A proposed model to adjust new baseline for on-going mitigation.
By Julie Yee
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Purpose: In 2010, the SRC recommended that monitoring data starting from 2005 be used to establish a new baseline for evaluating changes in fatality rates during the post-2009 monitoring period. The reason for the new baseline is that monitoring data collected during 2005-2009 was more evenly distributed over space and time than previous data collected prior to 2005. However, one complication of re-establishing the baseline using later data is that mitigation actions began being implemented during this period and, as a result, the fatality rates have likely been reduced from the original pre-settlement baseline when mitigations had not yet occurred. The purpose of this document is to propose a method for adjusting the new baseline to better reflect fatality rates from the pre-settlement period.

In order to do this, I propose a model which uses the 2005-2009 data to calculate estimated reductions associated with these mitigation actions, which include seasonal shutdown and turbine removal. The baseline fatality rate can then be adjusted upward to project back what that rate might have been without any mitigations.

Estimating seasonal shutdown: Previously (P-055), I proposed a model to estimate the percent reduction in the fatality rate during turbine shutdown compared to turbine operation, while controlling for seasonal variation, assuming that random variation in fatality counts followed a Poisson distribution. I now propose to use the same model with several modifications. (1) I replaced the Poisson distribution with a negative binomial distribution which performs better when count data are too dispersed to fit a Poisson model. (2) In order to gain insight on compensatory mortality, I incorporated a turbine start-up indicator to identify whether there were greater fatalities during search intervals in which turbines are first turned on after an extended shutdown, compared to intervals in which turbines were already operating. (3) Although the data seems insufficient to identify variation among individual years, it seems to model better when pooling pairs of years together. In order to partly address inter-annual variation, I explored models with different rates between the two pairs of bird years, 2005-06 versus 2007-08. (4) Fatality rates are adjusted for obs. detection as well as scavenger removal.

Page 3 illustrates what the data looks like for string 517, and pages 4-11 show samples of statistical output showing daily fatality rate estimates based on 4 versions of models using all strings from bird years 2005-08, separately for red-tailed hawks and burrowing owls. All models contain seasonal, seasonal shutdown, and start-up effects, and differ only in the handling of years: (1) 2005-08 combined, (2) 2005-06 only, (3) 2007-08 only, and (4) 2005-08 combined but with differences between 2005-06 and 2007-08.

Estimating hazardous turbine removal: The task of estimating the effect of hazardous turbine removal has been challenging, because this mitigation has occurred unevenly over space and time. According to the currently proposed adaptive management plan, it will continue to occur in stages. Moreover, the removal of any turbines often affects the hazard configuration at the remaining turbines. I propose to extend the model to include additional covariates representing these time-varying conditions at the string level. For example, there could be four covariates defined as the numbers of turbines rated 9-10, 8-8.5, 7-7.5, and <7. As hazardous turbines are removed, the numbers of turbines may decrease or shift among hazard classes. If the data are adequate, then the model would calculate hazardous turbine removal effects in association with those changes, and I anticipate we would see larger effects for turbine reductions in the higher hazard classes than in lower hazard classes.

I have not tested this modeling concept on hazardous ranking data. It was only last spring when hazardous rankings were completed, the rankings are not in my dataset, and anyway they do not reflect conditions prior to early turbine removals. But I would like to explore whether there is enough information about those turbines to assign them an approximate ranking. Scientific expert opinion should figure prominently here.

<u>Other considerations: Sample size, adaptive management, and spatial variation</u>:
It's more difficult to produce solutions when there are fewer fatalities. The analysis produces more model warnings and errors for the American kestrel and golden eagle species than for the red-tailed hawk and burrowing owl. The same is true when grouping 2 or more years rather than separating years. I see two avenues for improvement on this issue. Firstly, as the adaptive management program progresses, new data will become available that could improve our precision on the effects of season, seasonal shutdown, and turbine removal. We can already see this with the attached RTHA and BUOW analyses by comparing the standard errors using 2 years of data versus 4 years. As part of the adaptive management process, it would be appropriate to annually reevaluate the seasonal, seasonal shutdown, and turbine removal effects, and even the adjusted 2005-2009 baseline (2005-2008 if using a 3-year baseline).

