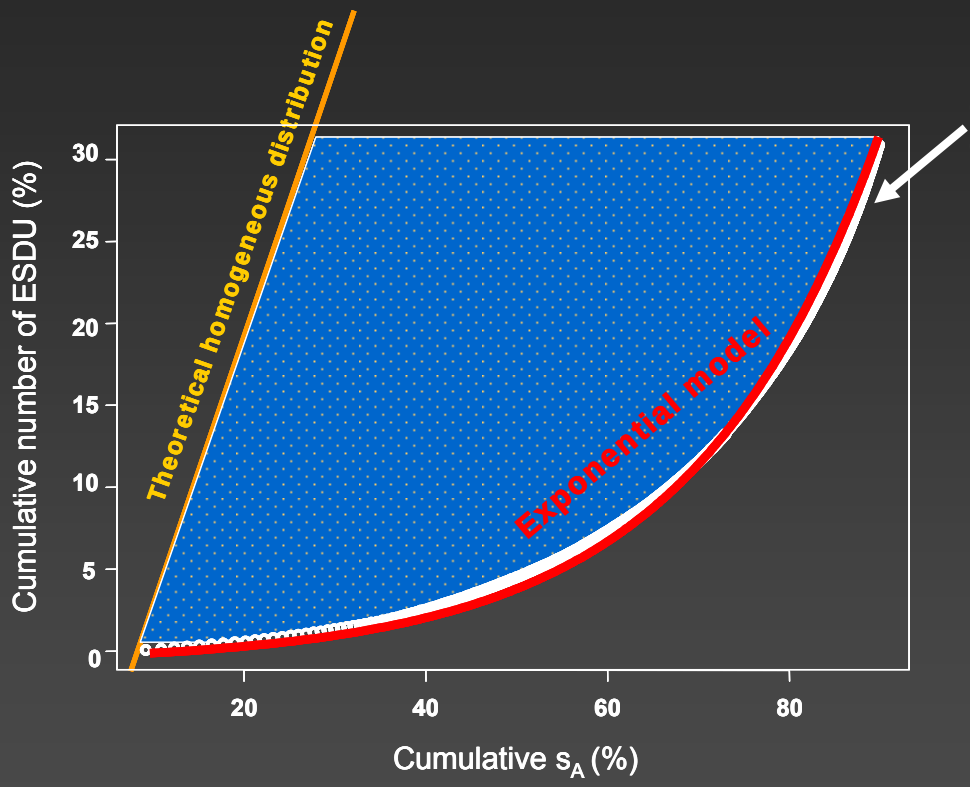
Input: Acoustic surveys
Biomass (s_A) attributed to anchovy by ESDU of 1 nm

Indicators:

- Biomass estimation B (IMARPE)
- Stock range S (by interpolation)
- Local biomass index: Mean biomass in ESDU with anchovy s_A+
- Space occupation index: %of ESDU with anchovy ISO
- ~~Gravity center~~
- Spatial concentration index
- Clustering index
- Fractal dimension

Spatial concentration index

Method: Comparing observed distribution of the biomass among ESDU to a theoretical uniform distribution



$$Ss = \int_0^{0.9} x - a.\exp(b.x)dx = \left[\frac{x^2}{2} - \frac{a}{b}.\exp(b.x)\right]_0^{0.9}$$

$$= 0.405 + \frac{a}{b}\left(1 - \exp(0.9b)\right)$$

Output:

