To:	Humboldt County Planning & Building Department 3015 H Street Eureka, CA 95501	From:	H. T. Harvey & Associates 983 University Avenue, Building D Los Gatos, CA 95032
		Date:	August 26, 2019

Reference: Summary of Collision Risk Modeling Efforts for General Audience

Marbled murrelets (*Brachyramphus marmoratus*) are federally threatened and state endangered seabirds that fly between the ocean where they forage and inland old-growth forests where they nest. In southern Humboldt County, development of a wind energy facility has been proposed by Humboldt Wind, LLC., which would require construction of a line (or string) of turbines along the top of Bear River Ridge and Monument Ridge. Because the proposed facility is located between the ocean and inland nesting habitat, there is potential for murrelets to encounter the wind turbines in the relatively rare event that individuals cross these ridges as they transit to and from nesting habitat.

Murrelets are unique seabirds because they fly inland to nest in forests rather than nesting on an island or on cliffs, as is the case for most seabirds. Inland flights by murrelets vary predictably in time (daily and seasonally) and space. Understanding these inland transit patterns is important to assessing how murrelets will be impacted by turbines installed along Bear River and Monument Ridges and how often they will possibly enter the turbine airspace.

Murrelets fly inland because they nest on the branches of large older trees and, in southern Humboldt County, appropriate trees are in preserves or parks along the Eel River and its tributaries (which includes Humboldt Redwoods State Park). Seasonally, inland flights by murrelets occur primarily during the breeding season due to the need for nesting adults to incubate eggs and feed chicks each day. Each morning during the breeding season, murrelets fly inland just before dawn (but with early morning light), either to exchange nest duties with their mates or to socialize with individuals trying to establish a nest. This activity predictably peaks just before sunrise and decreases shortly after sunrise. When feeding chicks, parents may make additional flights to their nest to deliver additional food to their chick late in the day (with activity peaking near dusk).

It is on these directed flights to and from nesting habitat that some murrelets may cross Bear River and Monument Ridges and risk encountering turbines. Across their range, murrelets often use waterways to navigate between the ocean and nesting habitat. Murrelets do not follow ridgelines to access nesting habitat; therefore, ridgelines are not used in the same way as waterways. However, on occasion, murrelets do take advantage of low points along ridgelines to cross between adjacent waterways. In southern Humboldt County, murrelets use the Eel River valley as their primary flyway and use smaller waterways, including Bear River, to a lesser extent. Bear River Ridge and Monument Ridge separate Bear River from the Eel River, thus, murrelets may occasionally cross these ridges to move between these waterways, especially at low points along the ridges.

Murrelets do not generally fly in total darkness but do fly in twilight. Based on radar monitoring, fewer murrelets crossed ridges when fog was present. Fog may delay the timing of morning flights to periods with more ambient light. Fog may also cause birds to fly lower along the valley flyways.

To estimate potential encounters between murrelets and turbines over 30 years (the permitted duration of the Project), we developed two mathematical models based on murrelet activity along these ridgelines (as measured with radar) and the resulting probability of encountering turbines. Radar was used to estimate passage over the site and, when possible, the vertical height of those flights to determine the percent of birds crossing ridges at risk height. These radar surveys provided an accurate estimate of passage rates (birds/km/day) for the breeding period with measurements conducted at 3-week intervals. Spatially, the turbine string was divided into 11 zones excluding large gaps (greater than 0.5 mile) between adjacent turbines and splitting zones based on topographical differences (peaks, low points, and elevational drops into the adjacent river valleys) in order to identify areas of greatest risk.

The simplest model was deterministic, meaning that it used a set of fixed inputs which allowed for calculating a single estimate of impact. The deterministic model was beneficial because allowed us to identify which model inputs had the greatest influence over the estimate of impact. Furthermore, this approach allowed for a separate assessment of risk for each of the 11 topographically delimited zones to enable turbine micro-siting decisions.

The more complicated model was probabilistic (also known as a Bayesian approach), meaning that inputs and their associated variability or uncertainty were defined using a full range of likely values rather than a single fixed value; this allowed us to calculate the most likely impact along with a range of values representing uncertainty about that estimate. Because the probabilistic model was able to incorporate variability and uncertainty associated with critical inputs, this effort produced a more realistic estimate of the most likely impact as well as a better understanding of the entire range of potential impacts expected over 30 years.

All inputs required for these models were based on what is known about murrelet biology as determined directly for Bear River and Monument Ridges and, as needed, from other studies of murrelets and seabirds in general. Inputs into both models included: 1) the rate of passage of murrelets over the ridges, 2) the vertical height of birds flying over the ridges, 3) the general areas along the ridges where birds flew over, 4) the speed of birds flying over the ridges, 5) the direction that birds were flying, 6) numbers of turbines installed, 7)turbine size, 8) turbine speed, 9) percent of time that turbines rotate, 10) 3-dimentional turbine blade profile, 11) year-to-year variation in the number of inland flying murrelets based on variation in ocean productivity, and 12) the probability that murrelets detect and avoid collisions with turbines. Radar surveys on the Project site were used to determine the passage rate over these ridges, the vertical height of crossings, speed of crossings, direction of flights, and the location of crossings.

