WASTED CURTAILMENT OR SMART CURTAILMENT FOR BATS

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Introduction

Project curtailment is the primary minimization strategy for bat fatalities at wind energy facilities. Studies indicate that curtailment during low wind speed (5.5 to 6.5 m/s and below) reduces bat fatalities by 42% or more (Arnett et al. 2008, Baerwald et al. 2009). However, wind speed alone is a poor predictor of fatality risk: More recent studies indicate that 25-75% of curtailed low wind speed hours have no bats within the rotor swept area, the zone of risk (Weller et al.) (Sutter et al. 2017).

An alternative approach, recently tested at a Wisconsin wind farm, is to curtail turbines only when bats are present, as indicated by acoustic monitors on a subset of the turbines. Under this smart curtailment approach bat fatalities were reduced by 83% and lost energy was reduced by approximately 40%, as compared to a wind speed only approach (90 vs. 150 MWh per year per turbine) (Sutter et al. 2017).

The effectiveness of the smart curtailment approach over traditional curtailment at the Wisconsin site was driven by temporal clustering of bat exposure to the rotor zone. The temporal clustering of exposure, and resultant success of the smart curtailment strategy, may have been due to site specific conditions at this Upper Midwest site. To evaluate this, data from a second site, located in the southwestern US, were analyzed. The second site is frequented by some of these same species (e.g., Eastern Red and Hoary) but also large numbers of Brazilian free-tailed bats (*Tadarida brasiliensis*). The Brazilian free-tailed bat differs from the other species in the following ways: it concentrates in large colonies (>1 million) instead of being solitary, it is adapted to fly at higher wind speeds, and although it is migratory its reproductive strategy differs so unlike the eastern red and hoary bats it is not engaging in breeding behavior during migration.

Methods

We utilized on-site meteorological and bat activity data at the proposed southwestern US wind farm to calculate energy yield and bat exposure rates in each 10-minute record over the course of a year and within the season of peak exposure. In the base case curtailment scenario, only wind speed is utilized as the curtailment trigger. In the smart curtailment scenario, the real-time bat exposure rate is combined with wind speed to trigger curtailment only when there is a relatively higher risk of bat fatalities.

For each scenario, we estimated the bat conservation value, expressed as the expected percent reduction in fatalities from a no curtailment condition, as well as the estimated lost energy and revenue.

Results

At the southwestern US site, bats were present in the rotor swept area, with 18,883 calls detected during the peak season (Figure 1) and over 9,000 detected in just 7 days (Aug 26 to Sep 1). Diurnally, activity peaks between the hours of 2100 through 0400 (Table 1). During nighttime hours, bats were present in 35% of the 10-minute records (Table 2). This indicates clumping of activity at several time-scales: within a year, within a season, within a month, and within a night.