The second avenue would be to model spatial variation. The baseline based on 1998-2003 data has been problematic because of uneven sampling across space and time (seasons and years). The above model accommodates some variation across time but not space, by which I am referring to the tendency of certain areas of the Altamont to have higher or lower rates of fatalities that are not explained by the mitigation effects. I propose extending the model to estimate a spatially explicit surface which represents areas tending toward higher and lower fatalities than what can be predicted by seasons, shutdowns and hazard configurations alone. This can be done by incorporating a nonparametric regression component into the model (such as GAM or other smoother), in which the fatality counts are allowed to vary smoothly over the spatial coordinates of strings. The resulting model would be semi-parametric because of its parametric (for seasonal and mitigation effects) and nonparametric components (for spatial variation)[1]. I don't know if the data are sufficient to support a semiparametric analysis, but this can be immediately tested once coordinates of the strings (or their centroids) are processed into the dataset. An additional potential benefit of using a spatially and seasonally explicit model is that it could allow us to incorporate 1998-2003 data back into the baseline.

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[1] Ruppert, D., M.P. Wand, and R.J. Carroll. 2003. Semiparametric regression. Cambridge University Press. 386 pp.

Sample dataset:

string	nturbines	birdyr	datesearched	winter	spring	summer	autumn	prevsearch	interval	ono1	ono2	ndays1	ndays2	startup	rc1	rc2	count
517	38	2005	11/29/2005	1	0	0	0	11/2/2005	27	1	0	27	0	0	25.23	0	0
517	38	2005	1/9/2006	1	0	0	0	11/29/2005	41	1	0	33	8	1	29.71	7.85	2
517	38	2005	2/24/2006	1	0	0	0	1/9/2006	46	0	1	46	0	0	41.90	0	0
517	38	2005	7/4/2006	0	0	1	0	5/23/2006	42	0	1	42	0	0	38.43	0	0
517	38	2005	8/8/2006	0	0	1	0	7/4/2006	35	0	1	35	0	0	32.31	0	0
517	38	2006	10/5/2006	0	0	0	1	8/8/2006	58	0	1	58	0	0	52.21	0	0
517	38	2006	11/15/2006	0	0	0	1	10/5/2006	41	0	1	41	0	0	37.56	0	0
517	38	2006	1/9/2007	1	0	0	0	11/15/2006	55	0	1	47	8	0	41.79	7.85	1
517	38	2006	2/12/2007	1	0	0	0	1/9/2007	34	1	0	34	0	0	31.43	0	0
517	38	2006	3/1/2007	0	1	0	0	2/12/2007	17	1	0	17	0	0	16.22	0	0
517	38	2006	3/27/2007	0	1	0	0	3/1/2007	26	0	1	26	0	1	24.34	0	0
517	38	2006	5/1/2007	0	1	0	0	3/27/2007	35	0	1	35	0	0	32.31	0	0
517	38	2006	6/13/2007	0	0	1	0	5/1/2007	43	0	1	43	0	0	39.30	0	0
517	38	2006	7/11/2007	0	0	1	0	6/13/2007	28	0	1	28	0	0	26.12	0	0
517	38	2006	8/16/2007	0	0	1	0	7/11/2007	36	0	1	36	0	0	33.19	0	0
517	38	2007	10/2/2007	0	0	0	1	8/16/2007	47	0	1	47	0	0	42.76	0	1
517	38	2007	10/30/2007	0	0	0	1	10/2/2007	28	0	1	28	0	0	26.12	0	1
517	38	2007	11/30/2007	1	0	0	0	10/30/2007	31	1	0	31	0	0	28.78	0	0
517	38	2007	1/14/2008	1	0	0	0	11/30/2007	45	1	0	45	0	0	41.03	0	1
