The use of GPS and compass loggers to reconstruct high-resolution trajectories in Cory's shearwaters (*Calonectris diomedea*) to investigate search strategies

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BIOLOGGING4
Fourth International Science Symposium on Bio-logging
Wrest Point Hotel and Conference Centre
Hobart, Tasmania, Australia
14-18 March 2011

Photos by Bruno D' Amicis

We acknowledge the Ministry of Environment and LIPU-UK for funding this research and a group of enthusiastic friends who helped us in the field and during data analysis

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The studied colonies

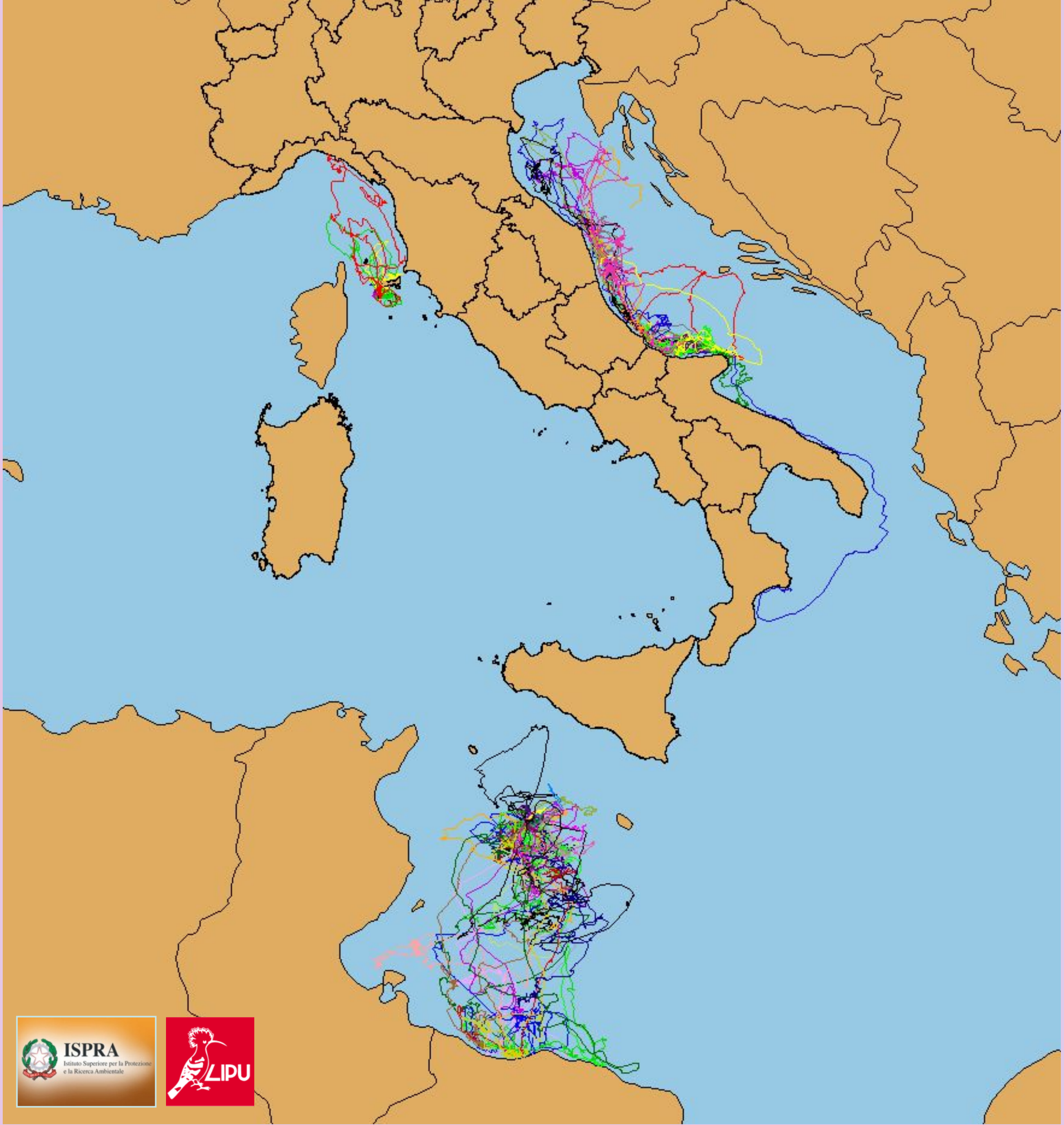
The Cory's shearwater: a "strictly" pelagic bird