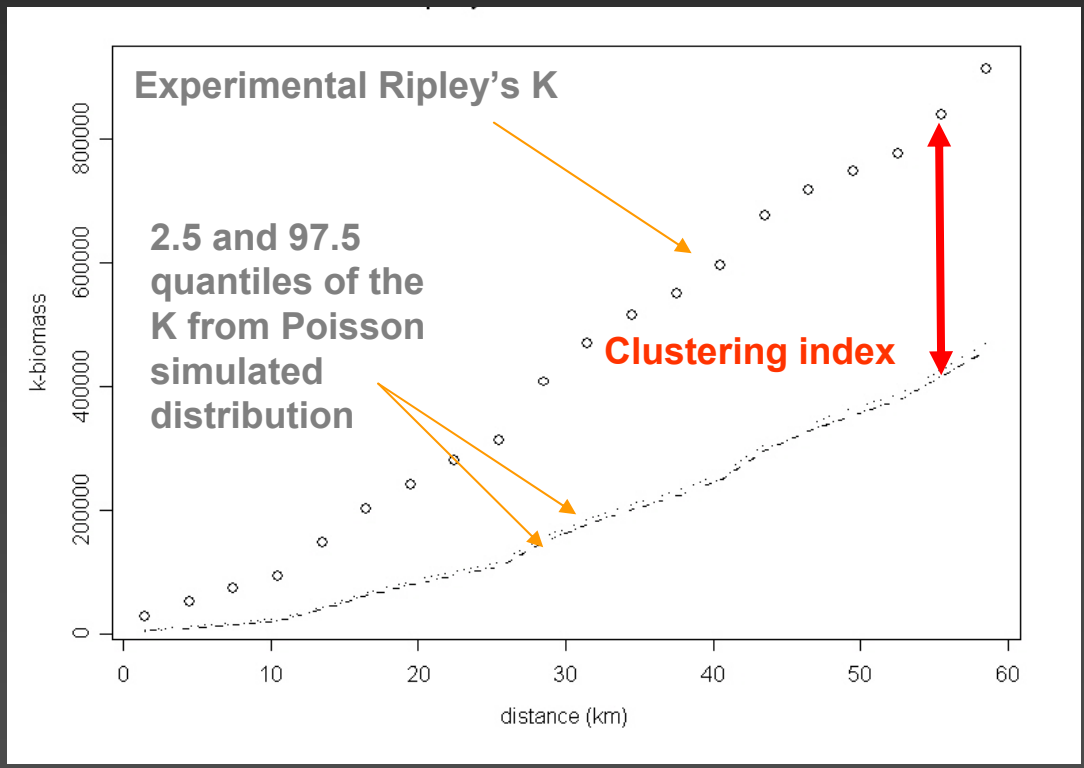
How does the biomass fill the space?

No indication on connectivity : relative abundance distribution, irrespective of location

S. Bertrand, E. Díaz and M. Ñiquen - 2004 - ICES Journal

Clustering index

Method: Ripley's K in general tests whether a distribution of points in space is random, clustered or inhibited
Here, modified marked Ripley's K (regular surveys) to examine the clustering of high-density sample units around each other
Comparison to theoretical Poisson random distribution (Monte Carlo simulation)

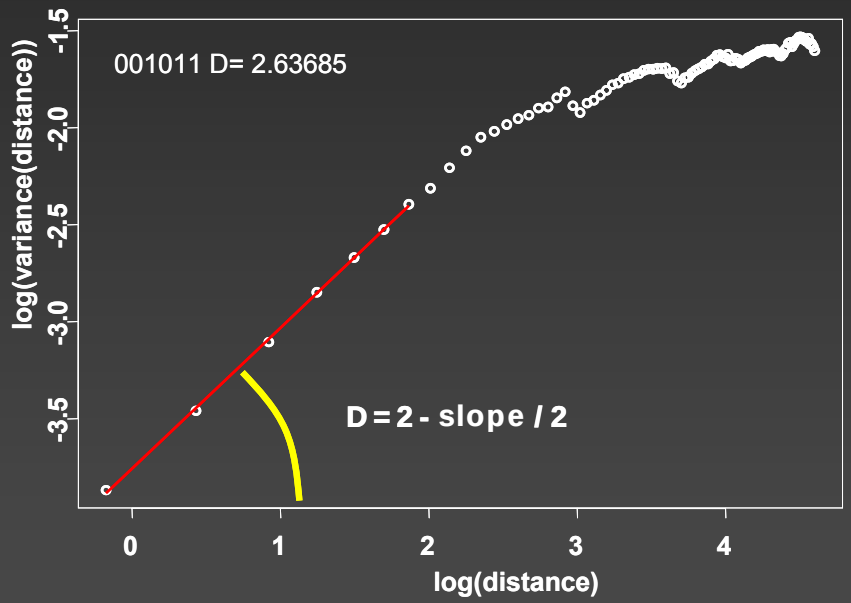


Output: "how much" the distribution is contagious?
there is an indication on connectivity of high energy agregations

