Model complexity and model choice for animal movement models

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Outline

Acknowledgements

People	**Michael Li**, **Madelon van de Kerk**, Dave Onorato, Madan Oli; many unnamed field biologists
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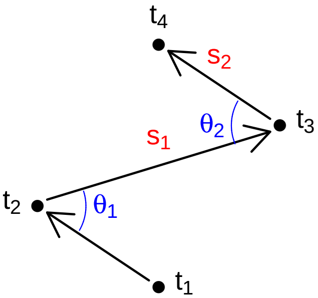
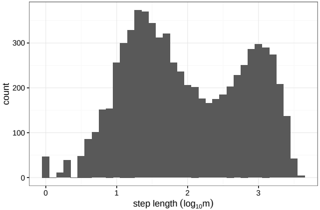
Outline

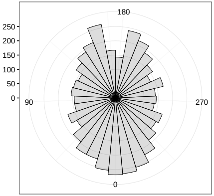
Animal movement: data

- observations:
  e.g. mass mark-recapture, longitudinal density, direct observation, telemetry (VHF, GPS)
- most methods provide a sequence of times and locations for each individual



- summaries:
  - home range (convex hull, kernel density estimate, etc.)
  - root-mean-squared displacement
  - step length and turning angle
- covariates: e.g. habitat map, individual characteristics (sex, age, weight . . .)





Animal movement: questions

- simple description
- how do animals' movements change as a function of their (internal or external) environment?
  what does that tell us about their biology?
- how might animals' distributions, etc. change when conditions (density, habitat, ...) change?

Outline

Biological/conservation issues

- Florida panther: *Puma concolor coryi*
- endangered subspecies
- severely reduced habitat
- small, isolated population
- currently recovering

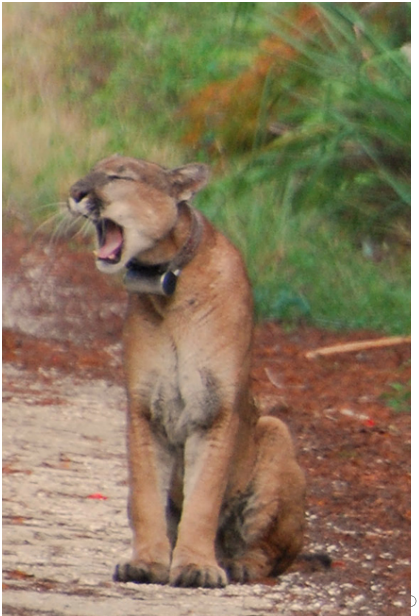
www.peer.org

Panther movement questions

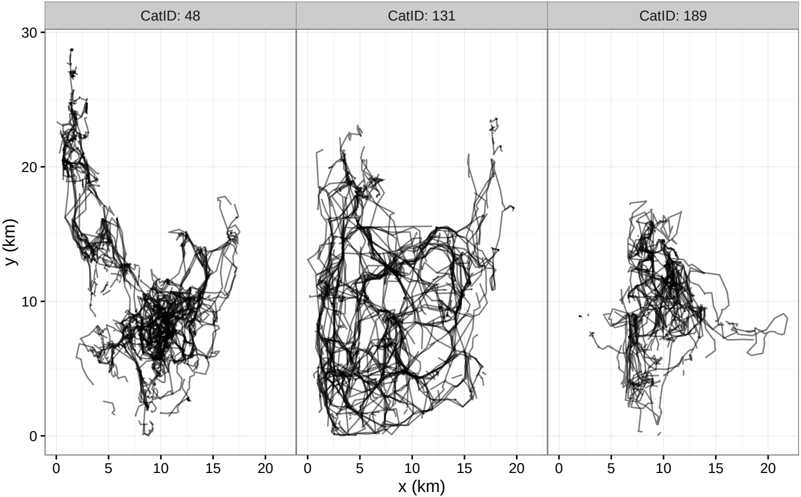
- movement variation by sex and life history stage (juvenile, adult, mom with kittens . . .)
- effects of movement on threats (intraspecific aggression, roadkill) ?
- predicting the effects of future changes in population density / population structure / habitat

Panther movement data

- panthers tracked, captured
- GPS collars
- 18 males (13 male, 5 female, 1-15 years old)
- 3200 panther days, hourly/bihourly; 49000 locations
- ?? per panther



