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SUPPLEMENTARY MATERIAL

The role of the bandwidth matrix in influencing kernel home range estimates for snakes using VHF telemetry data

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Table S1. Beta estimates, standard errors (s.e.), and *P* values for fixed effects in the linear mixed-effects model for eastern indigo snake annual and seasonal home range size at the 80% volume contour

Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full). The reference levels were the single-parameter REF and females and the response variable (home range size) was log-transformed

	Annual home range			Seasonal home range		
	Beta	s.e.	*P* value	Beta	s.e.	*P* value
(Intercept)	3.5704	0.1650	0.0000	3.5958	0.1628	0.0000
REF-uc	–0.1348	0.0371	0.0004	–0.2226	0.0533	0.0000
LCV-s	–0.5449	0.0653	0.0000	–0.6925	0.0676	0.0000
LCV-f	–0.5298	0.0638	0.0000	–0.6801	0.0645	0.0000
PI-uc	–0.3741	0.0318	0.0000	–0.4977	0.0463	0.0000
SCV-uc	–0.2553	0.0325	0.0000	–0.3549	0.0466	0.0000
Number of fixes	0.0015	0.0036	0.6749	0.0079	0.0064	0.2214
Sex (males)	1.4956	0.2444	0.0000	1.2853	0.2215	0.0000
REF-uc × fixes	0.0000	0.0009	0.9748	0.0002	0.0030	0.9496
LCV-s × fixes	–0.0069	0.0016	0.0000	–0.0155	0.0037	0.0000
LCV-f × fixes	–0.0067	0.0016	0.0000	–0.0153	0.0036	0.0000
PI-uc × fixes	–0.0019	0.0008	0.0152	–0.0036	0.0026	0.1655
SCV-uc × fixes	–0.0026	0.0008	0.0014	–0.0051	0.0026	0.0513

Table S2. Beta estimates, standard errors (s.e.), and *P* values for fixed effects in the linear mixed-effects model for rattlesnake home range size at the 80% volume contour. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full). The reference level was the single-parameter REF and the response variable (home range size) was log-transformed.

	Beta	s.e.	*P* value
(Intercept)	4.7061	0.2861	0.0000
REF-uc	–0.4735	0.1050	0.0000
LCV-s	–1.3246	0.1873	0.0000
LCV-f	–1.1412	0.2331	0.0000
DPI-uc	–1.0117	0.0973	0.0000
SCV-uc	–0.8375	0.0967	0.0000
Number of fixes	–0.0605	0.0394	0.1529
REF-uc × fixes	0.0457	0.0145	0.0026
LCV-s × fixes	0.0054	0.0258	0.8366
LCV-f × fixes	–0.0357	0.0322	0.2722
DPI-uc × fixes	0.0356	0.0134	0.0105
SCV-uc × fixes	0.0375	0.0133	0.0068

Table S3. Mean proportion of points not included by the home range volume contour(s) with range in parentheses

Volume contour values are in the column "Vol. Cont." Results for the 95% and 99% volume contours are reported in the text. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full)

Data set	*N*	Vol. Cont.	REF-s	REF-uc	LCV-s	LCV-f	PI-uc	SCV-uc
Highlands annual	8	80%	0.07 (0.03–0.12)	0.08 (0.03–0.12)	0.04 (0.00–0.10)	0.05 (0.00–0.10)	0.06 (0.03–0.09)	0.07 (0.03–0.11)
Highlands annual	8	90%	0.02 (0.00–0.04)	0.02 (0–0.04)	0.01 (0–0.04)	0.01 (0.00–0.04)	0.02 (0.01–0.03)	0.03 (0.01–0.04)
Highlands annual	8	95%	0.00 (0.00–0.02)	0.01 (0.00–0.02)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.01)
Highlands annual	8	99%	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
Brevard annual	21	80%	0.05 (0.00–0.11)	0.06 (0–0.11)	0.02 (0.00–0.09)	0.02 (0.00–0.09)	0.05 (0.01–0.11)	0.05 (0.01–0.11)
Brevard annual	21	90%	0.01 (0.00–0.04)	0.01 (0–0.03)	0.00 (0.00–0.03)	0.01 (0.00–0.06)	0.01 (0.00–0.04)	0.01 (0.00–0.03)
Brevard annual	21	95%	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
Brevard annual	21	99%	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
Highlands seasonal	33	80%	0.05 (0.00–0.16)	0.06 (0.00–0.10)	0.04 (0.00–0.10)	0.04 (0.00–0.10)	0.05 (0.00–0.10)	0.06 (0.02–0.10)
Highlands seasonal	33	90%	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.00 (0.00–0.03)	0.01 (0.00–0.03)	0.00 (0.00–0.02)	0.01 (0.00–0.03)
Highlands seasonal	33	95%	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
Highlands seasonal	33	99%	0.00	0.00	0.00	0.00	0.00	0.00

			(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)
			0.02	0.04	0.02	0.03	0.03	0.03
Brevard seasonal	35	80%	(0.00–0.09)	(0.00–0.12)	(0.00–0.09)	(0.00–0.09)	(0.00–0.12)	(0.00–0.11)
			0.00	0.00	0.00	0.00	0.00	0.00
Brevard seasonal	35	90%	(0.00–0.03)	(0.00–0.03)	(0.00–0.00)	(0.00–0.03)	(0.00–0.00)	(0.00–0.03)
			0.00	0.00	0.00	0.00	0.00	0.00
Brevard seasonal	35	95%	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)
			0.00	0.00	0.00	0.00	0.00	0.00
Brevard seasonal	35	99%	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)
			0.03	0.04	0.03	0.04	0.04	0.03
Rattlesnake	17	80%	(0.00–0.10)	(0.00–0.10)	(0.00–0.10)	(0.00–0.28)	(0.00–0.10)	(0.00–0.10)
			0.01	0.01	0.00	0.02	0.00	0.00
Rattlesnake	17	90%	(0.00–0.03)	(0.00–0.03)	(0.00–0.00)	(0.00–0.28)	(0.00–0.00)	(0.00–0.00)
			0.00	0.00	0.00	0.02	0.00	0.00
Rattlesnake	17	95%	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.28)	(0.00–0.00)	(0.00–0.00)
			0.00	0.00	0.00	0.02	0.00	0.00
Rattlesnake	17	99%	(0.00–0.00)	(0.00–0.00)	(0.00–0.00)	(0.00–0.28)	(0.00–0.00)	(0.00–0.00)

Fig. S1. Relative bias (mean and 95th quantile) of eastern indigo snake annual (Highlands 12 month) home range size (80% volume contour) by estimator at 3, 6, 9, and 12 month sampling durations with 1, 2, 3, 4, or all fixes per month. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