M. Gutiérrez, G. Swartzman, A. Bertrand and S. Bertrand – 2005 – under review

Fractal dimension

Method : Computing the empirical variogram on presence-absence data
Determining slope at the origin of the log-log variogram



Fractal dimension

D = 2 - β/2

For a space with 2 dimensions

Output : degree of patchiness of the agregations (Frontier 1987)

For this species, in this ecosystem
High D ≈ high patchiness ≈ fish dispersed in a large favourable habitat (type Niña)
Low D ≈ low patchiness ≈ fish densely agregated in coastal refuge areas (type Niño)

S. Bertrand, J. M. Burgos, F. Gerlotto and J. Atiquipa – 2005 – ICES journal

INDICATORS FOR FISHERS' BEHAVIOUR

Fishers behaviour from observers at sea : CPUE indicators

Travel duration TD

Searching duration SD

Number of fishing sets FSN

Mean inter-fishing sets distance IFSD

Fishing sets Inertia I

Standardised catches: filling rate of the hold

FRH = Trip catch / Hold capacity

Time efficicency indices: TDE, SDE

Technical efficacy index: FSNE

Spatial efficacy indices: IFSDE, IE

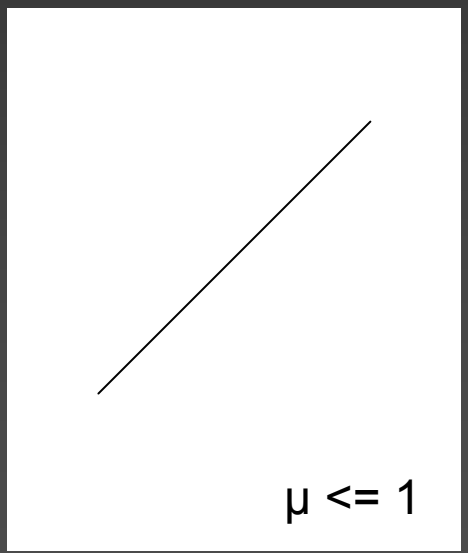
Fishers' behaviour from satellite data : sinuosity index of trajectories

Input: Vessel monitoring system data (1 position.hour^{-1} for the whole fleet)

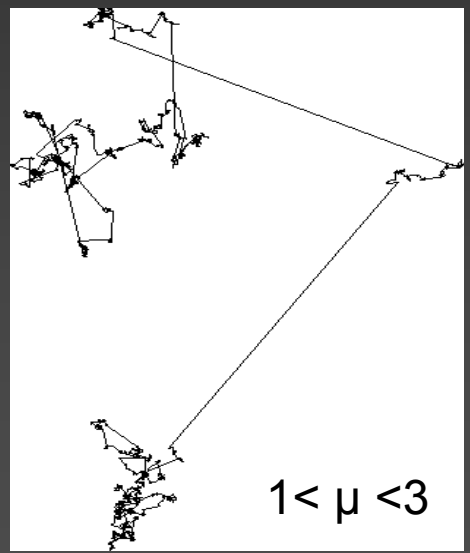
In a general way, any trajectory can be modelled by the pdf of the step length distribution with the general form:

