Ecological Archives E086-156-A1

Ian D. Jonsen, Joanna Mills Flemming, and Ransom A. Myers. 2005. Robust state–space modeling of animal movement data. *Ecology* 86:2874–2880.

Appendix A. A figure (Fig. A1) showing likelihood surface plots and maximum-likelihood point estimates of Argos error distribution parameters and a table (Table A1) showing maximum-likelihood estimates of *t* distribution parameters fit to Argos data.

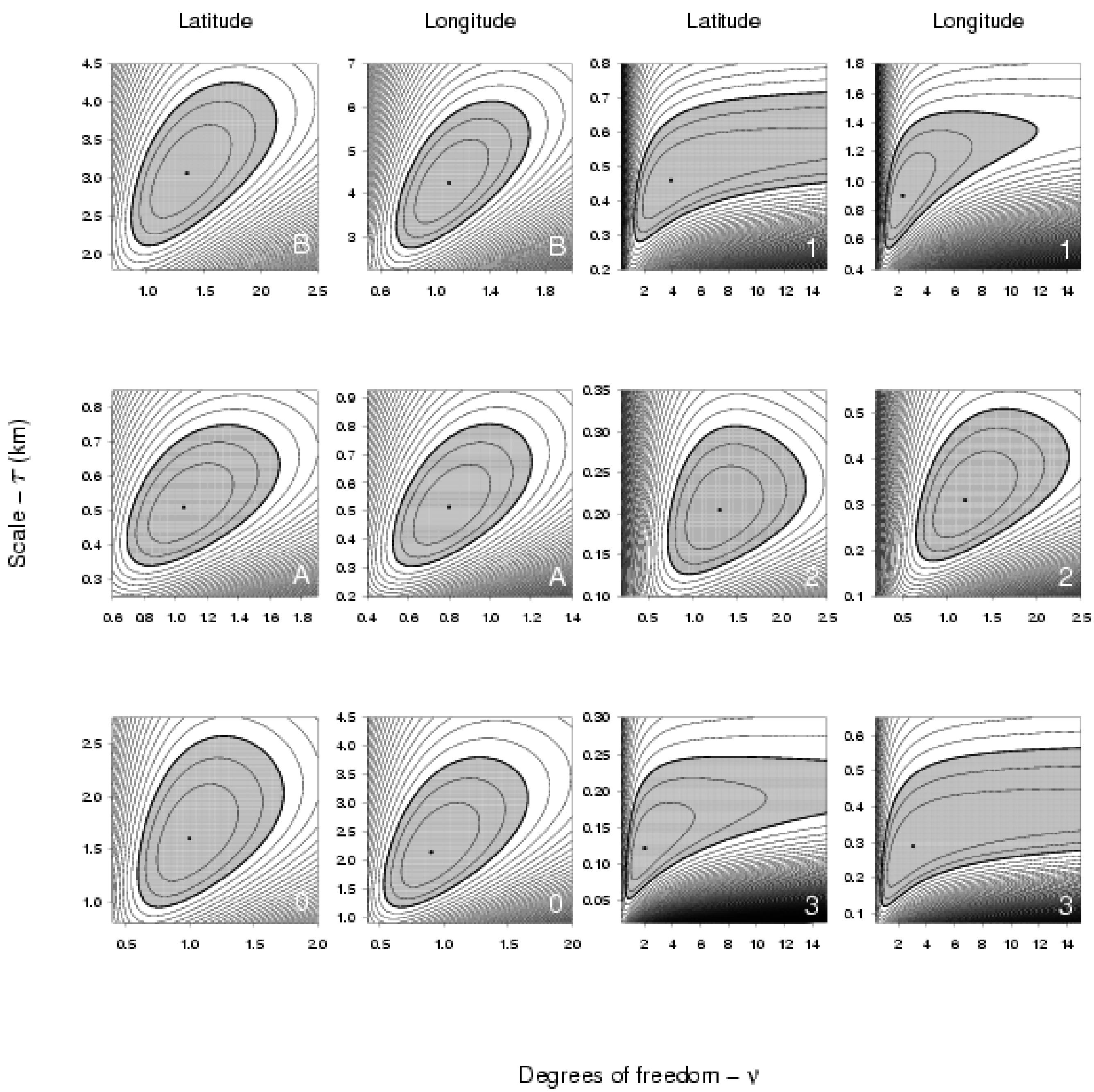

FIG. A1. Joint log-likelihood surface plots for *t*-distribution parameters, τ and ν, for longitude and latitude. Argos location quality class is indicated in the lower right corner of each panel. The 95 % confidence region on each panel is indicated by the gray-shaded region. Maximum-likelihood point estimates for τ and ν are indicated by the filled circles. The contour interval is -1 moving away from the maximum-likelihood point estimate. Note the different axis scales on the panels.

TABLE A1. Maximum-likelihood estimates and standard errors of *t*-distribution parameters fit to Argos data from (Vincent et. al. 2002). The scale parameters τ_{lon} and τ_{lat} denote longitude and latitude, respectively. Similarly, ν_{lon} and ν_{lat} are the degrees of freedom for longitude and latitude, respectively. μ_{lon} and μ_{lat} are fixed at the known location of the caged seals. Units for the τ's are in kilometers.