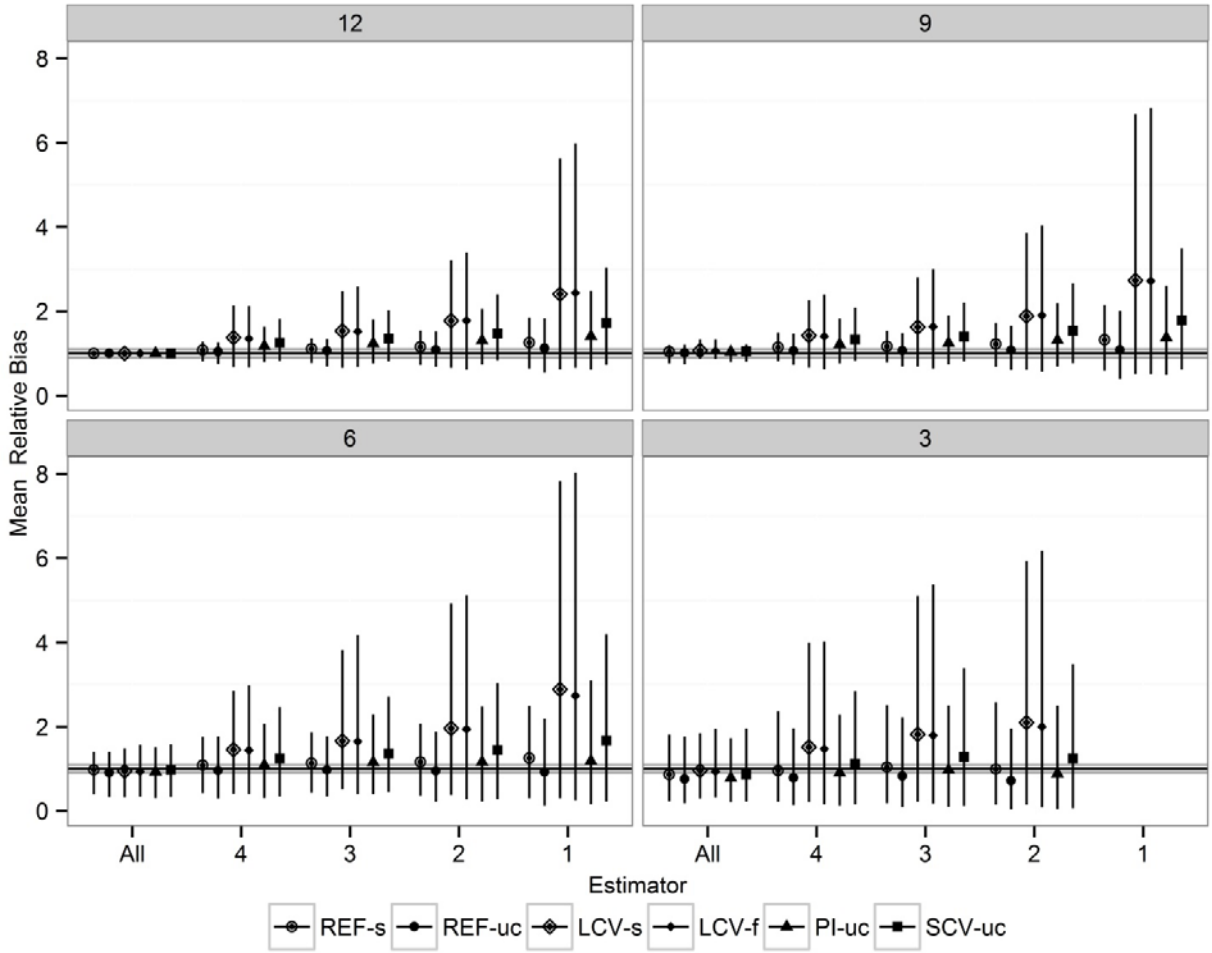

Fig. S2. Volume of intersection (mean and 95th quantile) of eastern indigo snake annual (Highlands 12 month) home ranges (80% volume contour) by estimator at 3, 6, 9, and 12 month sampling durations with 1, 2, 3, 4, or all fixes per month. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

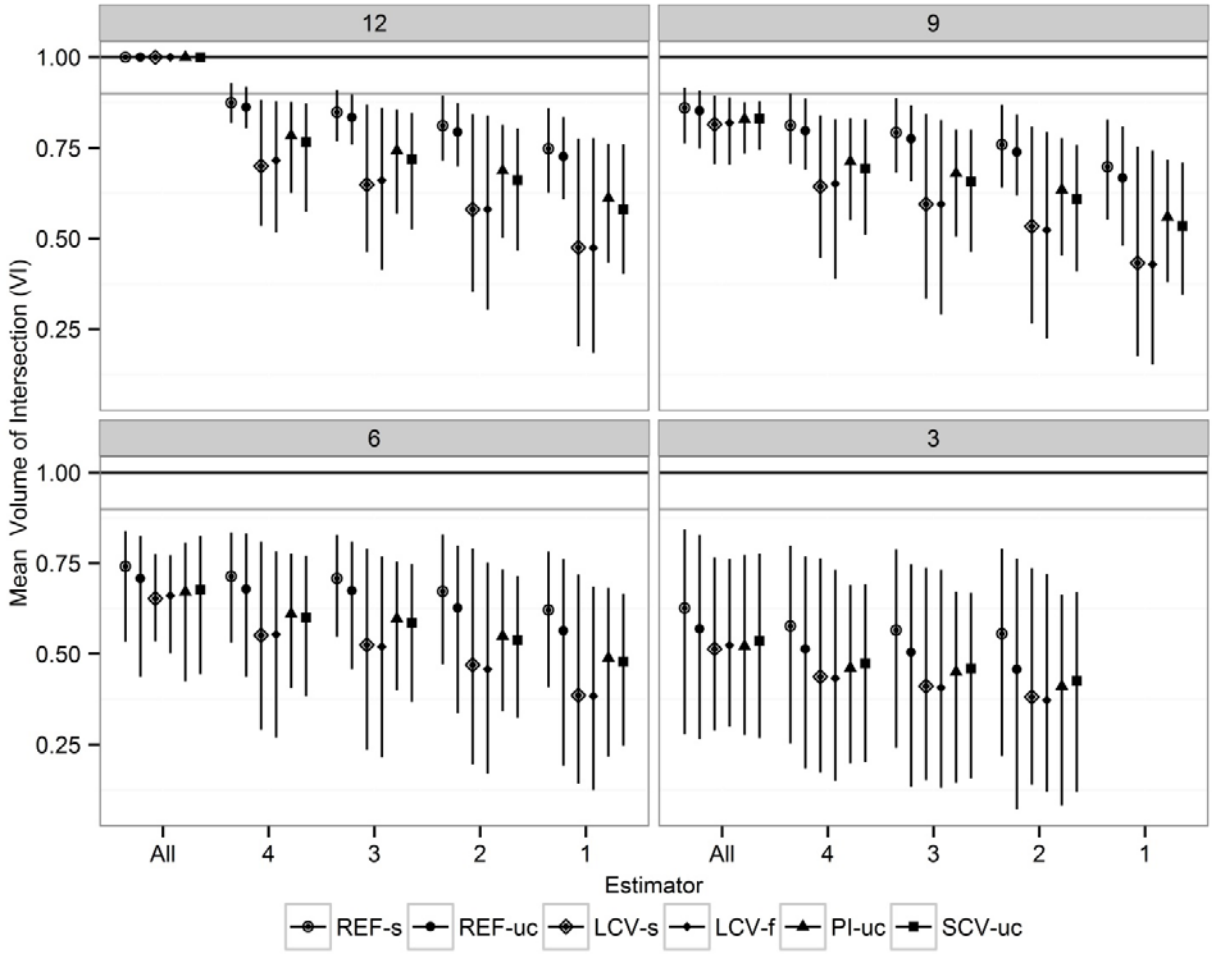

Fig. S3. Relative bias (mean and 95th quantile) of eastern indigo snake annual (Highlands 11 month) home range size (95% volume contour) by estimator at 3, 6, 9, and 11 month sampling durations with 1, 2, 3, 4, or all fixes per month. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