$$P(N(x)) \sim x^{-\mu}$$

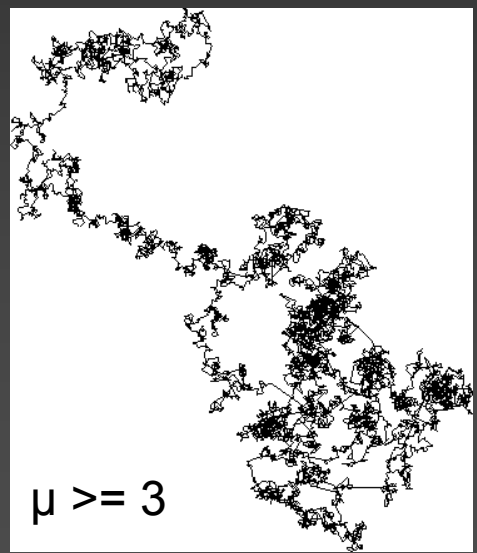
Ballistic motion



Lévy motion

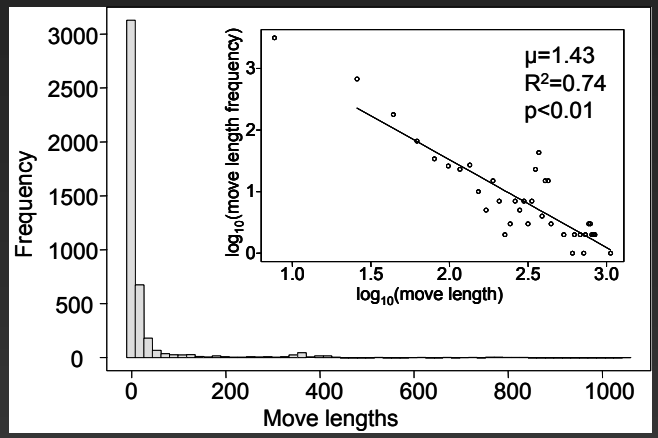


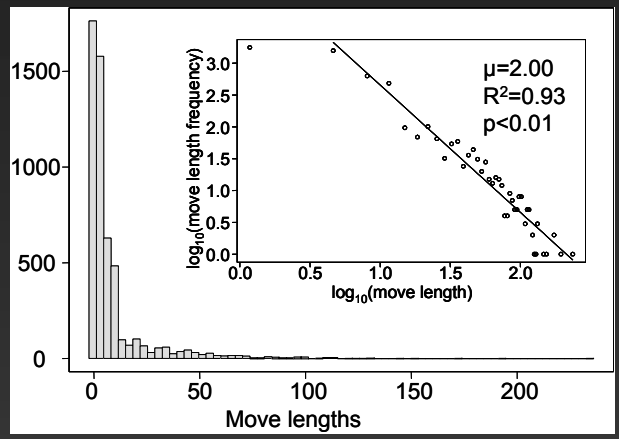
Brownian motion

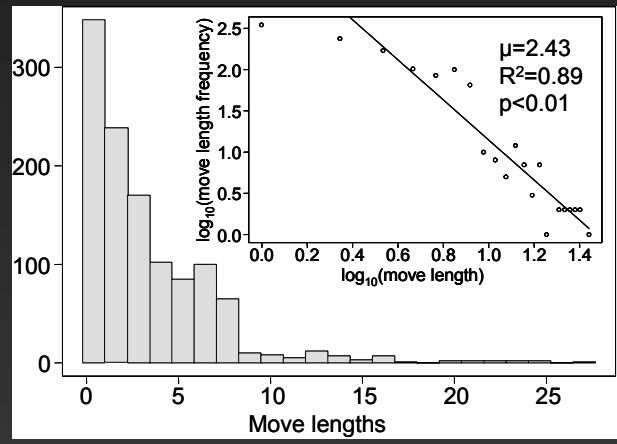


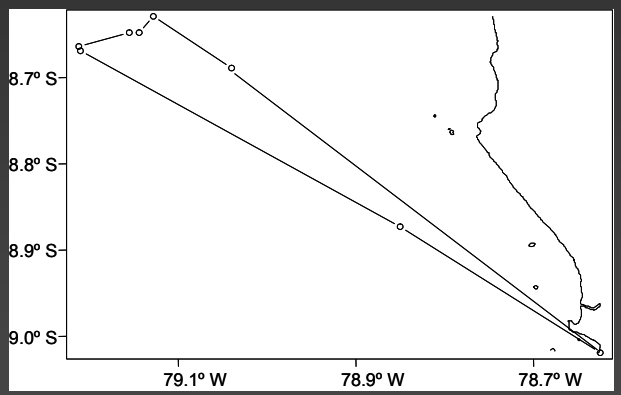
Sinuosity

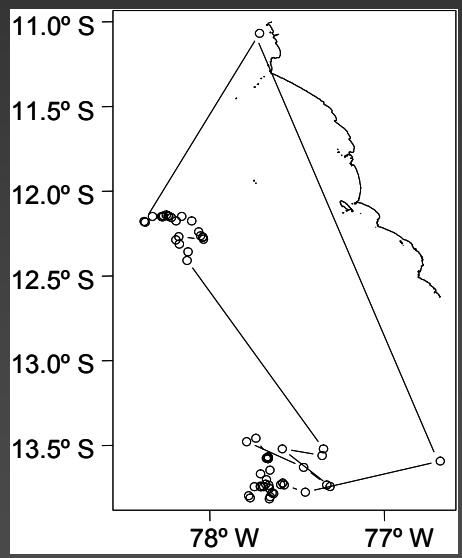
Fishers' behaviour from satellite data : sinuosity index of trajectories