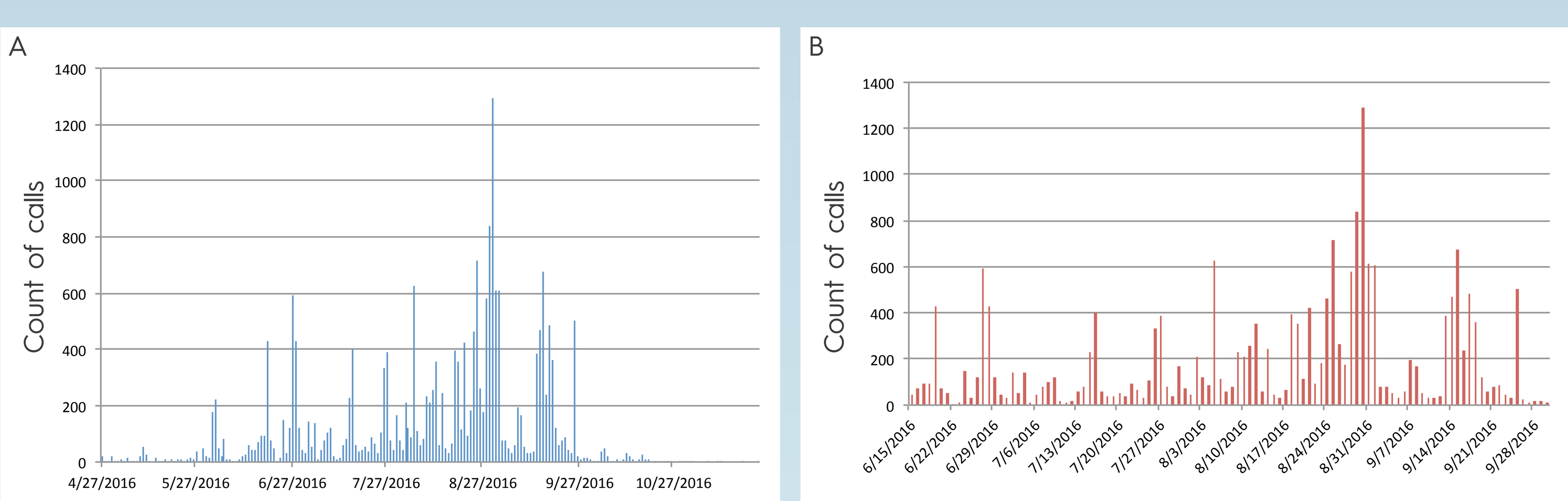

Figure 1. A) Bat activity by date for the entire monitoring season (April 27 to November 23); and, B) the peak season (June 15 to September 30).

This temporal clustering is further evidenced by the fact that when one bat call is detected there is a high likelihood of additional calls being detected within the same 10-minute interval (Figure 2). For example, at wind speeds below 10 m/s, there is an 80.5% probability of at least one additional call detected, a 51.6% probability of at least 4 additional calls, and a 32% probability of at least 9 additional calls. The temporal concentration of bat activity is similar to the Upper Midwest site, despite the multitude of differences between the two sites. This southwestern site is an ideal candidate for smart curtailment.

sum of bat activity (total number of calls in bin)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	-	-	-	1	40	293	404	978	956	19	-	-
1	-	-	-	-	66	473	358	1,204	920	11	1	-
2	-	-	-	1	41	515	577	1,775	787	6	-	-
3	-	-	-	-	23	310	573	1,675	639	8	-	-
4	-	-	-	-	12	53	601	1,053	393	5	-	-
5	-	-	-	-	1	-	93	383	94	3	-	-
6	-	-	-	-	-	-	-	-	5	1	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	4	-	-
20	-	-	-	8	1	-	-	28	53	14	2	-
21	-	-	-	12	26	15	50	551	124	41	-	-
22	-	-	-	14	49	132	164	516	405	29	1	-
23	-	-	-	9	57	210	327	1,191	661	22	1	-