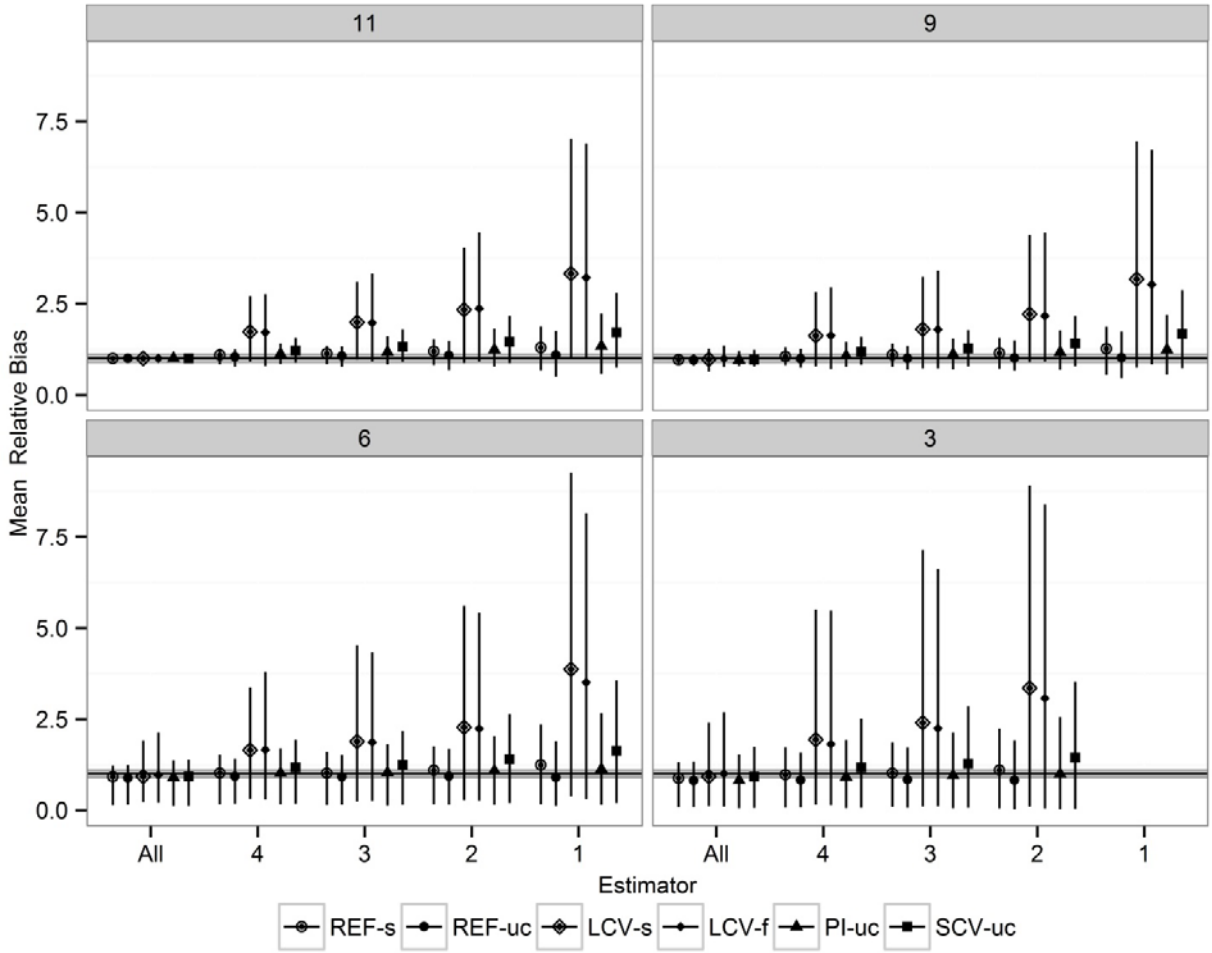

Fig. S4. Volume of intersection (mean and 95th quantile) of eastern indigo snake annual (Highlands 11 month) home ranges (95% volume contour) by estimator at 3, 6, 9, and 11 month sampling durations with 1, 2, 3, 4, or all fixes per month. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