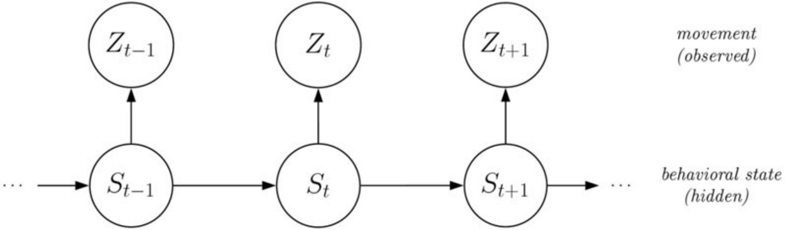
example movement tracks



Outline

Hidden Markov models

- finite mixture model with temporal dependence
- discrete time steps
- discrete latent state; *transition matrix*
- observations from *emission distributions* (continuous or discrete, univariate or multivariate)
- **multiphasic movement** (Fryxell et al., 2008; Langrock et al., 2012)



Hidden Markov models (cont.)

state:

$$S_t \sim \mathrm{Multinomial}(S_{t-1}, \mu_{S,t})$$
$$\mu_{S,t} = \mathrm{multi\text{-}logistic}(\mathbf{X}_{S,t}\boldsymbol{\beta}_S)$$

emission:

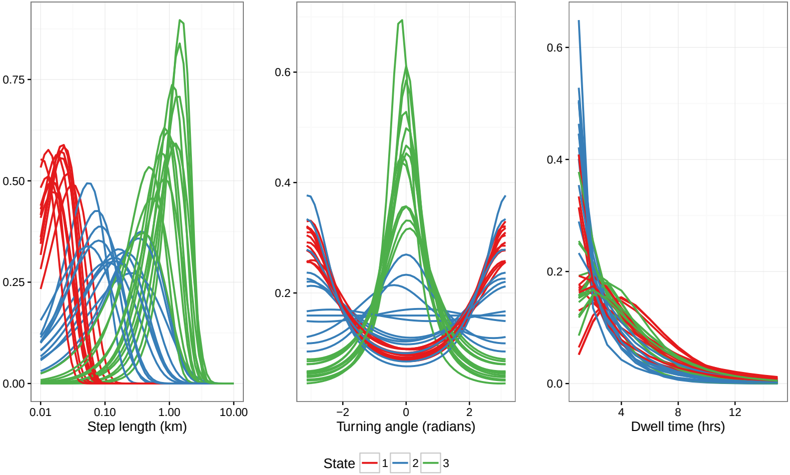
$$\mathbf{Z}_t \sim \{\mathrm{Dist}_1(\mu_{Z_1,S_t}), \ldots, \mathrm{Dist}_n(\mu_{Z_n,S_t})\}$$
$$\mu_{Z_i,S_t} = g^{-1}\left(\mathbf{X}_{Z_i,t}\boldsymbol{\beta}_{Z_i,S_t}\right)$$

Hidden Markov models (part 3)

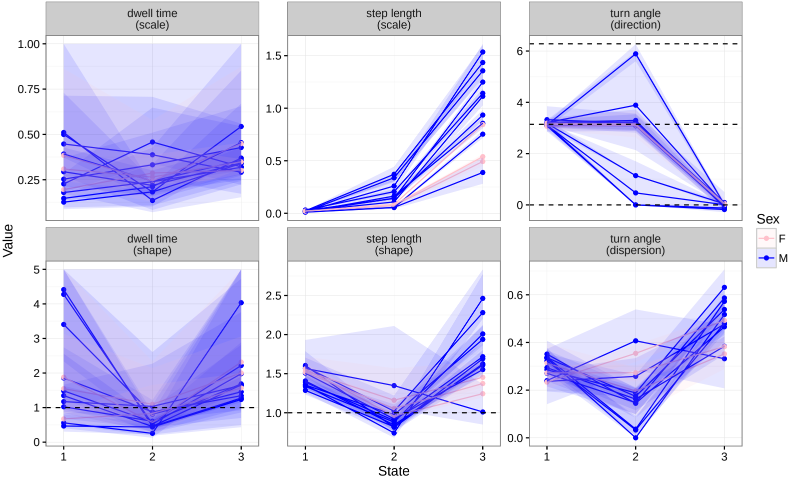
- *forward-backward algorithm* for estimating parameters
- *Viterbi algorithm* for estimating most probable state sequences
- `depmixS4` package (Visser and Speekenbrink, 2010) (also `moveHMM` (Michelot et al., 2016))
- hidden *semi-Markov* models: allow for non-geometric *dwell distributions* (Langrock, 2011; Augustine, 2016): `move.HMM`