Table 1. Total count of bat calls by monthly/diurnal bin

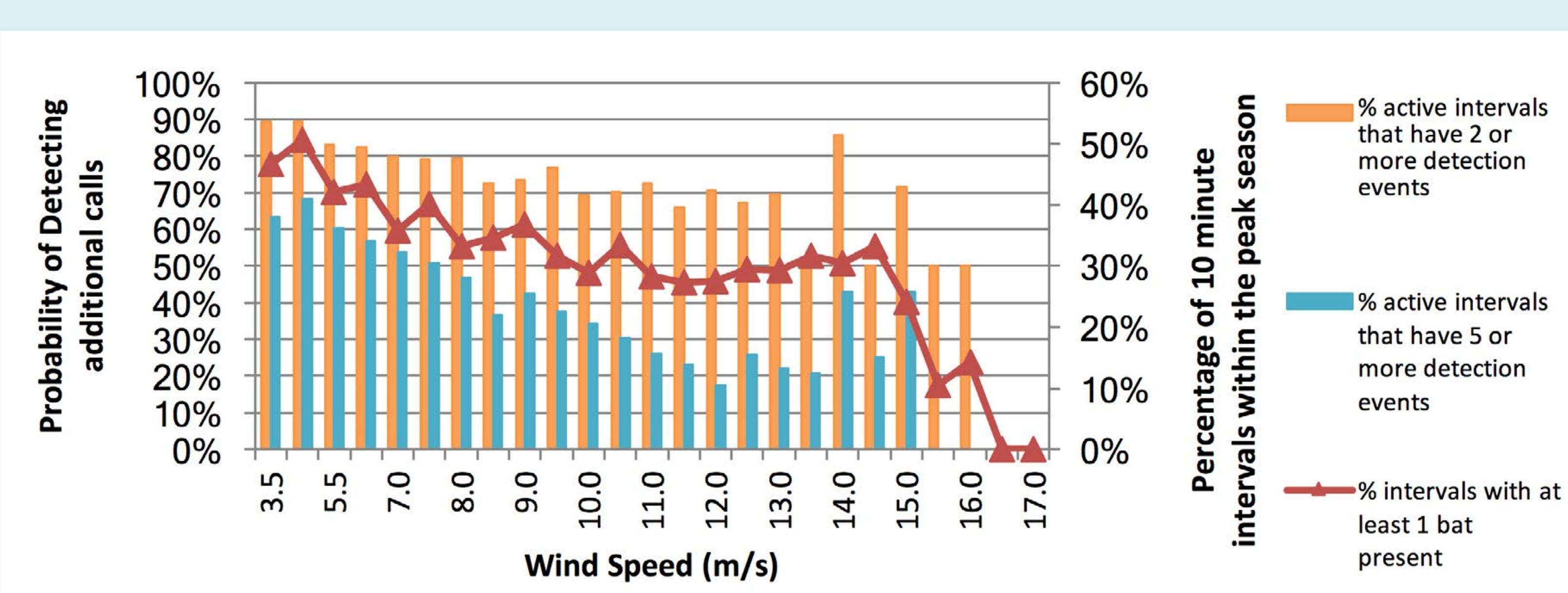

Figure 2. Temporal distribution and intensity of bat activity by wind speed

	Count of 10 minute intervals from 1/2 hr before sunset to a ½ hour after sunrise	% with at bats present	% with bats absent
with or without bat calls	7474	NA	NA
with at least 1 bat call	2642	35.35%	64.65%
with at least 2 bat calls	1854	24.81%	75.19%
with at least 5 bat calls	948	12.68%	87.32%
with at least 10 bat calls	526	7.04%	92.96%

Table 2. Clumped distribution of bat activity within intervals

Bat activity Level	Number of bat calls detected	% of bat calls detected
≥ 1 call per interval	18883	
≥ 2 calls per interval	18095	95%
≥ 5 calls per interval	15624	83%
≥ 10 calls per interval	12866	68%

Table 3. Tendency of bat activity to aggregate

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.3%
1	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.4%	0.4%	0.4%	0.3%
2	0.3%	0.4%	0.4%	0.4%	0.4%	0.3%	0.4%	0.3%	0.4%	0.4%	0.4%	0.4%
3	0.3%	0.4%	0.5%	0.4%	0.4%	0.3%	0.4%	0.3%	0.4%	0.4%	0.4%	0.3%
4	0.3%	0.4%	0.4%	0.4%	0.4%	0.3%	0.4%	0.3%	0.4%	0.4%	0.4%	0.3%
5	0.3%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.3%
6	0.3%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.3%
7	0.3%	0.4%	0.4%	0.4%	0.3%	0.2%	0.2%	0.2%	0.3%	0.4%	0.4%	0.3%
8	0.3%	0.4%	0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.3%	0.4%	0.3%
9	0.2%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%
10	0.2%	0.4%	0.4%	0.3%	0.3%	0.2%	0.3%	0.2%	0.3%	0.3%	0.3%	0.3%
11	0.2%	0.4%	0.4%	0.3%	0.3%	0.2%	0.3%	0.2%	0.3%	0.3%	0.3%	0.3%
12	0.2%	0.4%	0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.3%	0.4%	0.3%	0.3%
13	0.3%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.2%	0.3%	0.4%	0.3%	0.3%
14	0.3%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.2%	0.3%	0.4%	0.3%	0.3%
15	0.3%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%
16	0.3%	0.3%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%
17	0.3%	0.3%	0.4%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%	0.4%	0.3%	0.3%
18	0.3%	0.3%	0.4%	0.4%	0.3%	0.3%	0.4%	0.3%	0.4%	0.5%	0.4%	0.3%
19	0.3%	0.3%	0.4%	0.4%	0.3%	0.3%	0.4%	0.3%	0.4%	0.5%	0.4%	0.3%
20	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.4%	0.5%	0.4%	0.3%
21	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.4%	0.5%	0.4%	0.3%
22	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.4%	0.5%	0.4%	0.3%
23	0.3%	0.3%	0.4%	0.4%	0.4%	0.3%	0.5%	0.4%	0.4%	0.5%	0.4%	0.3%