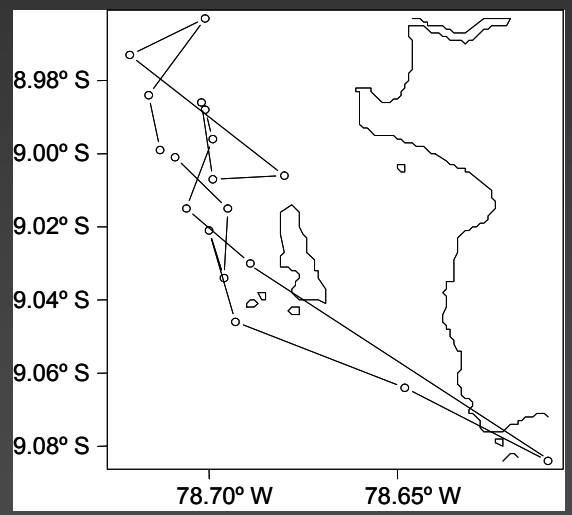


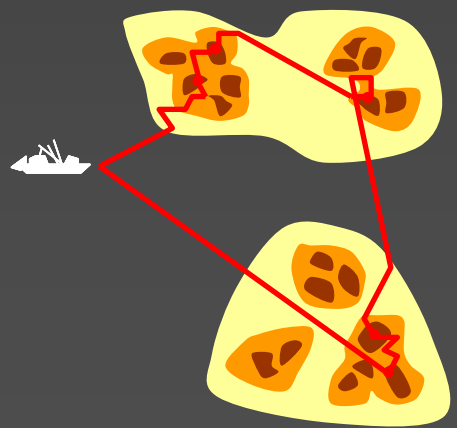












Output : μ as an index of sinuosity of vessels' trajectories
A new, unbiased and purely spatial effort index

S. Bertrand, R. Guevara, A. Bertrand and F. Gerlotto – 2005 – in prep.

INTEGRATION OF DATA FROM FISHERIES AND FROM ACOUTIC SURVEYS

What are the impacts of biomass distribution in space on fishing efficiency (CPUE)?

Method Statistical multivariate approach
(ACP + Mixed hierarchical classification)

Spatial scale

Large

Medium

Small

High S low B/S

Low S high B/S

Low Ss/var(s_A+)

High Ss/var(s_A+)