Outline

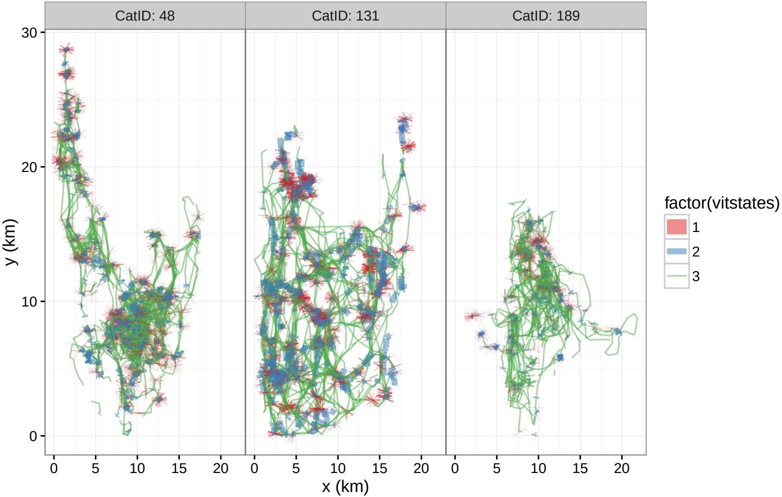
State distributions



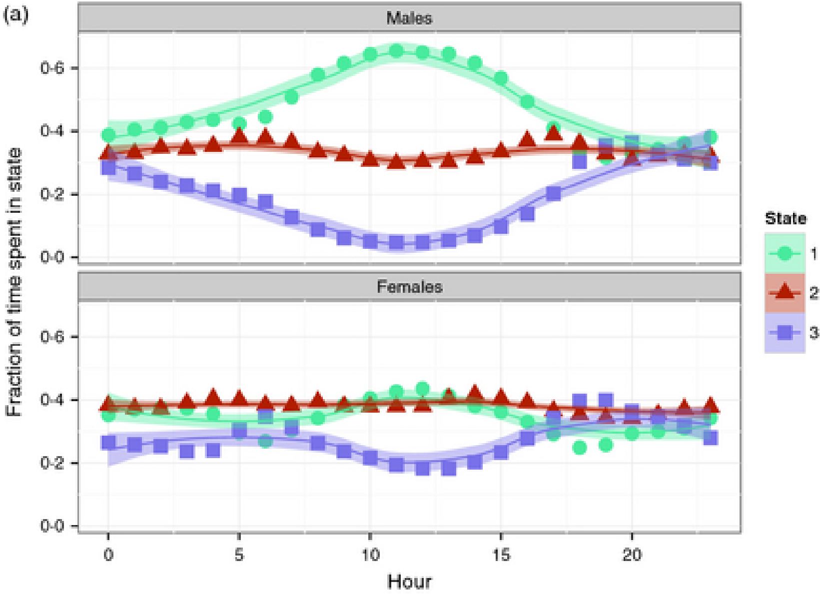
Parameter estimates



Tracks with Viterbi estimates



Diurnal variation



what can we conclude so far?

good news

- basic biology: males move faster, farther
- three states are identifiable, sensible
- dwell distributions approximately geometric (HSMM $\rightarrow$ HMM)

bad news

- diurnal variation in Viterbi results - but it's not in the model!
- estimates of model complexity are too high