Compass-loggers

Compass bearings records angles of movement with a a resolution of < 0.1° and collect data each 5 s. 1 excursion per bird during incubation and chick-rearing.

GPS-loggers

Main device used for this study. Fixes were collected each 10 min. 1 excursion per bird during incubation and chick-rearing.



<u>The</u>

<u>LIPU-BirdLife Italy data-set</u>

<u>on the map!</u>

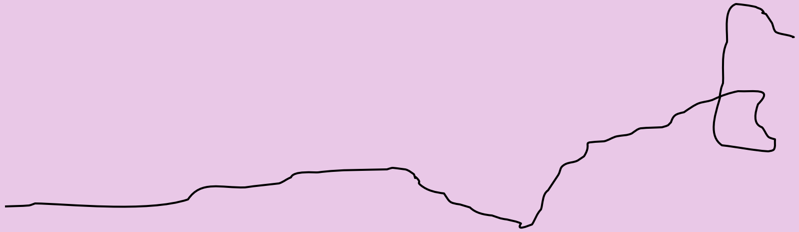
Because the sample from Arcipelago Toscano is yet small we considered only Tremiti (26) and Linosa (79) data sets

A total of 19 Compass logger and 86 GPS tracked birds

Introduction

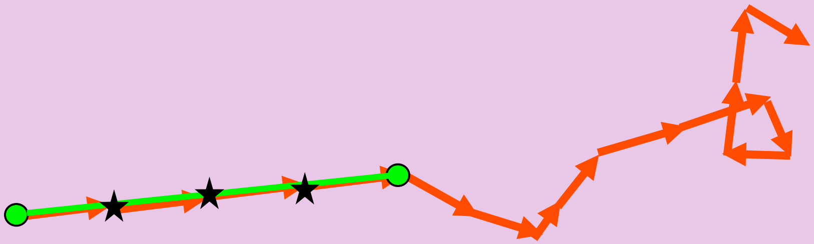
Our aim is to analyse the foraging excursions of a central place forager recorded by compass- and GPS-loggers

How can we represent an excursion?



Let us suppose this is the actual path…

Classical approach: uniform sampling in time

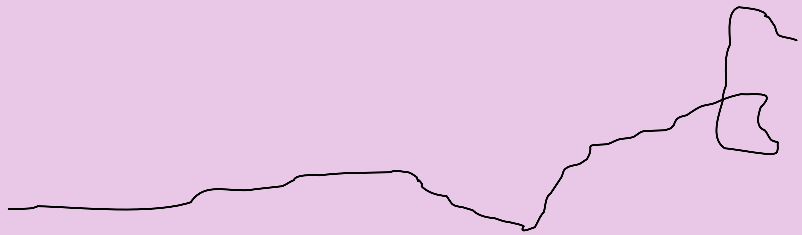


Strong undersampling of long displacements

Too many turning angles around 0°

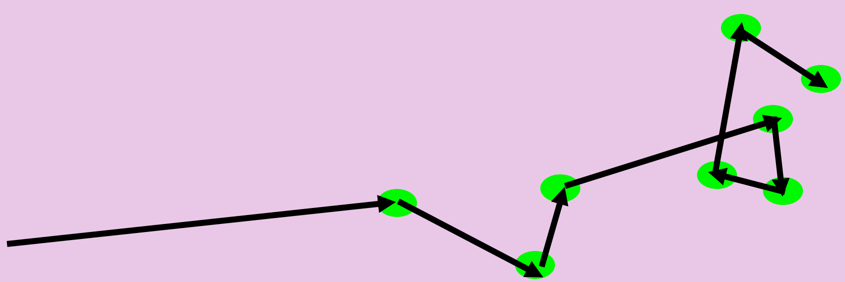
This displacement is artificially divided in 4 smaller segment

How can we represent an excursion?