517	38	2007	2/19/2008	1	0	0	0	1/14/2008	36	0	1	36	0	1	33.19	0	0
517	38	2007	3/25/2008	0	1	0	0	2/19/2008	35	0	1	35	0	0	32.31	0	0
517	38	2007	4/24/2008	0	1	0	0	3/25/2008	30	0	1	30	0	0	27.90	0	0
517	38	2007	6/3/2008	0	0	1	0	4/24/2008	40	0	1	40	0	0	36.69	0	0
517	38	2007	7/8/2008	0	0	1	0	6/3/2008	35	0	1	35	0	0	32.31	0	0
517	38	2007	8/12/2008	0	0	1	0	7/8/2008	35	0	1	35	0	0	32.31	0	0
517	38	2007	9/11/2008	0	0	1	0	8/12/2008	30	0	1	30	0	0	27.90	0	0
517	38	2008	10/15/2008	0	0	0	1	9/11/2008	34	0	1	34	0	0	31.43	0	0
517	38	2008	11/12/2008	0	0	0	1	10/15/2008	28	0	1	28	0	0	26.12	0	0
517	38	2008	12/10/2008	1	0	0	0	11/12/2008	28	1	0	28	0	0	26.12	0	0
517	38	2008	1/12/2009	1	0	0	0	12/10/2008	33	1	0	33	0	0	30.55	0	0
517	38	2008	2/11/2009	1	0	0	0	1/12/2009	30	1	0	30	0	0	27.90	0	0
517	38	2008	3/9/2009	0	1	0	0	2/11/2009	26	0	1	26	0	1	24.34	0	0
517	38	2008	4/6/2009	0	1	0	0	3/9/2009	28	0	1	28	0	0	26.12	0	0
517	38	2008	5/5/2009	0	1	0	0	4/6/2009	29	0	1	29	0	0	27.01	0	0
517	38	2008	6/3/2009	0	0	1	0	5/5/2009	29	0	1	29	0	0	27.01	0	0
517	38	2008	7/6/2009	0	0	1	0	6/3/2009	33	0	1	33	0	0	30.55	0	0
517	38	2008	8/11/2009	0	0	1	0	7/6/2009	36	0	1	36	0	0	33.19	0	0
517	38	2008	9/10/2009	0	0	1	0	8/11/2009	30	0	1	30	0	0	27.90	0	0
517	38	2009	10/20/2009	0	0	0	1	9/10/2009	40	0	1	40	0	0	36.69	0	0
517	38	2009	11/16/2009	1	0	0	0	10/20/2009	27	0	1	27	0	0	25.23	0	0

variable	description
nturbines	number of turbines in string
birdyr	bird year designation
datesearched	date searched
winter, spring, summer, autumn	season indicator. 1 if true, 0 if false. Only one of these can be true.
prevsearch	previous search date
interval	length of search interval
ono1	operation/non-operating indicator, for shutdown status. 0 if operating, 1 if shutdown.
ono2	ono2 is opposite of ono1. Used when operating status changes during interval.
ndays1	number of days under ono1 status
ndays2	number of days under ono2 status
startup	indicates if turbines started up (following seasonal shutdown) in this interval. 1 if true, 0 if false.
rc1	cumulative Ri for days under ono1 status (Ri summed across days)
rc2	cumulative Ri for days under ono2 status (Ri summed across days)
count	number of American kestrel fatalities found

So, for example, two kestrels were found on 1/9/2006 at string 517. The previous search was on 11/29/2005, resulting in a 41-day interval. Turbines were shutdown during the first 33 days, followed by 8 days of operation until 1/9/2006 when these two kestrels were found. Turbines were started up in this interval following seasonal shutdown. We don't know whether these kestrels were killed during the non-operational or operational period of this interval, but we can portion the cumulative Ri (for scavenger adjustment) corresponding to both periods. The next search occurred on 2/24/2006 resulting in a 46-day interval. No fatalities were found and turbines in this string were operating during the full interval.