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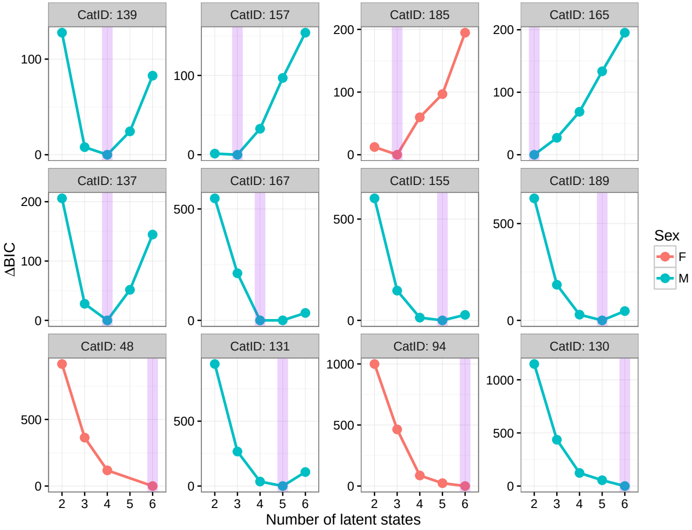
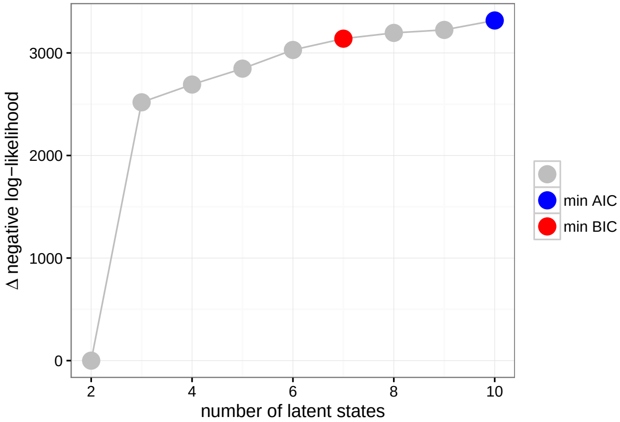
Model complexity (bad news)



Model complexity (Manx shearwaters, Dean et al. (2013))



Outline

Expanding the model

Attempting to fix these problems:

- extend the model to allow covariates
- specifically, allow for diurnal variation
  - simplify model (log-Normal step length only)
  - *fixed* state-specific emissions parameters (step length mean and std dev)
  - time-varying transition parameters
  - also try *finite mixture models* (independent occupancy)
- how much does this help?

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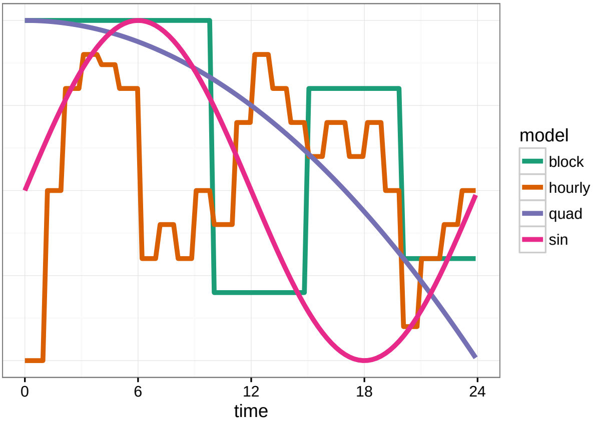
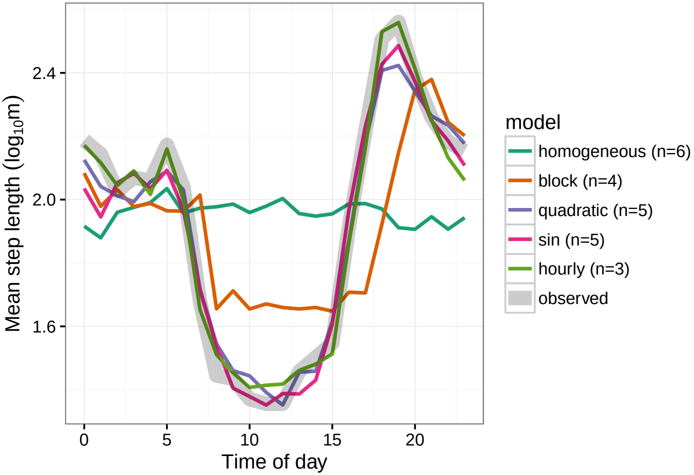
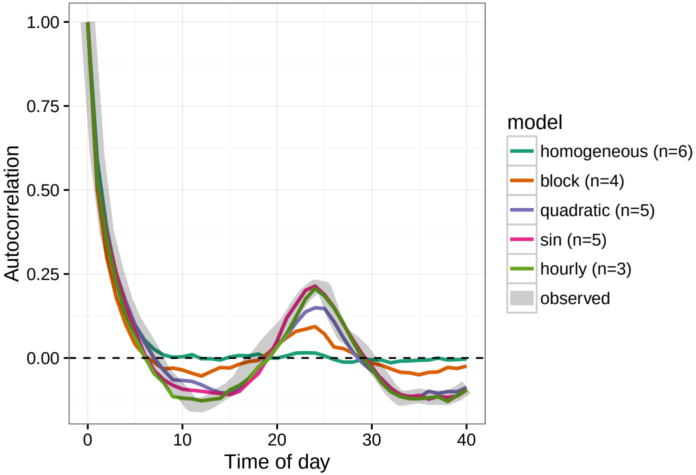
Temporal models



