

Template Model Builder (TMB) for fitting switching state-space models to animal tracks

Kim Whoriskey, Marie Auger-Méthé, Christoffer Moesgaard Albertsen, Joanna Mills Flemming, Eddie Halfyard, Harri Pettit-Wade, Aaron Fisk, Damian Lidgard, Sara Iverson, Don Bowen

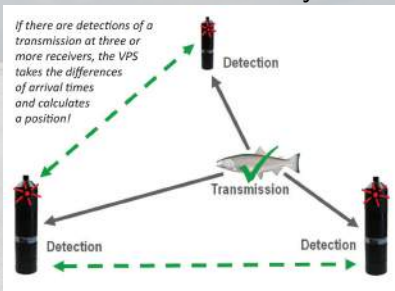


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Telemetry and State-Space Models

Acoustic Telemetry



www.vemco.com



Dave Yurkowski

Satellite Telemetry



Damian Lidgard

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Can now estimate:

- True locations
- Drift
- Behaviours
- Environmental effects
- Population effects

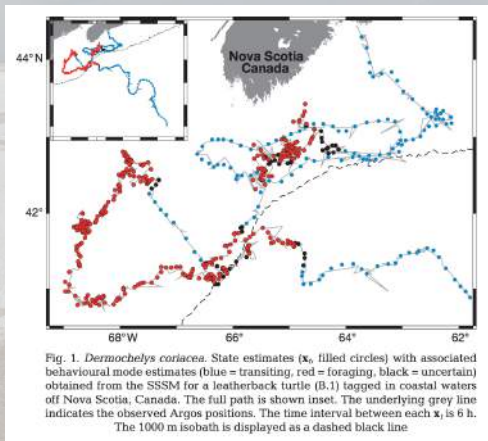


Fig. 1. *Dermochelys coriacea*. State estimates (\mathbf{x}_t , filled circles) with associated behavioural mode estimates (blue = transiting, red = foraging, black = uncertain) obtained from the SSSM for a leatherback turtle (B.1) tagged in coastal waters off Nova Scotia, Canada. The full path is shown inset. The underlying grey line indicates the observed Argos positions. The time interval between each \mathbf{x}_t is 6 h. The 1000 m isobath is displayed as a dashed black line

Jonsen et al. (2007)

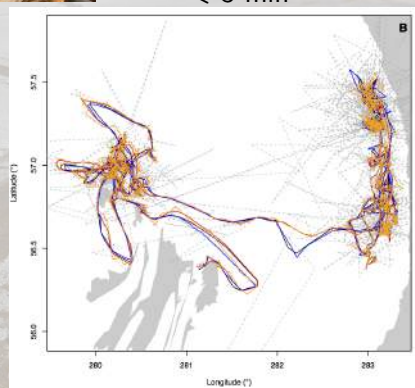
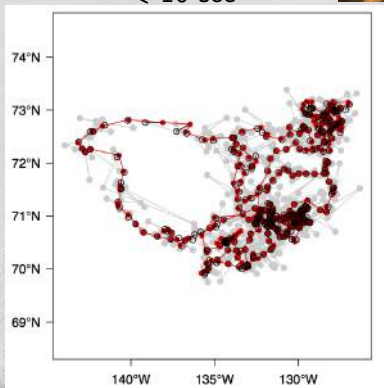
TMB and SSMs

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< 10 sec

< 3 min



Auger-Méthé et al. 2015

Albertsen et al. 2015

Discrete-Time Correlated Random Walk with Switching (DCRWS)

Ecology, 86(11), 2005, pp. 2874–2880
© 2005 by the Ecological Society of America

ROBUST STATE-SPACE MODELING OF ANIMAL MOVEMENT DATA

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Model Formulation

$$\mathbf{d}_t = \mathbf{x}_t - \mathbf{x}_{t-1} \quad \mathbf{d}_t \sim \gamma \mathbf{T} \mathbf{d}_{t-1} + N_2(0, \Sigma)$$

$$\mathbf{T}(\theta) = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \quad \Sigma = \begin{pmatrix} \sigma_{lon}^2 & \rho \sigma_{lon} \sigma_{lat} \\ \rho \sigma_{lon} \sigma_{lat} & \sigma_{lat}^2 \end{pmatrix}$$

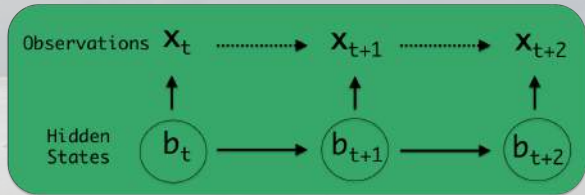
$$\mathbf{y}_{t,i} = (1 - j_i) \mathbf{x}_{t-1} + j_i \mathbf{x}_t + \epsilon_t$$