P-176
Analysis on Shutdown Effect using Negative Binomial Model

RTHA fatalities

Model 1. Seasonal effects are assumed (Winter, Spring, Summer, and Autumn) where birdyr in (2005,2006,2007,2008)

The NLMIXED Procedure

Additional Estimates								
Label	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000180	0.000028	12E3	6.42	<.0001	0.1	0.000134	0.000227
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000092	0.000014	12E3	6.75	<.0001	0.1	0.000070	0.000114
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000077	9.196E-6	12E3	8.34	<.0001	0.1	0.000062	0.000092
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000173	0.000024	12E3	7.24	<.0001	0.1	0.000134	0.000213
Shutdown Effect	-0.6802	0.09030	12E3	-7.53	<.0001	0.1	-0.8288	-0.5317
Startup Effect	0.001053	0.000713	12E3	1.48	0.1396	0.1	-0.00012	0.002226

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

Startup Effect is the average additional fatalities/turbine per search interval in which seasonal shutdown ends.

Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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P-176
Analysis on Shutdown Effect using Negative Binomial Model

RTHA fatalities

Model 2. Seasonal effects are assumed (Winter, Spring, Summer, and Autumn) where birdyr in (2005,2006)

The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000214	0.000039	4347	5.54	<.0001	0.1	0.000151	0.000278
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000151	0.000028	4347	5.34	<.0001	0.1	0.000105	0.000198
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000105	0.000017	4347	6.24	<.0001	0.1	0.000077	0.000132
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000261	0.000061	4347	4.26	<.0001	0.1	0.000160	0.000362
Shutdown Effect	-0.5346	0.1961	4347	-2.73	0.0064	0.1	-0.8573	-0.2119
Startup Effect	0.000586	0.001254	4347	0.47	0.6404	0.1	-0.00148	0.002649

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P-176
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The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000114	0.000034	7419	3.37	0.0008	0.1	0.000058	0.000170
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000059	0.000014	7419	4.10	<.0001	0.1	0.000035	0.000083
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000058	0.000010	7419	5.57	<.0001	0.1	0.000041	0.000075
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000147	0.000026	7419	5.76	<.0001	0.1	0.000105	0.000190
Shutdown Effect	-0.6151	0.1497	7419	-4.11	<.0001	0.1	-0.8612	-0.3689
Startup Effect	0.001180	0.000926	7419	1.27	0.2028	0.1	-0.00034	0.002703

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P-176
Analysis on Shutdown Effect using Negative Binomial Model

RTHA fatalities

Model 4. Seasonal effects are assumed (Winter, Spring, and Autumn) where month(datesearched) in (10,11,12,1,2,3) and birdyr in (2005,2006,2007,2008)

The NLMIXED Procedure

Additional Estimates								
Label	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000228	0.000036	6009	6.31	<.0001	0.1	0.000169	0.000288
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000205	0.000051	6009	4.02	<.0001	0.1	0.000121	0.000288
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000304	0.000056	6009	5.40	<.0001	0.1	0.000211	0.000397
Period Effect (2007-2008 relative to 2005-2006)	-0.5135	0.08350	6009	-6.15	<.0001	0.1	-0.6509	-0.3761
Shutdown Effect	-0.5924	0.1087	6009	-5.45	<.0001	0.1	-0.7712	-0.4135
Startup Effect	0.000118	0.000889	6009	0.13	0.8944	0.1	-0.00134	0.001580

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

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Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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P-176
Analysis on Shutdown Effect using Negative Binomial Model

BUOW fatalities

Model 1. Seasonal effects are assumed (Winter, Spring, Summer, and Autumn) where birdyr in (2005,2006,2007,2008)