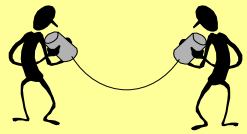
Weak

Strong

Patchiness scale

Impact on Peruvian anchovy purse seiners activity

Fishing ground selection



Searching for interesting aggregations

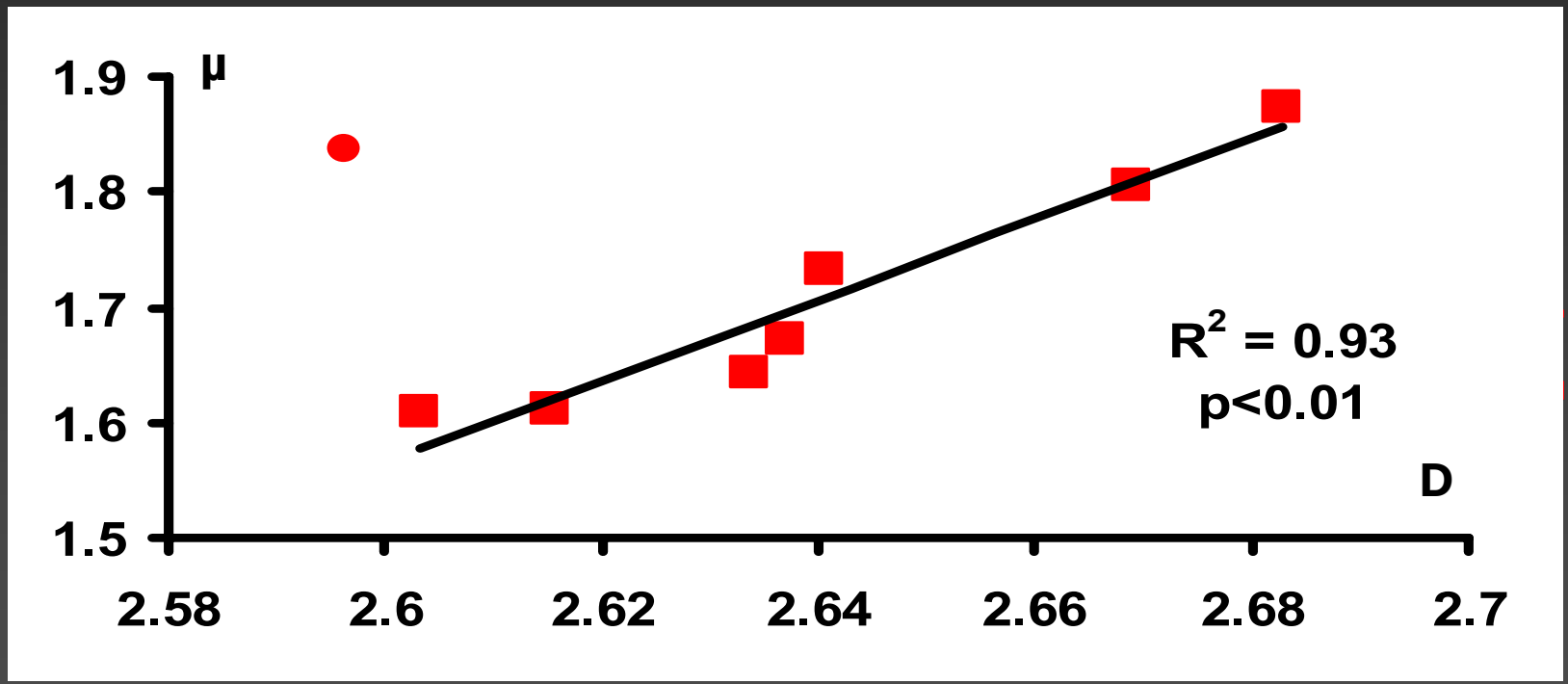
Fishing a school

S. Bertrand et al. 2004 – ICES Journal

Relationships between fish distribution and fishers' spatial behaviour across scales.

Method Statistical correlation between scale invariant indicators?

NS relationships between μ and Biomass/Stock range/s_A+/ISO/concentration/clustering



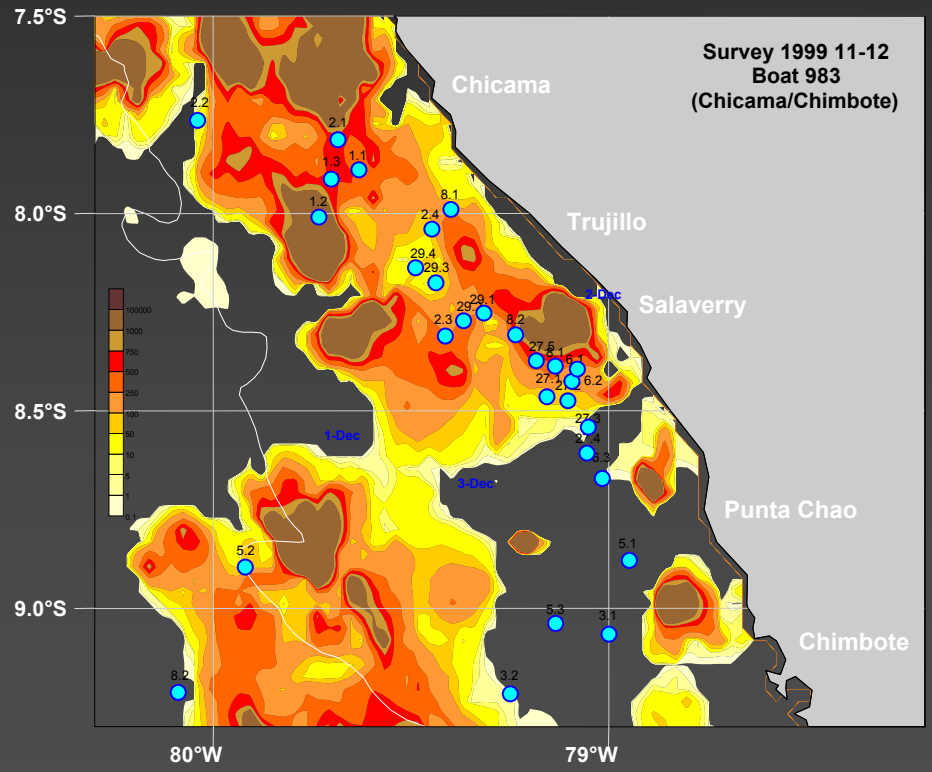
S. Bertrand, J. M. Burgos, F. Gerlotto and J. Atiquipa – 2005 – ICES journal