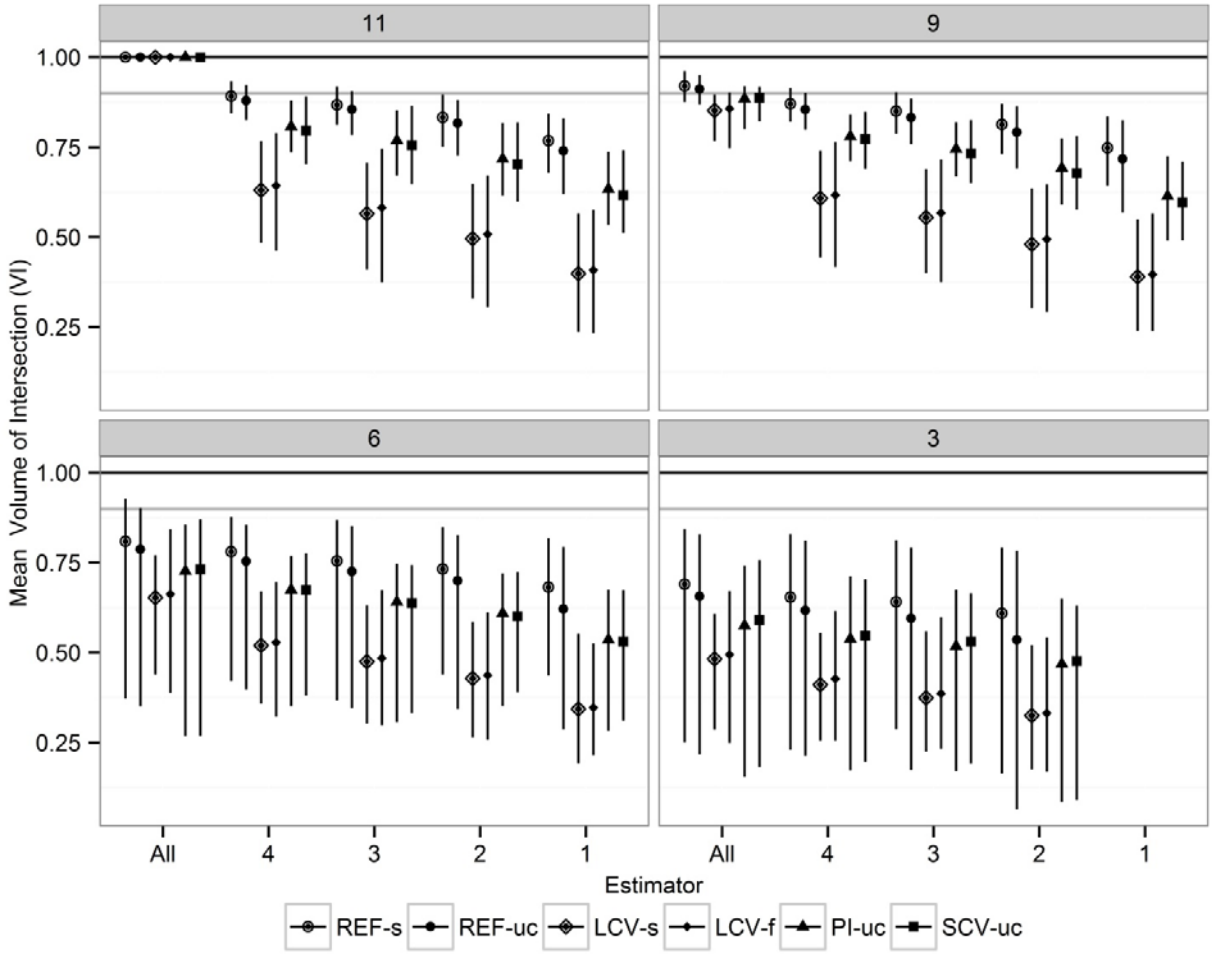

Fig. S5. Relative bias (mean and 95th quantile) of eastern indigo snake annual (Brevard) home range size (95% volume contour) by estimator at 3, 6, 9, and 12 month sampling durations with all fixes per month. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

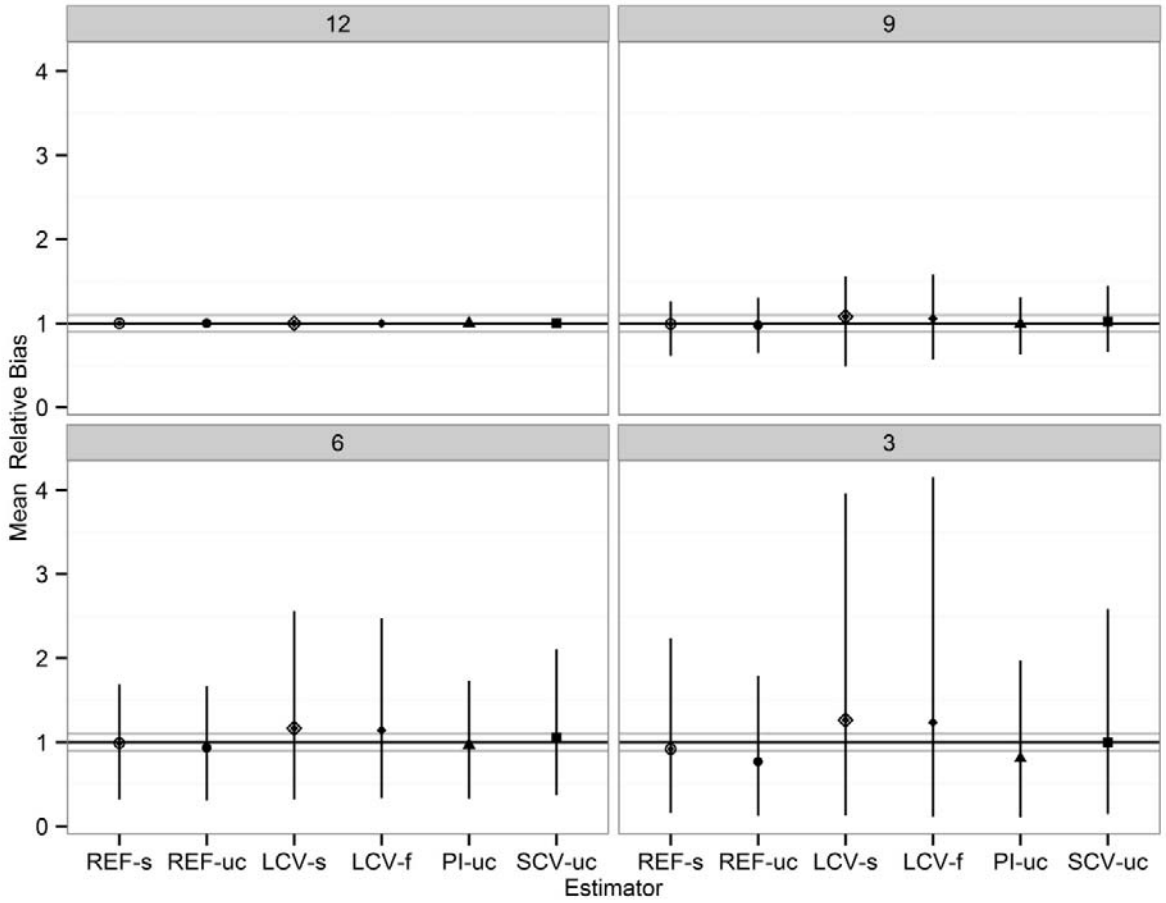

Fig. S6. Volume of intersection (mean and 95th quantile) of eastern indigo snake annual (Brevard) home ranges (95% volume contour) by estimator at 3, 6, 9, and 12 month sampling durations with all fixes per month. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

