Memorandum

Project# 3305-03

March 24, 2023

To: Amy Wang, Project Manager, David J. Powers & Associates

From: Sharon Kramer, Scott Terrill, and Sophie Bernstein, H. T. Harvey & Associates

Subject: Final Assessment of the Potential Impacts of The Bay Lights 360 Project on Birds and Fish

Per your request, H. T. Harvey & Associates is providing an assessment of the potential impact of The Bay Lights 360 Project on birds and fish. Drs. Scott Terrill and Sharon Kramer have reviewed the project description and are providing their assessments of potential project impacts to fish and birds.

Sharon Kramer has conducted research on fish ecology in Hawaii, Australia, and California/Oregon/Washington for her Masters of Science and PhD, with numerous publications. Scott Terrill conducted research on avian migration for both his Masters of Science and his PhD and has published approximately 30 scientific publications. He has conducted studies on bird migration in the United States, Mexico, Germany and Austria. Both resumes are attached as PDFs.

Overview of the Project

The Bay Lights 360 Project (Project) proposes to extend the existing Bay Lights installation on the north-facing side of the upper deck level of the West Span[1] to 2033, and involves replacing existing light-emitting diode (LED) white lights on the Bay's (outward-facing) side of the vertical suspension cables and adding additional new fixtures to the driver's (inward-facing) side of the same cables. The existing LED lights will be removed, then replaced with newly updated and more robust fixtures (nodes) on the Bay's and driver's (outward- and inward- facing, respectively) sides of the same suspension cable to create a 360-degree view of the lights. Forty-eight thousand (48,000) energy-efficient LED lights, each 1.75 inches by 2.75 inches, will be installed, replacing the 30,000 existing fixtures (i.e., there will be 18,000 more fixtures than the existing display). The technical details and intensity of the lights will remain the same as the current installation (existing conditions).

The LED lights will be secured to the vertical suspension bridge cables on strings in full height of the suspension cables at one foot spacing. The light temperature will be 4,000 kelvin and brightness will be 87 lumens (at 100-percent brightness) for all fixtures, consistent with the existing lighting. The lights will be attached to the outer part of the bridge suspension cables with ultraviolet (UV) resistant heat stabilized nylon

[1] There are currently no LED lights, nor does the Project propose to install any, on the south-facing side of the upper deck of the Bay Bridge's West Span.

black zip ties at six-inch intervals, so no paint disturbances will occur to the bridge structure and no repainting will be required. Installation of the lights will not cause permanent disturbance to the bridge structure or ground disturbance off the bridge. Light fixtures can be replaced individually if needed.

The backbone fiber trunk line, power line and electrical boxes from previous installation will remain in place without modifications, except the internal back plate of the electrical boxes with the existing power supply and fiber switch components will be removed and replaced with new components.

The bridge lights will be visible from all directions (360-degree view) and will be lit from dusk to dawn. The light strands on both sides of the cables can be turned off or dimmed independently of each other with their own separate controls. The light fixtures can also be physically adjusted (rotated). The light display will be controlled by the artist and appear to be moving in a wave like and alternating flickering, non-repeatable but abstract pattern, consistent with existing conditions.

The Project will be installed over a period of four to six months during the evening/overnight hours, which will require nightly closures of the outside traffic lanes (lanes 4 and 5). It is anticipated that the proposed installation will start in May, 2023, and be fully installed by December, 2023. The new LED light strands will be installed from 9:00 p.m. to 5:00 a.m. Sunday through Friday nights, and from 11:00 p.m. to 6:00 a.m. Saturday nights if needed. The crews will utilize bosun chairs for the high cables and/or bucket trucks for the shorter cables (up to 80 feet) for the removal and installation.

The power usage for the energy-efficient LED system is estimated at maximum of 48 kilowatt-hours (kwh) based on 48,000 fixtures at one watt each, assuming all lights are on constantly. Daily energy equates to a maximum of 48 kwh times the number of hours the lights are on (between dawn and dusk), which thus changes throughout the year. Lights will be on for the longest duration during winter months.

