NOAA FISHERIES

Alaska Fisheries Science Center

Learning to Crawl

Development and training of NMFS scientists in animal movement modeling

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March 1, 2018

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What is ‘crawl’?

- An add-on package for the R statistical environment that has fitting, prediction, and simulation capabilities for animal movement modeling of telemetry data
- Science centers collect telemetry data for protected species to determine habitat use
- ‘crawl’ can be used to model these data itself or provide a means to pass corrected output to other modeling methods

What is ‘crawl’? (technical details)

- Fits a continuous-time correlated random walk movement model (CTCRW)
- Can predict animal location at times when the animal is not observed (e.g., regular time intervals or ‘diving’ times).
- Can simulate paths conditioned on the observed data.
  - account for location error in other analyses

Overview (2016-17 Toolbox Project)

- **Training workshops**
  - 2 crawl workshops (AFSC and SWFSC)
  - 1 template model builder (SWFSC planned but cancelled)
- **Outreach**
  - Travel to crawl related research and receive feedback
- **Improve documentation**
  - Restructure examples
  - Online book
- **Integrate crawl with other R packages**
  - Streamline methodology for supplementing other movement analysis packages with crawl output
- **Modernize crawl**
  - Bring crawl into the tidyverse

crawl training workshops

- Targeted towards NMFS personnel
- 3-day agenda
  1. CTCRW model theory / crawl basics
  2. Telemetry data management and model fitting
  3. Bring your own data day
- 2 locations
  - AFSC (~ 20 attendees)
  - SWFSC (~ 10 attendees)
- Variety of PR species represented: turtles, sharks, monk seals, sea lions, fur seals, killer whales

Travel for outreach / development training

- **ESRI user conference** (training)
  - Integrating spatial output in formats useful for OPR offices
- **EURING 2017** and **Bio-logging 2017** (outreach)
  - Presentation of movement methodology using crawl
- **Rstudio::conf** (training)
  - Training in modern tools and methods for R programing and data management
- **ISEC 2018** (outreach)
  - Co-teaching workshop on animal movement methodology using crawl and other methods

Improve documentation

- Repository of crawl examples
  https://github.com/dsjohnson/crawl_examples
  created to allow easy access and user submissions
- Overhaul outdated crawl documentation within package
- Online book
  https://jmlondon.github.io/crawl-workshop/crawl-theory.html
  serve as a reference for future analysis

Integrating crawl output with other packages

Process imputation- using simulation to handle location uncertainty

- Want to do this analysis:
  $\boldsymbol{\mu}$ = continuous known path
  $[\boldsymbol{\mu}|\boldsymbol{\theta}]$ = movement model
- But have data
  y = locations at sparse times with error

Integrating crawl output with other packages

- Bayesian inference

$$[\boldsymbol{\theta}|\boldsymbol{y}] = \int [\boldsymbol{\mu}|\boldsymbol{\theta}][\boldsymbol{\mu}|\boldsymbol{y}]d\boldsymbol{\mu}$$

- Use crawl to draw simulations from $[\boldsymbol{\mu}|\boldsymbol{y}]$ then average desired quantities from $[\boldsymbol{\mu}|\boldsymbol{\theta}]$

Integrating crawl output with other packages

- Other movement packages using crawl imputation
  - **momentuHMM**- Hidden Markov Models for animal movement
  - **ctmcmove**- Continuous-time Makov chain models for animal movement
- Both of these packages allow spatial covariates
  - critical habitat
  - migration corridors
  - example: Wilson et al. (2018) Methods in Ecol. & Evolution

Modernizing crawl

This PDF was later amended to make the document 508 compliant.

- **Shinyapps.io** Deploy web apps quickly and easily for use. Collaborate with ERD SWFSC researchers
- **tidy crawl** Making crawl compliant with other tidyverse packages
  - tidyverse packages allow easy analysis over many individuals
  - easy to use parallel computations