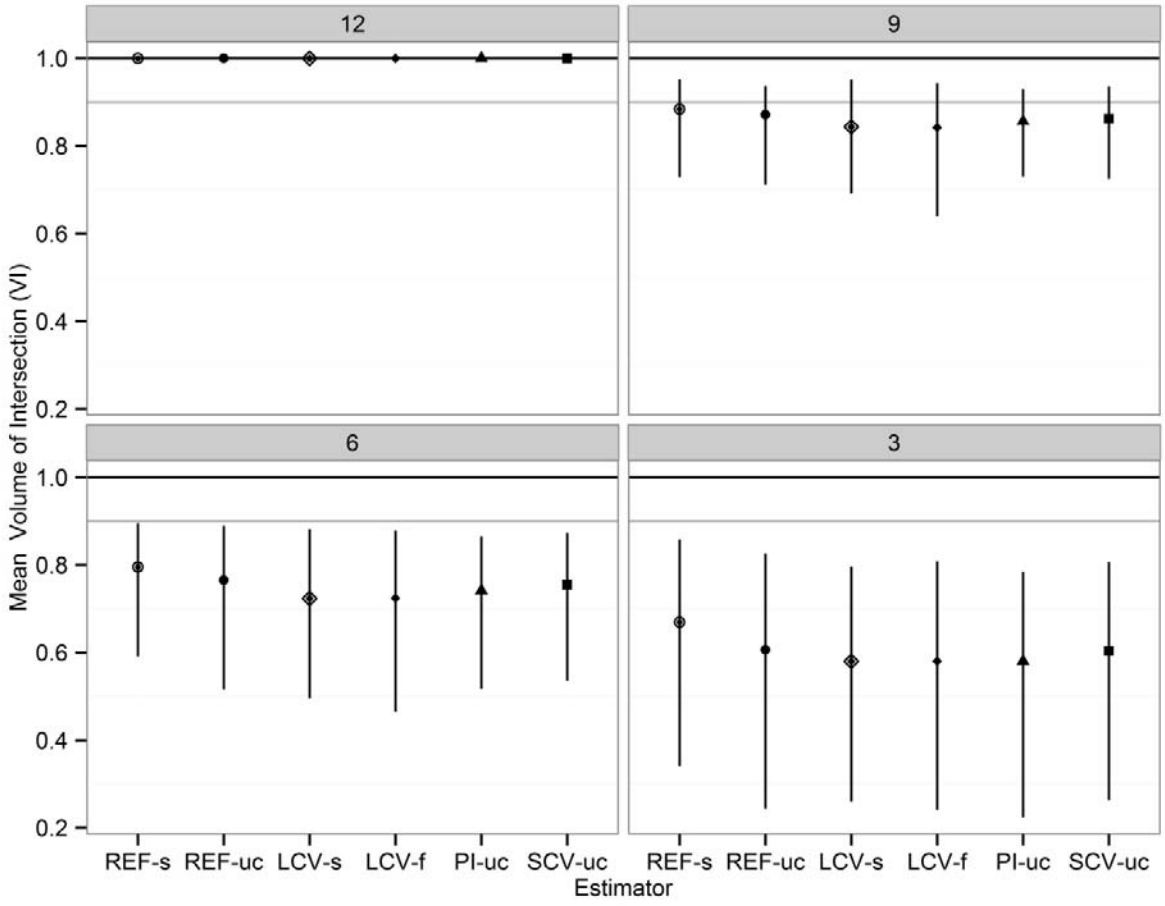

Fig. S7. Relative bias (mean and 95th quantile) of eastern indigo snake seasonal (Highlands) home range size (95% volume contour) by estimator at 3, 4, 5, and 6 month sampling durations with 1, 2, 3, 4, and all fixes per month. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full). Points without error bars have 95th quantiles that exceeded the scale of the y-axis.

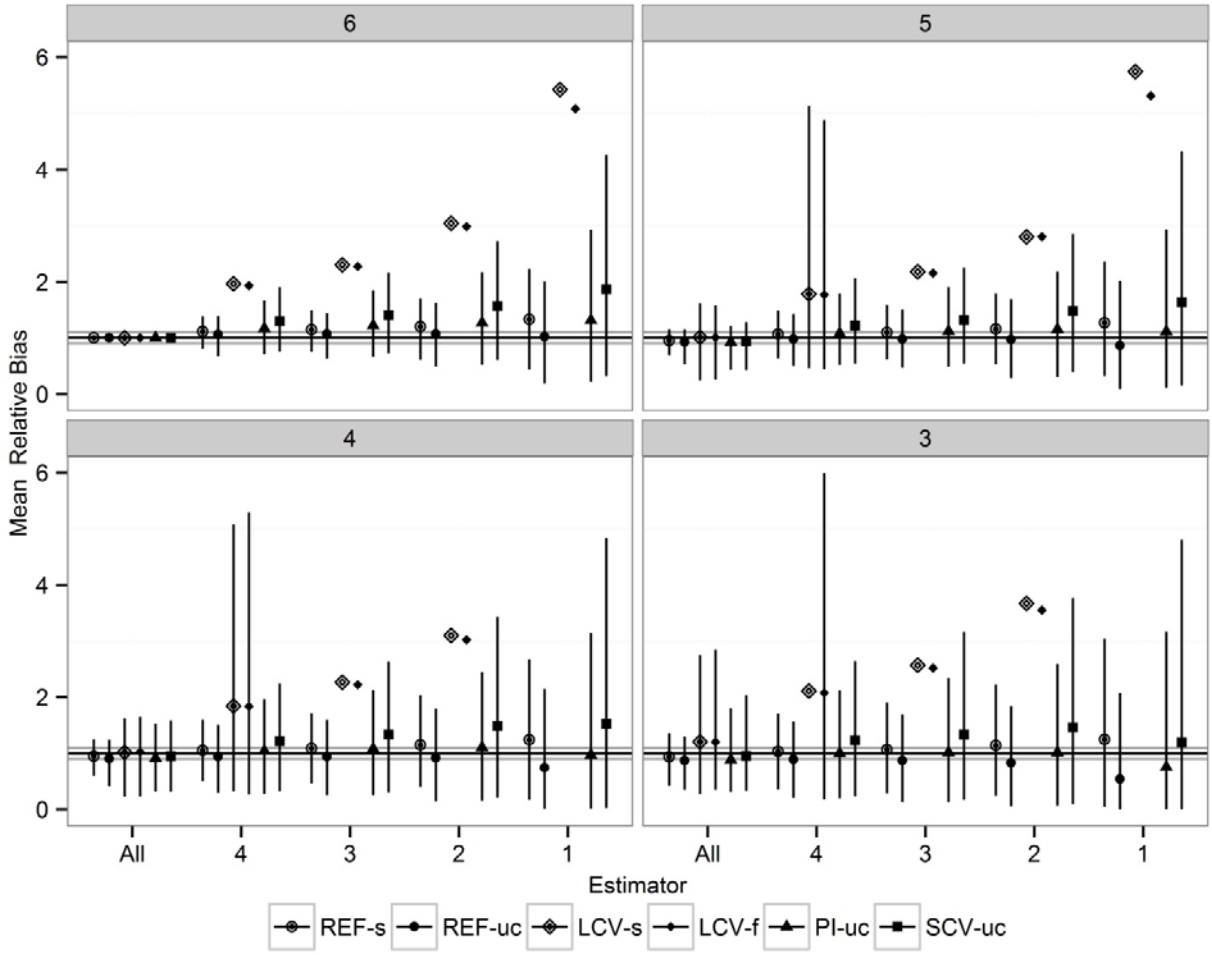

Fig. S8. Volume of intersection (mean and 95th quantile) of eastern indigo snake seasonal (Highlands) home ranges (95% volume contour) by estimator at 3, 4, 5, and 6 month sampling durations with 1, 2, 3, 4, or all fixes per month. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