A worst-case turbine scenario was assumed by both models, including installation of the largest turbines being considered and assuming that turbines will rotate at maximum speed. It is recognized that these assumptions are unrealistic and result in an overestimation of impact but, until decisions are made regarding turbine model, this was the most prudent approach.

Variation in the number of birds potentially exposed to the turbines across years was estimated using the relationship between a long-term data set on inland flying murrelets in the Eel River Valley and variation in ocean productivity, a reliable predictor of year-to-year changes in nesting activity. More murrelets will nest (and, therefore, fly inland more often) when ocean food conditions are good (which is reliably indicated by indices of ocean productivity index). For the deterministic model, 35 years of ocean productivity data were used and in probabilistic model the entire 118-year dataset of ocean productivity was used to forecast variability of inland flight activity of murrelets over the next 30 years based on historical ocean productivity regimes. Both models have been updated using the second year of radar survey data and that information has been put into context of the long-term ocean productivity measures to provide context to both years of data.

Birds approaching a wind turbine can avoid interaction by avoiding the entire area, making movement to fly above or around the turbines, or take evasive action if they fly near the rotor swept zone. Birds at both land-based and ocean-based wind facilities are known to avoid turbines using all three methods. At onshore wind facilities, birds typically manage to completely avoid turbines except for raptors and other species prone to distraction while pursuing prey and defending territories as they fly near turbines. Murrelets should not become distracted as they transit near Bear River and Monument Ridges because they are only passing through the area and there is no food or territories for them to defend along these ridges. Because there are no operating wind facilities in the range of the murrelet, avoidance by murrelets has not been directly assessed. However, based on every other bird studied thus far, the avoidance rates used for both collision risk models are conservative and err in the favor of murrelet by overestimating risk. We calculated take estimates with the deterministic model using a range of different avoidance rates (0.99, 0.98, 0.97, 0.96, and 0.95), although for purposes of this summary we only report for the most realistic avoidance rate (0.98).

It is important to note that murrelets are relatively small in body size and are very fast fliers. Even when an individual enters a rotor swept zone, most will pass through unharmed. The most commonly used physics-based model of bird-turbine interactions calculated that, in the absence of avoidance behaviors, only 4.3 % of passages through a rotor swept zone would result in collision for the largest turbine under consideration. Each collision predicted by modeling efforts was assumed to be fatal.

RESULTS

Based on passage during the 2018 breeding season using a conservative estimate of avoidance (0.98) and a 47 turbine layout including removal of all turbines from the three zones with the greatest risk, the deterministic model estimated an average of 0.176 birds each year, or 1 individual every 5.68 years (5.27 birds over 30 years) would collide with turbines proposed along Bear River and Monument Ridges. Based on passage in 2019, the deterministic model estimated 0.246 birds each year, or 1 individual every 4.06 years (7.38 birds over 30 years) would collide with turbines.

If the 2018 estimates from the 47-turbine layout are adjusted to reflect the variability in ocean conditions that account for variability in the proportion of murrelets flying inland to reproduce in a given year, the number of collisions estimated for average conditions was 0.176 birds per year (ocean conditions were average in 2018). In 2019 ocean conditions were above average and the collision risk was 0.246 that year. If the risk was adjusted for ocean condition, and then extrapolated over the 30-year period, the estimate of collision would be 5.27 birds based on 2018 passage and 6.85 birds based on 2019 passage rate.

Only the deterministic model was used to assess how risk varied across the turbine string, on a zone-by-zone basis. As expected, passage along the turbine string was not uniform and varied between the topographically delineated zones. In 2018 across the 11 zones, the lowest estimate of passage rate was 0.000 birds/km/day and the greatest was 0.683 birds/day/km. In 2019 across the 11 zones, the lowest estimate of passage rate was 0.078 birds/km/day and the greatest was 0.973 birds/day/km. As would be expected based on what is known about inland transit patterns of murrelets and their preference for flying inland along waterways, passage rate was found to be greatest in zones that descended into the adjacent Eel and Bear River Valleys. Turbines in three highest risk zones were subsequently eliminated from the turbine string with the 47-turbine layout resulting in a 36% overall decrease in risk.

In 2018, the probabilistic model estimated that the mean number of collisions was 0.10 birds each year or 2.94 birds over 30 years based on a 47-turbine layout. In 2019 the estimated mean was 0.12 birds each year or 3.70 birds over 30 years. For probabilistic assessments of eagle-turbine interactions, the U.S. Fish and Wildlife Service recommended that the upper bound of 80% on the estimate of risk be used as a conservation-based estimate of risk. Instead of an 80% bound, here we used the upper bound on the uncertainty of 95% resulting in only 5% of the uncertainty possible above that bound. In 2018 the upper bound on the estimate was 0.20 birds/year (upper limit was 6.17 birds in 30 years) and in 2019 was 0.26 birds/year (upper limit was 7.77 birds in 30 years). Like the deterministic model, these estimates assumed a worst-case scenario by setting turbine-specific operational factors (e.g., turbine size, blade speed) to their maximum value. In contrast to the deterministic model, the probabilistic approach allowed for a more accurate accounting of variability and uncertainty of model inputs that were identified using the deterministic approach to have the greatest impact on the estimates of risk (specifically avoidance probability, year-to-year variation in passage rate, and flight speed). Thus, the most precautionary estimate calculated by the models in either year was 7.77 birds in 30 years of the project.