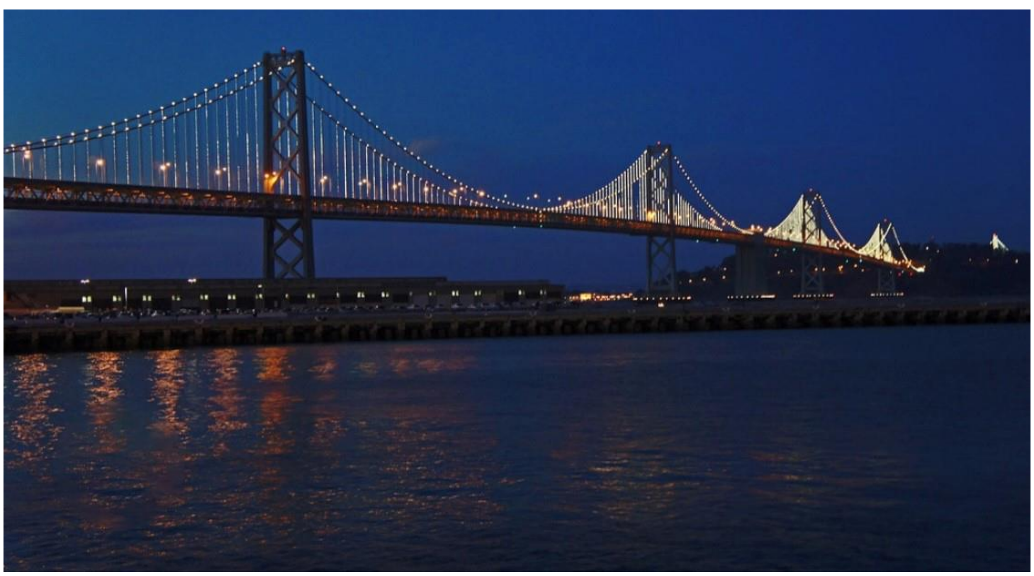

Photo 1: Nighttime view of Bay Bridge with The Bay Lights art display partially visible looking west from the San Francisco shoreline, towards Yerba Buena Island and hills.