Let us suppose this is the actual path…

Another approach: Sampling at turning points



How identify important turning points?

Which is to say: how to understand any a change of motivation?

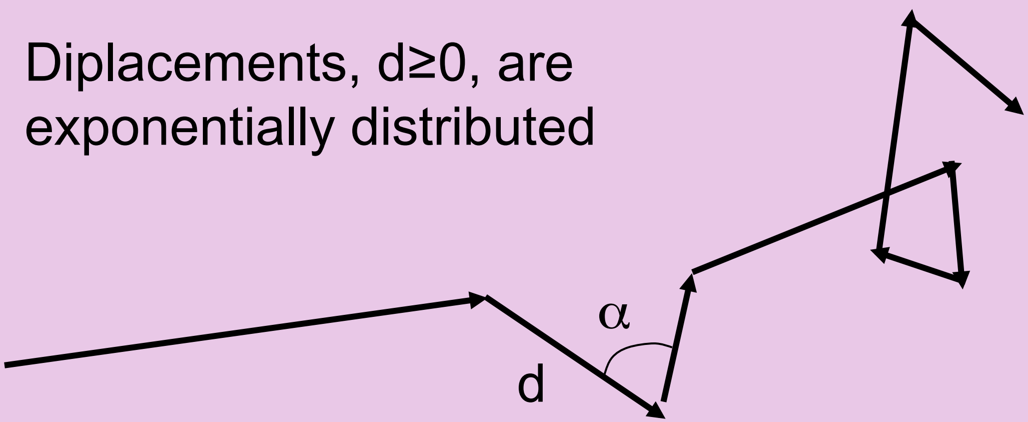
Introduction

Bayesian analysis can help but we have to formulate explicit hypotheses about search mechanisms used.

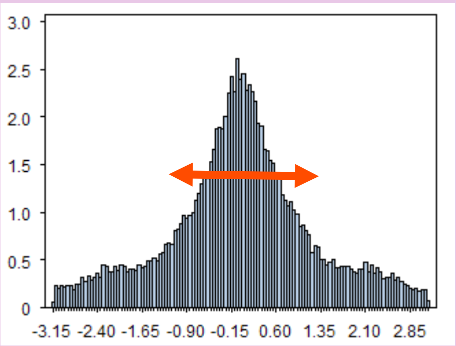
We consider 3 different models

1 Simple correlated random walk CRW (Turchin 1998)

Diplacements, $d \geq 0$, are exponentially distributed



Turning angles α have mean 0 and the distribution is wrapped normal or wrapped Cauchy or Mardia's in $[-\pi, \pi]$



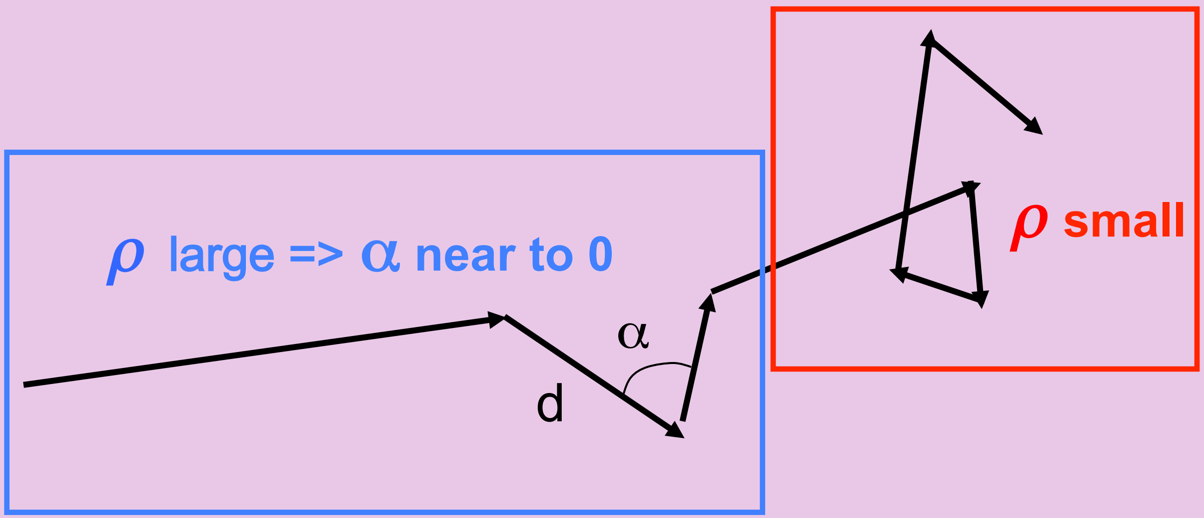
ρ to be estimated controls the dispersion of the angular distribution