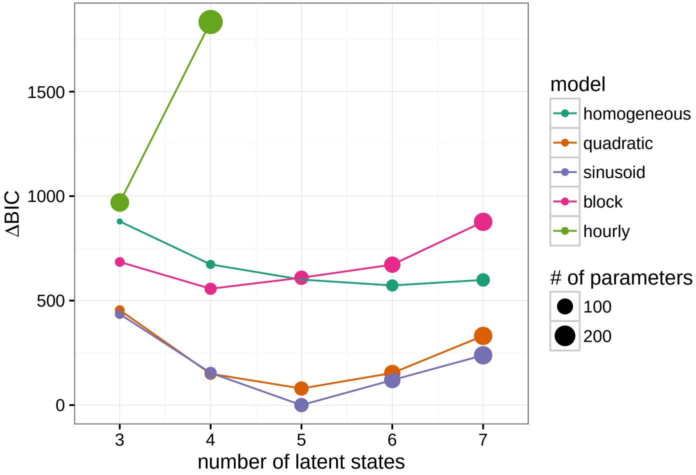
Temporal patterns (step length)



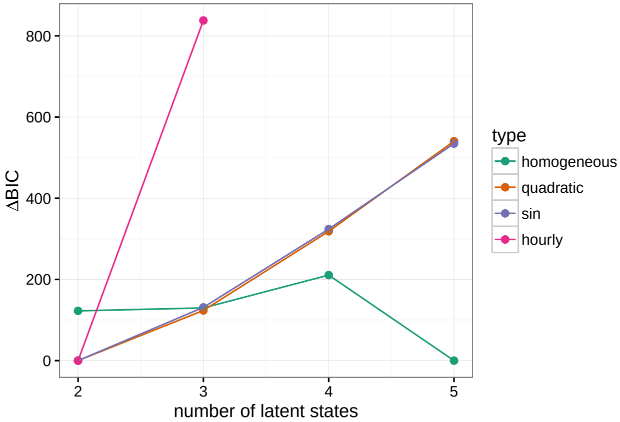
Temporal patterns (autocorrelation)



Goodness of fit/model complexity



Model complexity: simulation



Diurnal model: conclusions

- diurnal structure greatly improves fit ($\Delta\mathrm{BIC} \approx 500$)
- slightly improves latent-state issue ($n = 6 \to 5$)
- lots left to do!
  - seasonal variation
  - incorporate habitat, home range behaviour
  - etc. etc. etc.

Outline

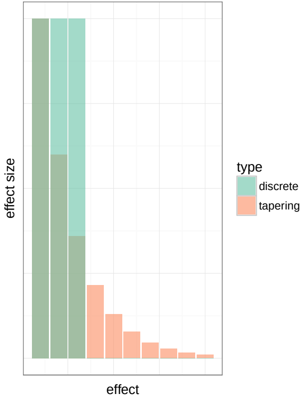
Big data and small models

- simple model families + model misspecification $\rightarrow$ overparameterization
- Gelman: "Sample sizes are never large": (blog post)

  > *N is never enough because if it were "enough" you'd already be on to the next problem for which you need more data.*

An aside on AIC vs BIC

- "should I use AIC or BIC? I heard that AIC is inconsistent ..."
- complexity penalty = 2 (AIC) vs $\log(n)$ (BIC)
- best prediction vs. model identification (Yang, 2005)
- *effect size spectrum*: tapering or discrete?



Animal movement: open challenges

- Cognition/memory (Bracis et al., 2015)
- Intraspecific interaction/collective movement (Delgado et al., 2014)
- Continuous-time movement models (Calabrese et al., 2016)
- Edges, barriers, and corridors (Beyer et al., 2016)
- Efficient (big-data) approaches (Brillinger et al., 2008)
- Putting it all together ...

Tools needed

- cross-validation (Wenger and Olden, 2012)
- protocols and tools for model checking (Potts et al., 2014); score tests?
- flexible computational frameworks (ecologists can't afford consultants/ there are too many species out there)

http://tinyurl.com/panthermoves;
http://www.slideshare.net/bbolker

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