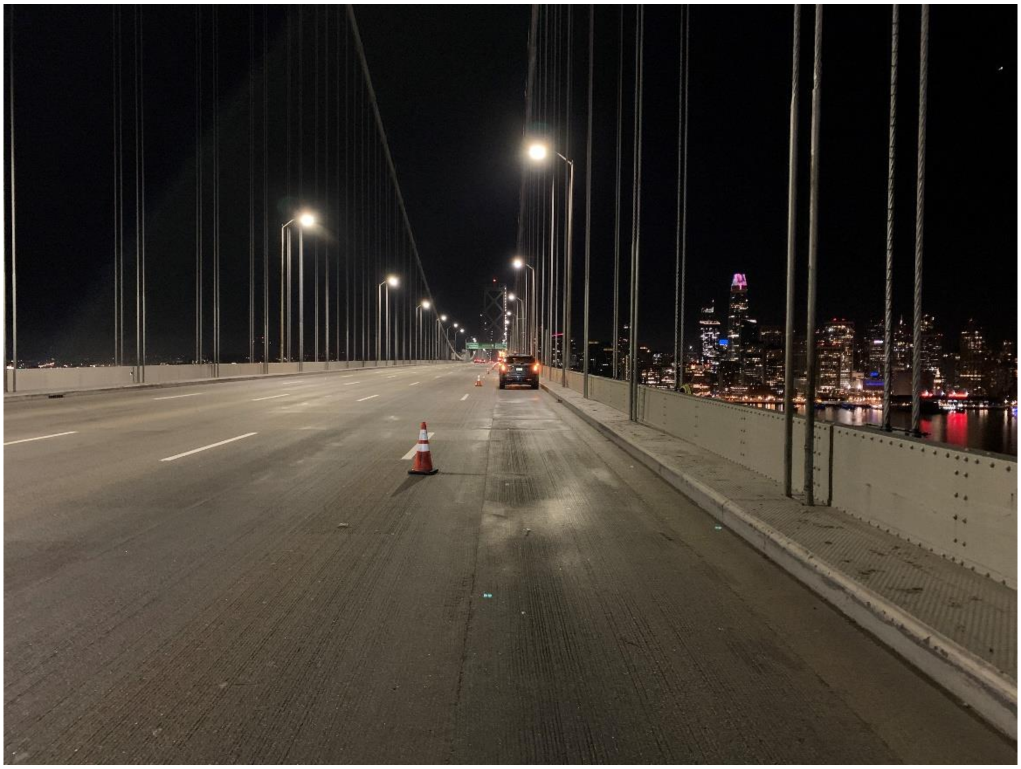

Photo 2: Nighttime view of suspension cables of the Bay Bridge with The Bay Lights art display looking west, toward the San Francisco shoreline, from upper deck of the Bay Bridge.

Fish Assessment

Historically, aquatic biota were adapted to natural nighttime light, only affected by the moon, stars, cloud cover, biological luminescence, and aquatic biota (Nightingale et al. 2006). Within the last ~100 years, fish have been exposed to artificial lighting at night (ALAN) and the impacts of ALAN has become a focus of scientific research. This document reviews scientific information that has been published since the existing project was installed and provides updated information on the potential effects of the proposed The Bay Lights 360 Project on steelhead (*Oncorynchus mykiss*), green sturgeon (*Acipenser medirostris*), and Chinook salmon (*Oncorhynchus tshawyscha*), which are listed under the Federal Endangered Species Act (FESA), and California state-listed (California Endangered Species Act; CESA) longfin smelt (*Spirinchus thaleichthys*). Each of these taxa have potential to be present in the Project area. As detailed below, adverse effects to FESA and/or CESA listed fish are not anticipated.

Species Review

Steelhead

Both adult and juvenile steelhead swim past the Bay Bridge. Adult steelhead usually migrate from the ocean to tributaries in the South Bay where they spawn from late December through early April. Their greatest activity occurs from January through March, when flows are sufficient to allow them to reach suitable habitat in far upstream areas. After hatching, juvenile steelhead remain in fresh water for one to four years before migrating to the ocean. The downstream juvenile migration occurs between February and May.

Acoustic telemetry of hatchery-reared steelhead smolts in the San Francisco Bay Estuary (SFBE) confirms that the region is primarily a migratory corridor (Chapman et al. 2015). Smolts were found to rapidly transit through the region (2-4 days), suggesting it is not used for rearing or smoltification, and that feeding in the area is opportunistic (Chapman et al. 2015). The majority of acoustic detections near the Bay Bridge were in the deeper channel along the western side, although this is likely a result of tidal effects and preference for deeper waters as opposed to their affinity for the location.

Unlike other Pacific salmonids, adult steelhead may survive and return to the ocean after spawning, and spawn for multiple seasons (Moyle, 2002). Their movements through the SFBE are likely rapid as well.

Green Sturgeon

Green sturgeon are believed to spend the majority of their lives in nearshore oceanic waters, bays, and estuaries. Green sturgeon in the SFBE spawn in the Sacramento River between March and July, with peak activity from April to June (Moyle et al. 1995, Adams et al. 2002, Miller et al. 2020). Juveniles spend 1-4 years in fresh and estuarine waters before migrating to the ocean (Beamesderfer and Webb 2002). Adults typically migrate into fresh water beginning in late February.

Information on green sturgeon has increased in recent years. Acoustically tagged green sturgeon have been reported to move relatively quickly through the SFBE to their spawning grounds (Miller et al. 2020). Other tracking studies in SFBE demonstrate how sturgeon detections are associated rapid movement and are distinctly directional, suggesting their use of the region as a migration corridor (Kelly et al. 2007; Lindley et al. 2011.). Their non-directional movement within the bay may be associated with foraging, when individuals move slowly and near the bottom (less than 33 feet deep) (Kelly et al. 2007). Green sturgeon have been found to be more active at night than during the day when in coastal marine waters (Erickson and Hightower 2007). However, in the Project region, activity appears to be independent of light level with no discernable peaks in activity at any particular time of day or light level (Kelly et al. 2007). Detections in the South Bay near the Bay Bridge peak between spring and summer, with peak presence between April, May and June (Miller et al. 2020).