<u>*Introduction*</u>

Bayesian analysis can help but we have to formulate explicit hypotheses about search mechanisms used.

We consider 3 different models

2 Adaptive correlated random walk (Benhamou 2007): a mixture of two different wrapped-Cauchy distributions. One (ρ large) characterises the movement among patches, the second (ρ small) the movement within patches.



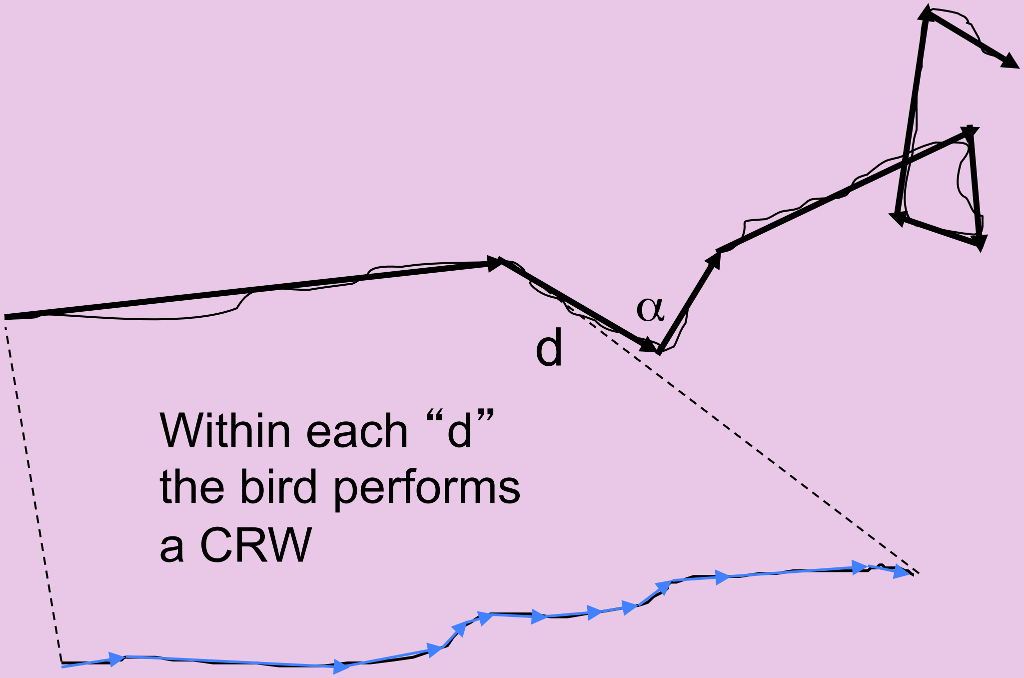
This model predicts area-restricted search

Introduction

Bayesian analysis can help but we have to formulate explicit hypotheses about search mechanisms used.