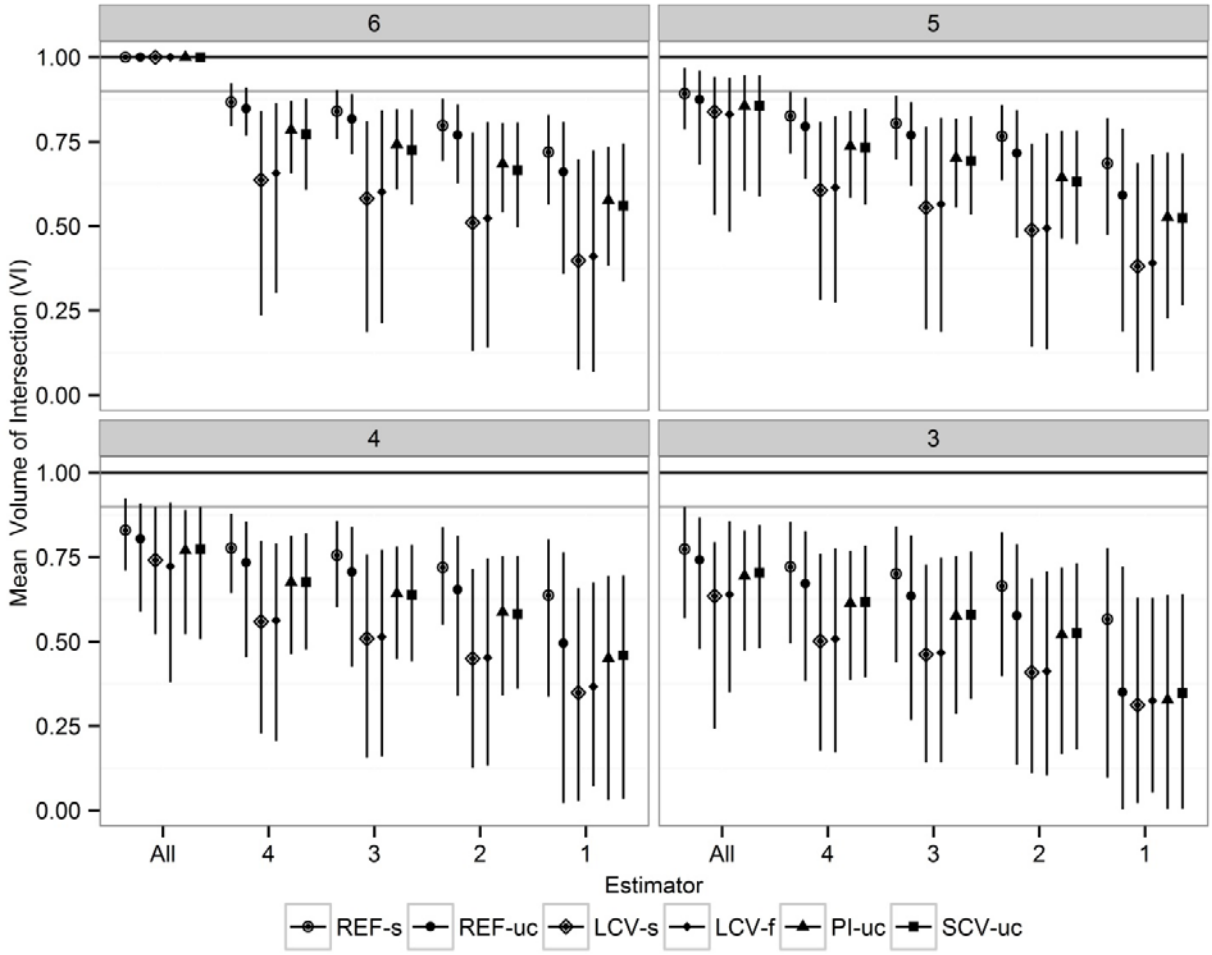

Fig. S9. Relative bias (mean and 95th quantile) of eastern indigo snake seasonal (Brevard) home range size (95% volume contour) by estimator at 3, 4, 5, and 6 month sampling durations with all fixes per month. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

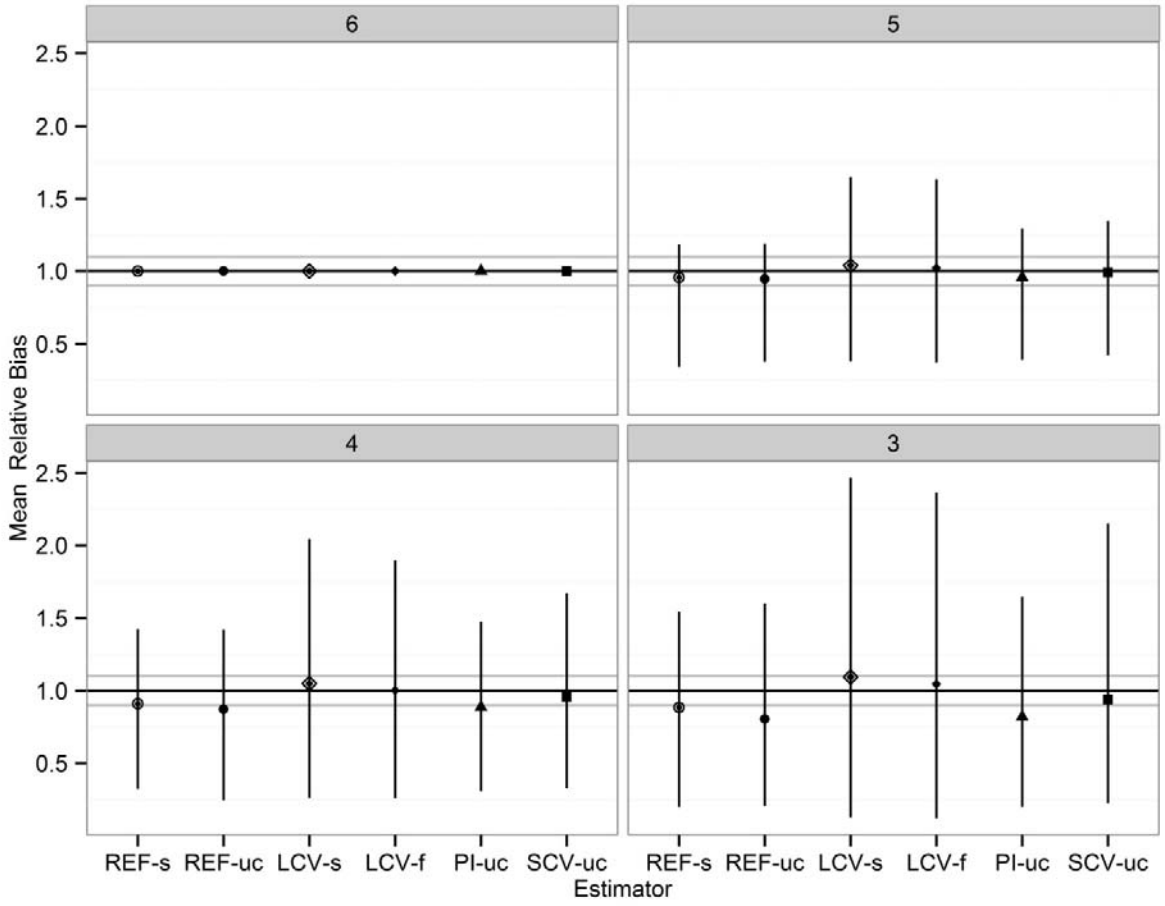

Fig. S10. Volume of intersection (mean and 95th quantile) of eastern indigo snake seasonal (Brevard) home ranges (95% volume contour) by estimator at 3, 4, 5, and 6 month sampling durations with all fixes per month. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