The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000525	0.000104	12E3	5.07	<.0001	0.1	0.000355	0.000696
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000173	0.000039	12E3	4.41	<.0001	0.1	0.000108	0.000237
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000292	0.000040	12E3	7.37	<.0001	0.1	0.000227	0.000358
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000326	0.000070	12E3	4.64	<.0001	0.1	0.000210	0.000441
Shutdown Effect	-0.2502	0.1926	12E3	-1.30	0.1939	0.1	-0.5671	0.06661
Startup Effect	0.000121	0.000526	12E3	0.23	0.8176	0.1	-0.00074	0.000986

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

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Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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P-176
Analysis on Shutdown Effect using Negative Binomial Model

BUOW fatalities

Model 2. Seasonal effects are assumed (Winter, Spring, Summer, and Autumn) where birdyr in (2005,2006)

The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000626	0.000139	4347	4.51	<.0001	0.1	0.000397	0.000855
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000321	0.000087	4347	3.67	0.0002	0.1	0.000177	0.000464
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000576	0.000091	4347	6.32	<.0001	0.1	0.000426	0.000726
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000733	0.000245	4347	2.99	0.0028	0.1	0.000330	0.001135
Shutdown Effect	-0.02507	0.3030	4347	-0.08	0.9341	0.1	-0.5236	0.4734
Startup Effect	-0.00048	0.000976	4347	-0.49	0.6262	0.1	-0.00208	0.001131

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

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Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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P-176
Analysis on Shutdown Effect using Negative Binomial Model

BUOW fatalities

Model 3. Seasonal effects are assumed (Winter, Spring, Summer, and Autumn) where birdyr in (2007,2008)

The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000466	0.000158	7419	2.95	0.0031	0.1	0.000207	0.000726
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000091	0.000036	7419	2.53	0.0114	0.1	0.000032	0.000150
Mean Fatalities/Turbine/Day w/o Shutdown (Summer)	0.000120	0.000031	7419	3.85	0.0001	0.1	0.000069	0.000171
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000224	0.000064	7419	3.48	0.0005	0.1	0.000118	0.000330
Shutdown Effect	-0.3789	0.2516	7419	-1.51	0.1322	0.1	-0.7929	0.03506
Startup Effect	0.000419	0.000608	7419	0.69	0.4905	0.1	-0.00058	0.001419

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

Startup Effect is the average additional fatalities/turbine per search interval in which seasonal shutdown ends.

Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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P-176
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BUOW fatalities

Model 4. Seasonal effects are assumed (Winter, Spring, and Autumn) where month(datesearched) in (10,11,12,1,2,3) and birdyr in (2005,2006,2007,2008)

The NLMIXED Procedure

Additional Estimates								
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Mean Fatalities/Turbine/Day w/o Shutdown (Winter)	0.000632	0.000132	6009	4.79	<.0001	0.1	0.000415	0.000850
Mean Fatalities/Turbine/Day w/o Shutdown (Spring)	0.000057	0.000056	6009	1.02	0.3068	0.1	-0.00003	0.000150
Mean Fatalities/Turbine/Day w/o Shutdown (Autumn)	0.000598	0.000156	6009	3.84	0.0001	0.1	0.000341	0.000854
Period Effect (2007-2008 relative to 2005-2006)	-0.5440	0.09972	6009	-5.46	<.0001	0.1	-0.7081	-0.3800
Shutdown Effect	0.01019	0.2641	6009	0.04	0.9692	0.1	-0.4243	0.4447
Startup Effect	0.000983	0.000509	6009	1.93	0.0534	0.1	0.000146	0.001820

Shutdown Effect is a proportional adjustment. For example, a Shutdown Effect = -0.4500 suggests a 45% reduction in rate of fatalities/turbine/day during shutdown.

Startup Effect is the average additional fatalities/turbine per search interval in which seasonal shutdown ends.

Period Effect is a proportional adjustment. For example, a Period Effect = -0.4000 suggests that the biennial bird years 2007-2008 had 40% lower rates than 2005-2006.

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