We consider 3 different models

3 Intermittent movement *sensu* Bartumeus & Levin (2008): birds shift between two behavioral modes: *reorientation* and *scanning.* A Lévy modulated CRW



Reorientation exhibits a uniform α distribution; d is power-tailed distributed (Lévy walk)

This model predicts area-restricted search

Introduction

We have considered the angles collected with gps- and compass-logger as a mixing of angular distributions. 3 different models:

$$F_1 = \log\left(\frac{1-\rho^2}{2\pi(1-\rho^2-2\rho\cos(\alpha))}\right)$$

correlated random walk

$$F_2 = \log\left[w\frac{1-\rho_1^2}{2\pi(1-\rho_1^2-2\rho_1\cos(\alpha))}+(1-w)\frac{1-\rho_2^2}{2\pi(1-\rho_2^2-2\rho_2\cos(\alpha))}\right]$$

adaptive correlated random walk

$$F_3 = \log\left(w\frac{1-\rho^2}{2\pi(1-\rho^2-2\rho\cos(\alpha))}+\frac{(1-w)}{2\pi}\right)$$

Intermittent movement

We used Montecarlo Markov Chains for estimating ρ and *w* (the fraction of a distribution)

Results. *Hypothesis 1: how much turning angles are homogenous?*

	GPS loggers	Compass loggers
CRW	3 3.5%	0 0.0%
Adaptive CRW	38 44.2%	3 15.8%
Intermittent	45 52.3%	16 84.2%
Total	86	19

Now we focus on these birds and try to see whether or not *displacements* are Lévy distributed

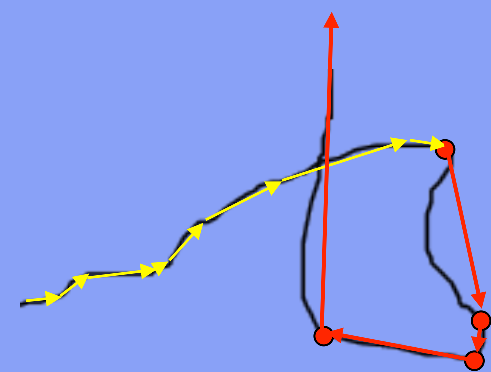
I compass loggers are characterised by a larger % of Intermittent (F_3) movement tactics than GPS loggers (χ^2=6.6 P=0.03)

Both methods show the presence of different movement tactics during foraging excursions of Cory's shearwaters

***Results**. Hypothesis 2: How to identify turning points in intermittent movements?*

Given that the MCMC analysis yields the fraction $(1-\hat{w})$ of angles derived from an uniform distribution

We assume that the largest angles represent turning points

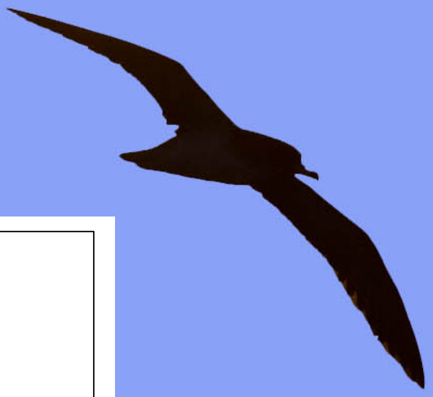


Yellow vectors have angles near 0 from wrapped Cauchy

Red vectors have large angles from an uniform distribution

Does it work? This is the problem …..