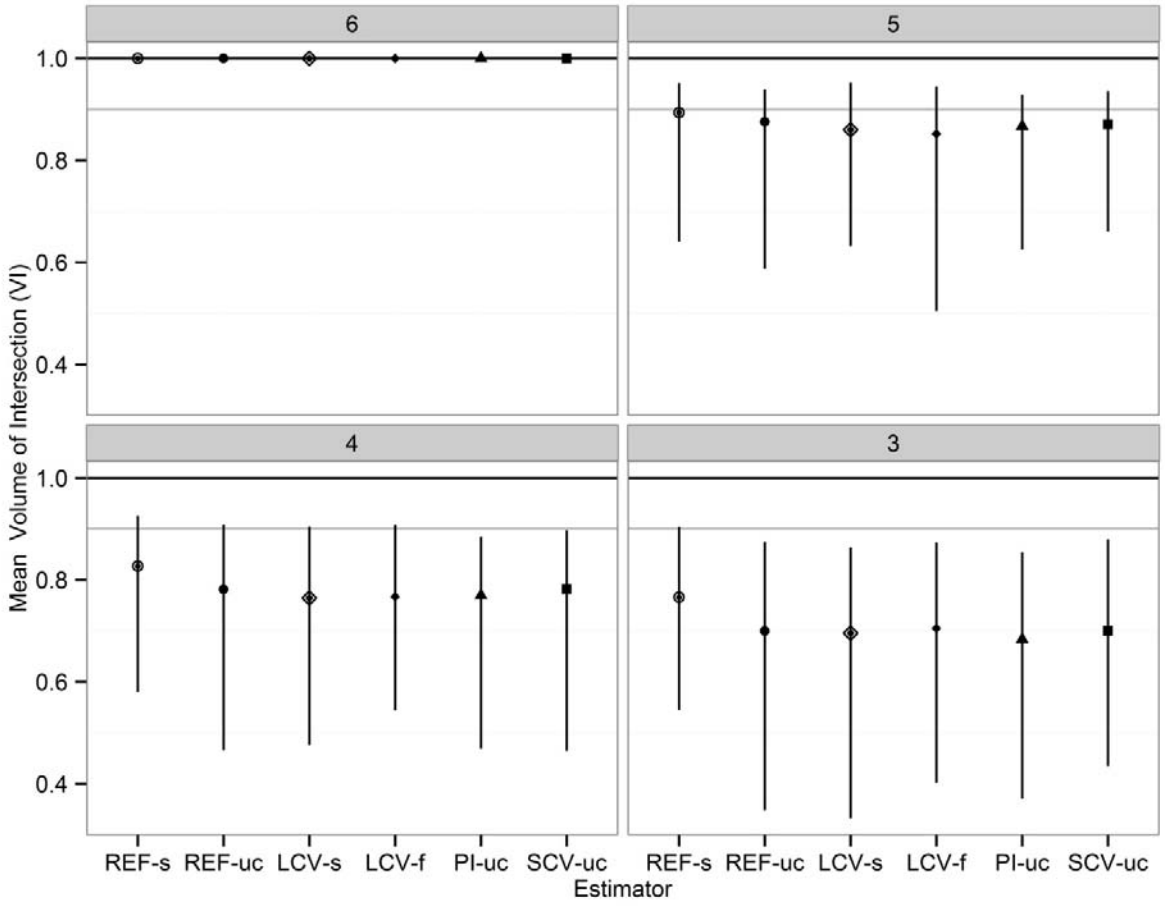

Fig. S11. Relative bias (mean and 95th quantile) of western rattlesnake seasonal (2 month) home range size (80% volume contour) by estimator at 0.5, 1.0, 1.5, and 2.0 month sampling durations with 1, 2, 3, 4, or all fixes per block. A value of one indicates no bias and the dark line indicates one while the gray lines indicate 0.90 and 1.10. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full). Mean relative bias for all LCV estimators was >7 for 1.5 and 2.0 month sampling durations with 1 fix per month. Points without error bars have 95th quantiles that exceeded the scale of the y-axis.

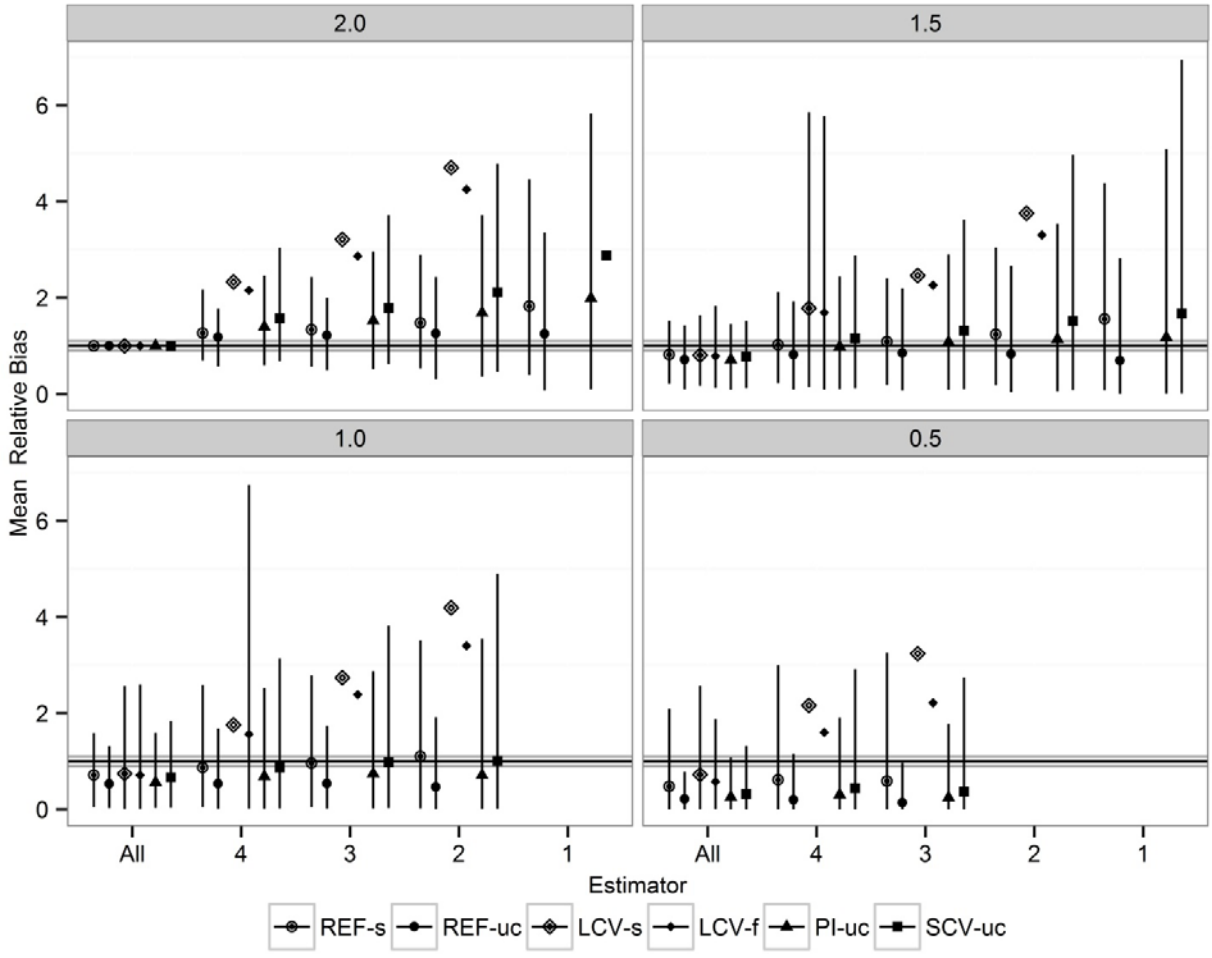

Fig. S12. Volume of intersection (mean and 95th quantile) of western rattlesnake seasonal (2 month) home ranges (80% volume contour) by estimator at 0.5, 1.0, 1.5, and 2.0 month sampling durations sampling durations with 1, 2, 3, 4, or all fixes per block. A value of one indicates identical utilization distributions and the dark line indicates one while the gray line indicates 0.90. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