Longfin smelt

Longfin smelt are a coastal/estuarine fish that moves into freshwater or slightly brackish waters of the delta and Sacramento/San Joaquin rivers to spawn in winter/spring (Baxter 1999). The life cycle of longfin smelt is complex and they can be found throughout the entire estuary, from the freshwater Sacramento-San Joaquin Delta downstream to the south bay, reaching marine waters (Rosenfield and Baxter 2007; Merz et al. 2013). A conceptual model of their exact timing is provided in Merz et al. 2013. Long-term sampling in the SFBE has shown a consistent pattern of bathymetric distribution, where juvenile longfin smelt tend to occur in greater abundance in deep-water habitats as they migrate into marine environments during summer months (Rosenfield and Baxter 2007). Recent studies confirmed a new spawning and recruitment location for longfin smelt in tidal wetlands at the southern end of the South Bay, suggesting that adults and juveniles migrate under the Bay

Bridge on their seaward and spawning migration (Lewis et al. 2020). Limited information exists for the effects of ALAN on longfin smelt.

Chinook salmon

Several runs of Central Valley Chinook salmon use the SFBE, and their timing within the bay depends on the run. Juveniles migrate through the SFBE on their seaward migration, and enter through either the main-stem of the Sacramento River or through secondary channels south of the main-stem of the Sacramento River (Perry et al. 2009), and adults return through on their spawning migration. Exact migration routes vary (Perry et al. 2009).

Recent tracking studies provide details on Chinook salmon movement and use of the SFBE. For example, acoustic tracking efforts of late-fall Chinook salmon smolts through SFBE (with receivers deployed along the Bay Bridge) provide information on their presence near the Project site as they migrate to sea: smolts were detected along the entire Bay Bridge, with greater detection frequency on the western side of the bridge where water is deeper, which aligns with a larger pattern that smolts rely on deeper channels for migration (Hearn et al. 2013). Their presence near the Bay Bridge was also relatively short in duration, and smolts were estimated to move rapidly through the bay within 2-4 days. Diel migration patterns (over 24-hour periods) of Chinook salmon smolts through the SFBE to sea suggest a routine preference for nocturnal movement (56.97% of detections occurred in the 14-hour 'darkness/night' period) (Chapman et al. 2013). However, the percentage of diel detections was lower in the estuary and nearby the Project site, compared to river spawning sites, the delta and ocean.

Effects on Fishes

Overview and previously described effects

Fishes are potentially affected by ALAN in several ways: changes to essential behaviors such as feeding, schooling, and migration, increased predation, and effects on metabolic processes and reproduction (Nightingale et al. 2006; Longcore et al. 2018a, b; Brayley et al. 2021). Similar to the existing installation, we expect impacts on fish to be associated with operation of the lights and not installation and removal. Once installed, the LED nodes for The Bay Lights 360 Project are not likely to represent a significant change from the existing conditions, even though there will be more nodes and fixtures on the bridge. The Project is not expected to affect spawning, since spawning of the previously described fishes is not likely to occur in the Project area. The Project is also not expected to delay migration past the bridge, because the SFBE and water below the Project area is primarily used as a corridor, and those moving through SFBE are likely using water quality cues to move quickly past the bridge. The Project is not anticipated to increase susceptibility of fishes to predation since the region is primarily a corridor, and as the bay already has high ambient light conditions and the light levels expected to reach the water will continue to be low. For example, it was estimated that approximately <0.02 lux[1] of additional indirect light would reach the water surface (note the Bay Bridge is already lit at night and there is an existing LED light sculpture that was first commissioned in 2013).

[1] Calculated using 12.3 lumens per node, for 5 strings on one suspension cable. Assumes light reaching the surface from each cable is not additive, using 250 ft as the approximate distance above the water.