***Results**. Hypothesis 2: How to identify turning points in intermittent movements?*



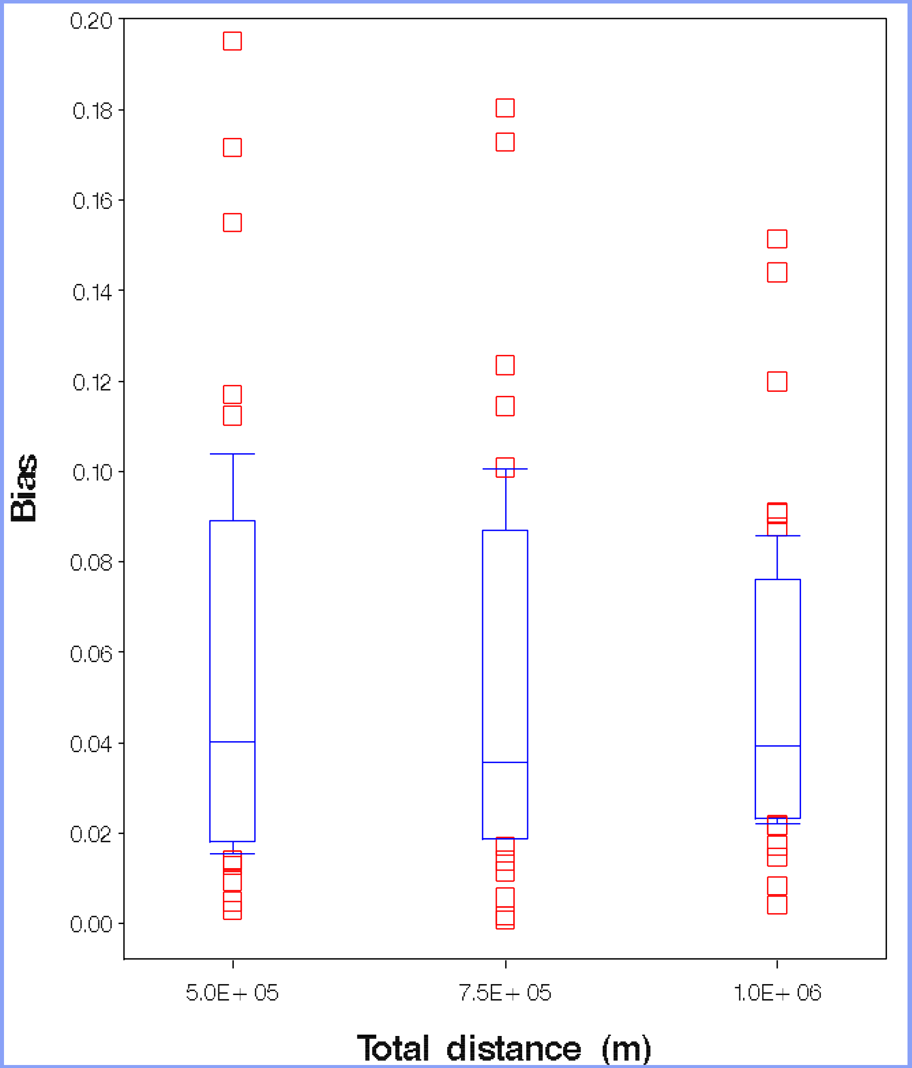
A Lévy distribution reads: $P(d) = ad^{-\mu}$

We have used simulations (with μ assigned) to check for method's reliability:

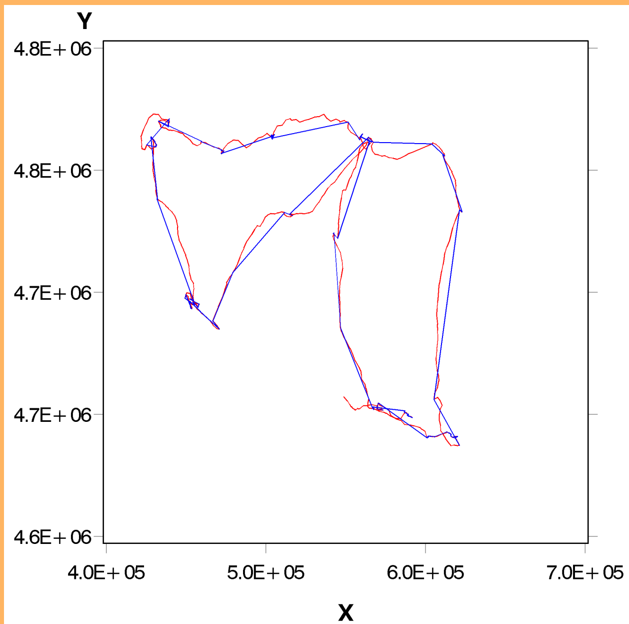
We estimated $\hat{\mu}$ from simulations

$$bias = \frac{|\mu - \hat{\mu}|}{\mu}$$

Bias is usually low (average 4%) and its variance decreases with excursion length