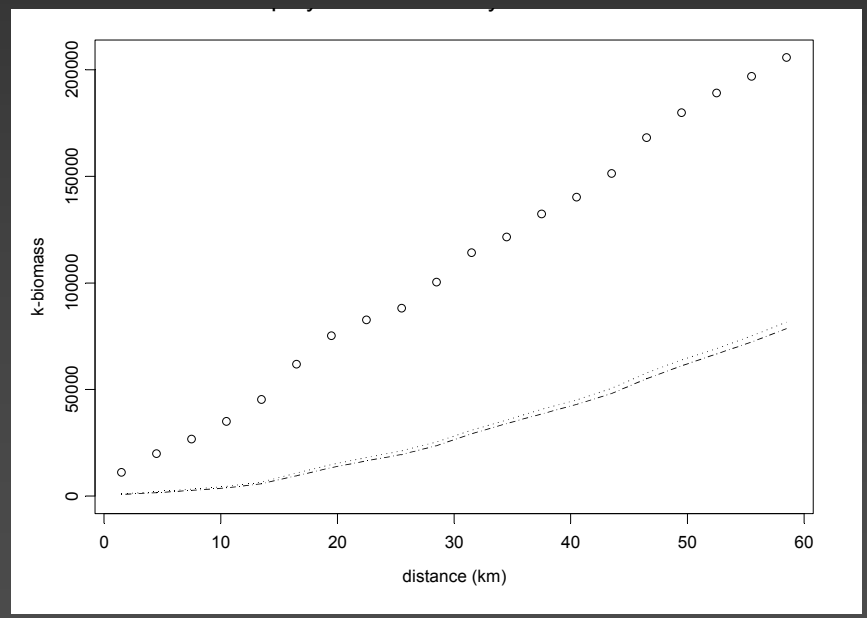
Fish distribution around fishing sets according to scale? Point process approach

Input: fishing sets positions and catches (from observers at sea) and fish distribution from concomittant acoustic surveys

Method: characterizing anchovy spatial distribution « around » fishing sets ;

Paired, marked Ripley's K





Output: index of spatial matching between fish and fishers

Work in progress

What did we learn from this approach?

On a methodological point of view

- Fisher's spatial behaviour may be modelled as random walk and characterized by a single parameter;
This parameter can be interpreted as the sinuosity of vessels' trajectories

An experimental and complementary approach of the hierarchical decision making models (Dorn, 2001): "promoting the view that fishing is, fundamentally, a decision process based on uncertain information about a stochastic environment."

- Some simple indicators based on widely collected spatialized data (acoustic/VMS...etc) provide a good description of hierarchically organized patterns and multi-scales interactions in the ecosystem

On a conceptual point of view

- Impacts of abundance and spatial distribution of fish on usual fisheries indexes (CPUE) may be opposite according to scales

- Fishers' movements do "respond" to fish distribution over a continuum of scales

- Proposing alternative indicators to CPUE for monitoring fisheries