Table 4. Percent of annual energy production in each 12x24 bin with no curtailment

The peak season of bat activity coincides with fairly high energy production (Table 4). A standard wind-speed only curtailment scheme would result in approximately 65% of that curtailment occurring in hours with no bats present (Table 2) which would have about twice the negative impact on energy yield assuming a 5.5 m/s cut-in condition (Table 5).

Scenario	Bat activity levels	Expected bat conservation (% reduction in fatalities)	Expected reduction in annual energy yield (MWh/l)	Expected reduction in annual energy yield (%)	Expected reduction in annual revenue ($/turbine): $20/MWh offtaker price	$30/MWh offtaker price	$40/MWh offtaker price	Notes (Curtailment = Pitching out blades)
Input: Wind Speed at or below 3.5 m/s								
1 Blanket	NA	16.7	0.73	0	14.60	21.90	29.20	Small biological benefit (~16.7% reduction). Revenue loss is small
2 Smart	1+	16.7	0.39	0	7.80	11.70	15.60	Small biological benefit (~16.7% reduction). Revenue loss is smaller
Input: Wind Speed at or below 5.5 m/s								
3 Blanket	NA	43.7	38.2	0.3	764.00	1,146.00	1,528.00	Moderate biological benefit (~40% reduction). Revenue loss is small.
4 Smart	1+	43.7	19.7	0.2	394.00	591.00	788.00	Moderate biological benefit (~40% reduction). Revenue loss is ~50% less (than Scenario 3) because curtailment is only occurring when bats are present
Input: Wind Speed at or below 6.5 m/s								
5 Blanket	NA	55.9	92.1	0.8	1,842.00	2,763.00	3,684.00	Reasonable biological benefit (~55% reduction). Revenue loss is about twice as much as the smart curtailment scenario below (scenario 6)
6 Smart	1+	55.9	47.5	0.4	950.00	1,425.00	1,900.00	Reasonable biological benefit (~55% reduction). Revenue loss per turbine reduced by ~50% (as compared to Scenario 5) because curtailment is only occurring when bats are present
Input: Wind Speed at or below 7.0 m/s								
7 Blanket	NA	61.3	143.4	1.2	2,868.00	4,302.00	5,736.00	Reasonable biological benefit (~60% reduction). Revenue loss is about twice as much as the smart curtailment scenario (Scenario 8)
8 Smart	1+	61.3	69.2	0.6	1,384.00	2,076.00	2,768.00	Reasonable biological benefit (~60% reduction). Revenue loss per turbine is moderate less than 50% (as compared to Scenario 7) because curtailment is only occurring when bats are present

Table 5. Comparison of energy loss and bat conservation benefit for several curtailment scenarios

Conclusion

Smart curtailment appears to be beneficial in areas outside of the Midwestern US and to a large range of species, including Brazilian free-tailed bats, which are prone to high level of fatalities at wind farms.

Pre-construction meteorological and bat activity data, such as the data used in this example, can be analyzed to estimate the biological benefit (estimated reduction in bat fatalities) and the effect on energy yield under various standard and smart curtailment scenarios. The results are useful for:

- Identifying an optimum curtailment scenario;
- Assessing whether smart curtailment is a "better" option than wind speed only curtailment;
- Estimate the costs of curtailment (in lost energy yield). This quantified cost can be used in negotiations with regulators (e.g., USFWS) regarding how much curtailment is required and/or how to value this mitigation when it is used to compensate for fatalities;
- Identify likely timing and duration of curtailment events (useful for PPA development).

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