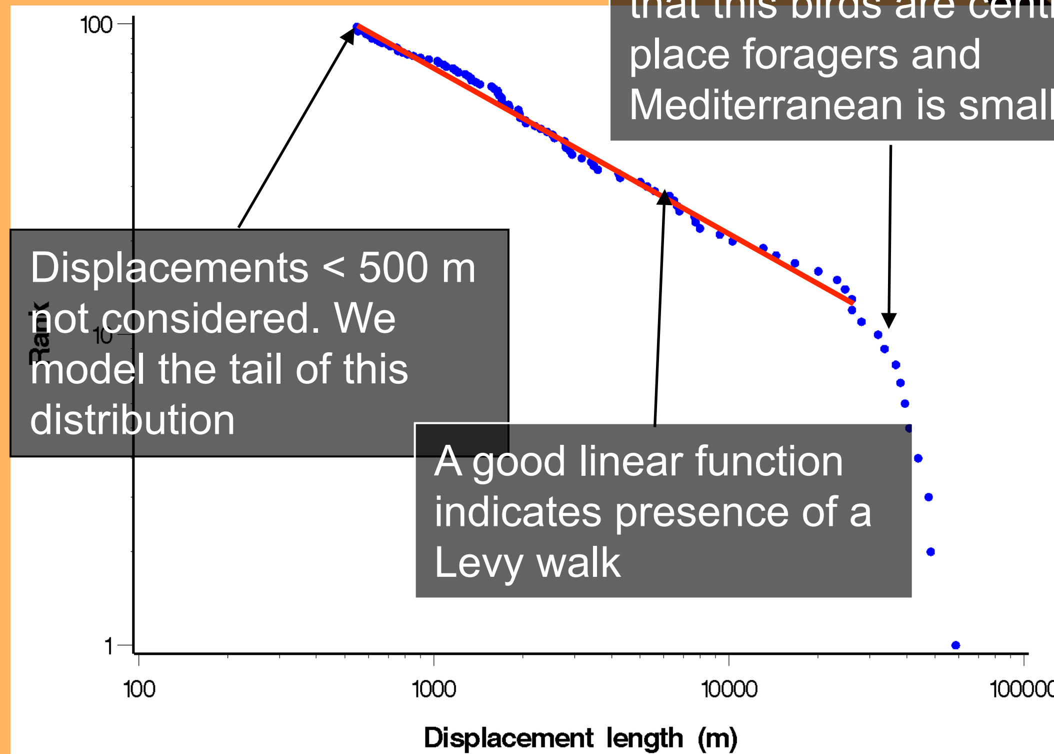


***Results**. Hypothesis 3: Which kinds of movement tactics are used by Cory's shearwaters?*



Blue lines represent the Lévy walk over imposed to the actual walk (red line)