Quality class	Longitude		Latitude	
	τ_{lon} (SE)	ν_{lon} (SE)	τ_{lat} (SE)	ν_{lat} (SE)
B	4.205 (0.684)	1.079 (0.190)	3.041 (0.434)	1.331 (0.246)
A	0.507 (0.100)	0.787 (0.133)	0.510 (0.082)	1.058 (0.188)
0	2.163 (0.518)	0.914 (0.211)	1.607 (0.324)	1.011 (0.221)
1	0.902 (0.181)	2.299 (0.941)	0.460 (0.092)	3.896 (2.607)
2	0.312 (0.067)	1.221 (0.321)	0.260 (0.037)	6.315 (4.145)
3	0.290 (0.098)	3.071 (2.795)	0.122 (0.037)	2.076 (1.167)

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Appendix B. Data regularization procedure and comparison of movement parameters derived from the regularized hooded seal data and those derived from state estimates from the DCRW model fit to the hooded seal data.

A useful feature of the state estimates obtained from our analyses is that they can be used to derive fundamental descriptors of movement behavior such as turning angles and movement rates. In order to evaluate our approach in this regard we compare turning angles and rates of movement derived from state estimates (obtained via the DCRW model) to those obtained using the data directly. Note that for the latter approach, one must first regularize the data to obtain locations at regular time intervals since behavioral parameters are only meaningful when derived either from a series of known start and end locations (we can not observe these with remote sensed data) or from a series of locations at regular time intervals (Turchin 1998).

Here we describe the data regularization procedure. Suppose we have a series of observed locations, $y_{t,i}$, sampled irregularly through time, where *t* represents the regular time interval and *i* indexes the observations within each interval $i = 1, \ldots, n_t$. By calculating a weighted average of the locations observed within an interval, we obtain an estimate of location for each time interval. This collection of estimates is then regularly spaced in time.

To obtain the regularized data presented in Fig. B1, we maximize the following likelihood for regular time intervals

$$P(y_i|\mu, \tau, \nu) = \prod_i^{n_t} t([y_i - \mu], \tau_i, \nu_i)$$

where $y_i - \mu$ is the average location, τ_i and ν_i are the scale and df estimates, respectively, associated with the quality class for each y_i. We fix τ_i and ν_i at the values presented in Appendix A (Table A1), leaving $y_i - \mu$ to be estimated.

Prior to conducting this regularization of the data, we removed the three extreme locations indicated in Fig. 1A. We fit wrapped Cauchy and Weibull distributions (e.g., Morales et al. 2004) to the turning angles and movement rates, respectively.

The distributions of turning angles calculated from the regularized data and from the state estimates differ little from one another, although the state estimates suggest a slightly broader distribution with more course reversals and a mean turning angle that favours turns to the left (Fig. B1). The movement rate distributions differ more substantially; the state estimates yield a larger mode and narrower distribution overall (Fig. B1). We have more confidence in the movement parameters derived from the state estimates because the uncertainty in the observations has been dealt with in a more complete manner, ie. both estimation error and process variability are accounted for, whereas the regularization procedure accounts only for estimation error.

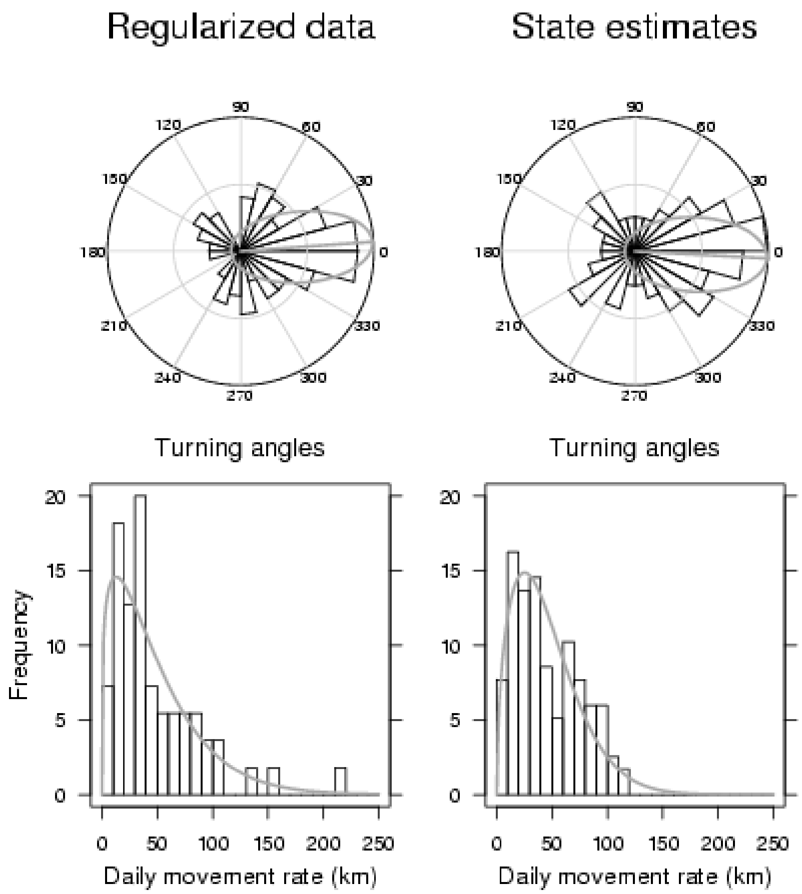

FIG. B1. Comparision of turning angle and movement rate distributions derived from regularized data and from state estimates. Turning angle distributions are displayed as circular histograms with wrapped Cauchy density estimates displayed as gray elipsiods. Mean turning angles are displayed as gray lines. Weibull density estimates are overlaid on the movement rate histograms (gray curves).

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