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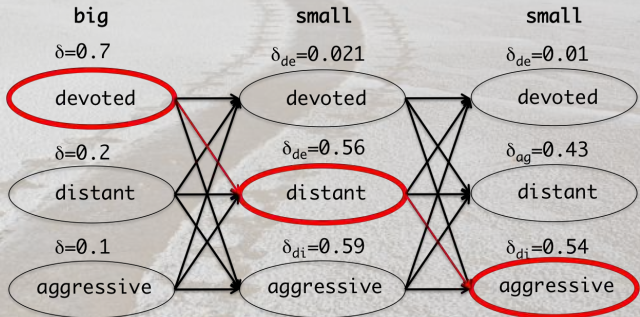
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The Hidden Markov Movement Model (The HMMM)

Hidden Markov Model



Viterbi Algorithm



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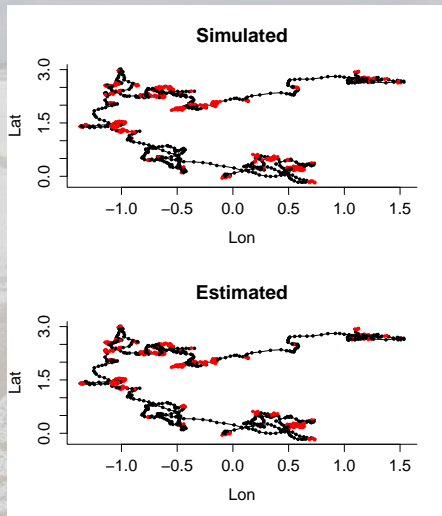
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Simulation Study

N = 100 tracks

Par	Difference: Mean \pm SD
θ_1	.021 \pm .03
θ_2	.084 \pm .10
γ_1	.019 \pm .02
γ_2	.028 \pm .04
σ_{lon}	.0004 \pm .00005
σ_{lat}	.0004 \pm .00005
ρ	.022 \pm .03
$\alpha_{1,1}$.013 \pm .02
$\alpha_{2,1}$.015 \pm .02

State Error Rate:
.14 \pm .02



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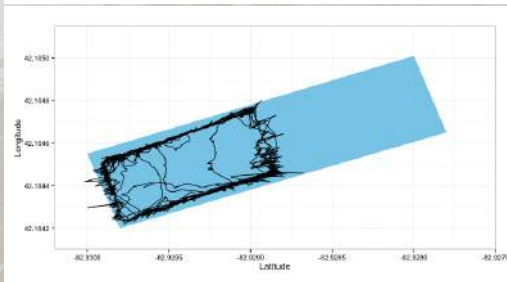
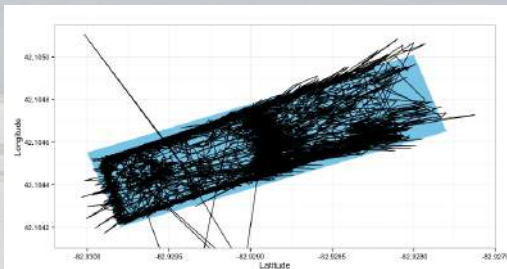
Application - Perch

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Parameter Estimates

Par	Value
θ_1	0.20
θ_2	3.11
γ_1	0.18
γ_2	0.78
σ_{lon}	0.0002
σ_{lat}	0.00008
ρ	0.26
$\alpha_{1,1}$	0.72
$\alpha_{1,2}$	0.28
$\alpha_{2,1}$	0.84
$\alpha_{2,2}$	0.16



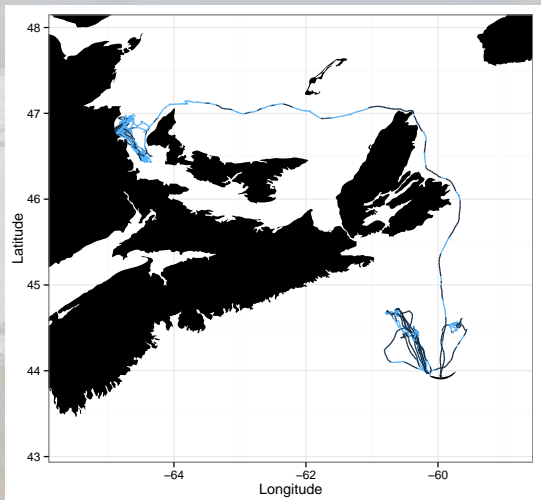
Application - Seals

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Parameter Estimates

Par	Value
θ_1	-0.004
θ_2	0.029
γ_1	0.92
γ_2	0.26
σ_{lon}	0.009
σ_{lat}	0.013
ρ	-0.07
$\alpha_{1,1}$	0.74
$\alpha_{1,2}$	0.26
$\alpha_{2,1}$	0.26
$\alpha_{2,2}$	0.88



Thankyouanyquestions?



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