Rank frequency (survival) plot



Maximum likelihood analysis

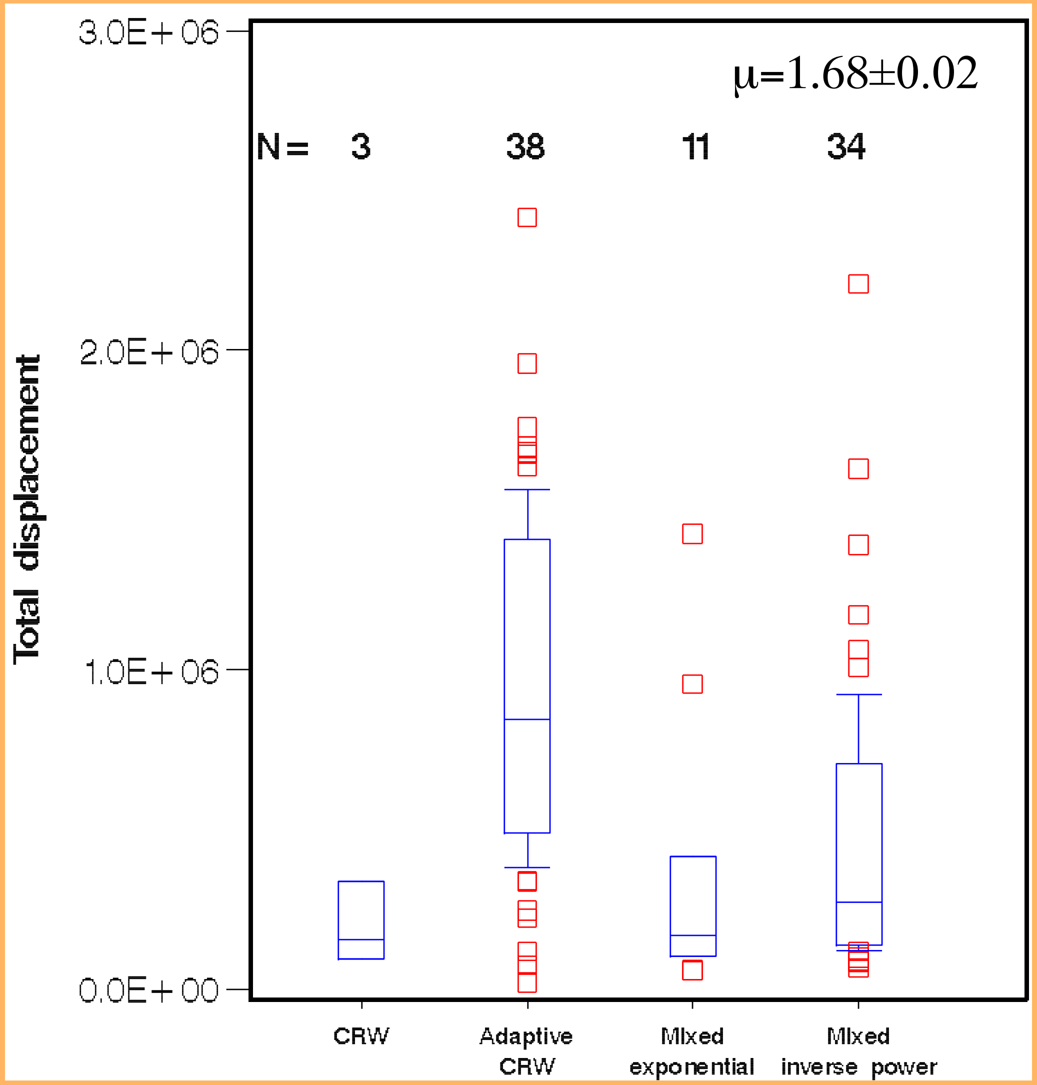
Power tail AIC=1889.5

Exponential AIC=1970.8

$\mu = 1.57 \pm 0.06$

Results. *Hypothesis 3: Which kinds of movement tactics are used by Cory's shearwaters?*

We Integrate angular and displacement analyses (from GPS sensor)



Movement tactics is correlated to excursion lenght

Both adaptive correlated random walk AND Lévy modulated CRW were observed

***Results**. Hypothesis 4: Which are the main correlates of movement tactics?*

We used generalised linear models with generalised logit link & multinomial distrbution. AIC model selection

Main model uses 3 explanatory variables:

- total excursion lenght,
- island (Linosa vs Tremiti)
- period (incubation vs chick-rearing)

	DF	χ^2	Pr
Excursion length	1	3.73	0.0534
Island	1	4.40	0.0360
Period	1	3.84	0.0500

Discussion

Discussion about search strategies has been recently very intense and previous reports of the use of Lévy walks has been disputed (Smouse et al 2010, for a review).

For angles we used Bayesian resolution of distribution mixtures which should be reliable

For displacements we used statistical methods recommended in recent literature (Benhamou 2007, Edwards 2008) such as maximum likelihood + information criteria and “survival” (rank-frequency) plots

Discussion

We performed analyses both on angles and displacements: integrating results, we recognise 4 movement tactics

We showed that foraging tactics may depend on ecological factors such as excursion length, colony and reproductive period.

In future our aim is to better understand the adaptive value of these movement tactics

1) Improving analysis of covariates

2) Verify eventual difference in foraging efficiency among the observed movement tactics

3) Use of switching- and edge- Bayesian models

Thank you for your attention!

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