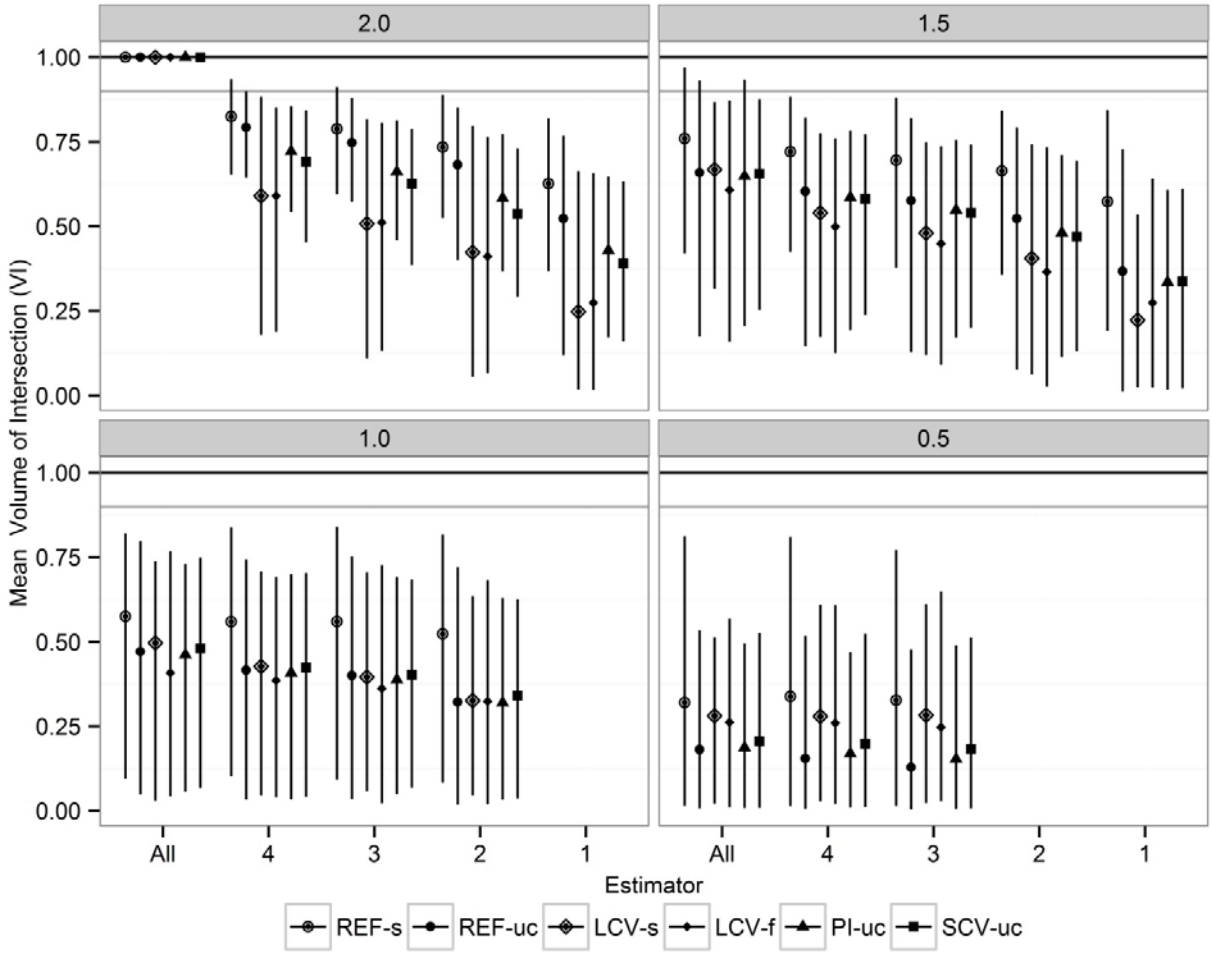

Fig. S13. Predicted eastern indigo snake annual and seasonal home range sizes (ha at the 80% volume contour) as a function of estimator and number of telemetry fixes. Only the predicted sizes for males are shown. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

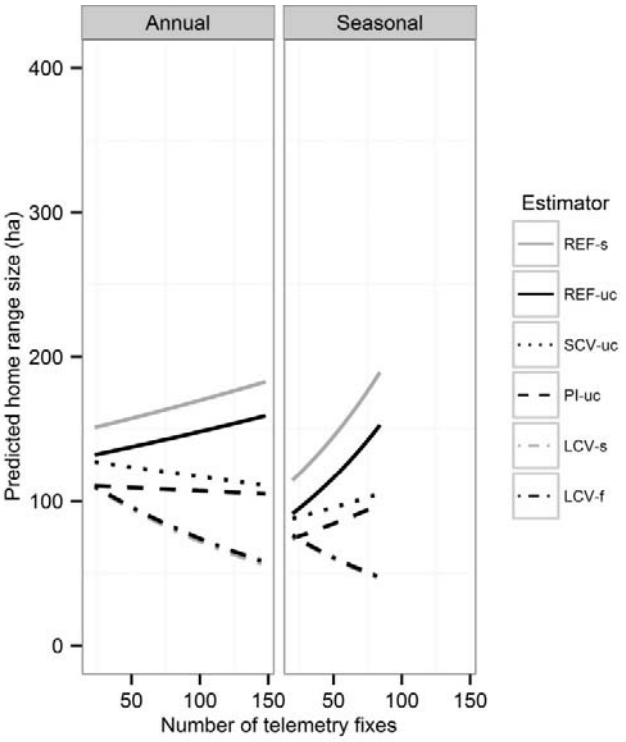

Fig. S14. Predicted western rattlesnake home range sizes (ha at the 80% volume contour) as a function of estimator and number of telemetry fixes. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).

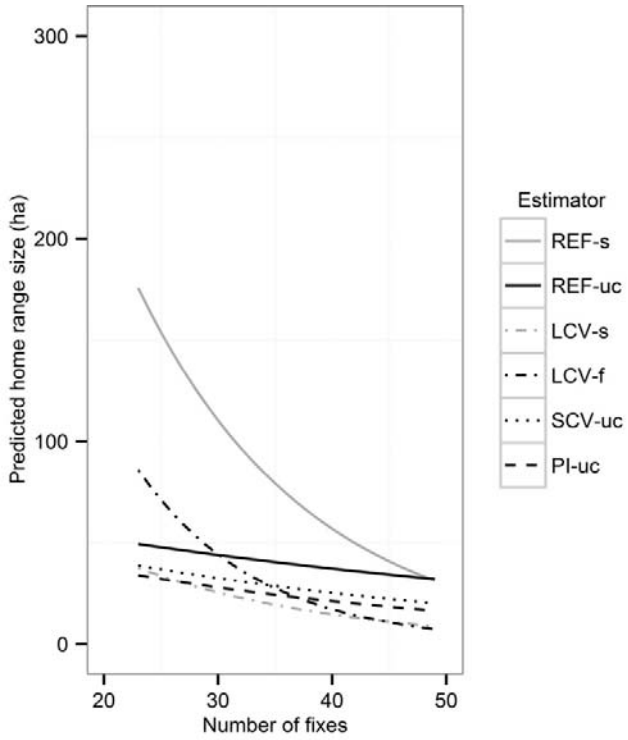

Fig. S15. Mean number of volume contours (± 1 SE) for eastern indigo snake seasonal home ranges at the 80%, 90%, 95%, and 99% volume contours for each estimator. The black horizontal line indicates one. Estimator codes denote the bandwidth selector (REF = reference, LCV = likelihood cross-validation, PI = plug-in, SCV = smoothed cross-validation) and matrix type (s = single-parameter, uc = unconstrained, f = full).