Since the installation of the existing LED light sculpture, additional studies have been conducted on the impacts of ALAN on fishes. Recent studies cover topics, including, for example, assessments of ALAN impacts on predator density and predation (Nelson et al. 2021) and experiments related to differential attraction of fish to lights with varying wavelengths (Tabor et al. 2021). These studies continue to support findings on spawning, predation, timing and movements that were discussed in the Technical Memo in 2011 for the existing LED installation as described below:

- Adults likely use water quality cues to move quickly into tributaries used for spawning;
- Changes in light levels from shading or dock lights may interrupt salmonid movement, (Johnson et al. 2005; Rondorf et al. 2010), but the greatest impact affecting the movement of juveniles and their susceptibility to predation are from the dramatic changes in light levels during the day, from bright light to shading;
- Strobes deter fish from swimming into portions of dams or navigational locks where there is increased risk of injury or mortality. These strobes are powerful, synchronously flashing lights, not equivalent to light levels reaching the water surface; and
- The activity of certain salmonids in San Francisco Bay, including green sturgeon, are independent of light level without discernable peaks in activity throughout the day or based on light level (Kelly et al. 2007).

Temperature effects

Since the installation of the existing project, the impact of LED light temperature on biota has become a research topic of interest. This is in part a result of the production of LED lights with spectral characteristics that can be controlled becoming more economically viable. Original LED lights provided full spectrum light by coating blue LEDs in phosphor. These LEDs had a high correlated color temperature (CCT), a lighting performance metric measured in degrees Kelvin (K), indicating a high proportion of blue and violet in the emissions (Longcore et al. 2018a). Generally, higher CCTs have greater effects on wildlife (Longcore et al. 2018a). Currently, more efficient LEDs with lower CCTs (associated with warmer, yellowish colors) and varying filtering technologies to reach a desired spectral signature exist and are competitive with older LEDs on the market (Longcore et al. 2018a).

Part of the reason LED light temperature has become a topic of interest is because technology has advanced to a degree where we can control for, and change, the light intensity, temperature, and spectral characteristics. Thus, more marine species are likely to be affected (Tidau et al. 2021, as lights that were previously outside of a species' visible light range and sensitivity may be replaced with lights of spectral signatures that are visible. Since this is a new field, limited species-specific information exists and work is ongoing.

A select few reviews incorporated salmonids into their analyses that help provide a gauge on the impact of light temperature. Longcore et al. 2018a developed an approach to predict the response of various taxa to different lamps based on their spectral output and identify response indices for a range of light sources, in an effort to minimize impacts on wildlife and avoid continual field studies. The two lamps with light temperatures similar to the ones used in the proposed Project (4000K) include the City of Los Angeles's (LA) LED Street Lights (4,300K) and the Yard Blaster (4,160K). These two lamps have nighttime performance indices that predict a lower impact than the impact relative to a 6,500K standard (D65, daylight). Each additional lux (unit of measurement for light intensity and illumination) from LA's LED Street Lights and the Yard Blaster have 50% and 62% of the effect on salmonids as an additional lux from daylight. Given the Project's use of 4,000K LEDs, any increase in luminosity will have a lesser effect than an additional lux of daylight. With the Project's lights being well above the water column, the amount of light reaching the water is further decreased. Longcore et al. 2018a also calculated the actinic power, or spectral response and characteristic of radiation that represents the capacity for a chemical change. Actinic power for different lamps were expressed as a percentage of total power for salmonids, providing a light pollution metric to describe the amount of energy from the lamp's spectrum that impacts a species. Very few of the tested lights concentrate power in areas of the spectrum that are attractive to salmonids, and LA's LED Street Lights and the Yard Blaster are several magnitudes lower than the standard for daylight lux (30 for D65, 27 for LA Lights and 29 for Yard Blaster). Lastly, the slope of the relationship between CCT and impact on juvenile salmonids is relatively steep compared to other taxa, with lower CCTs associated with lower predicted effects. This suggests that lower CCT LEDs may be an effective tool in reducing impacts on juvenile salmon (Longcore et al. 2018b). The light temperature of the display is not expected to change relative to existing conditions.

Although research has been conducted on static versus dynamic LEDs with varying light spectra with respect to effects on fish, it has not fully explored the difference between static versus dynamic lights of varying temperatures. For example, studies have assessed the ability to use LED's of varying spectra for behavioral guidance, particularly as a means to repel them from entrapment (Hansen et al. 2018, 2019). A 2018 experiment testing the movement and spatial responses of salmonids to varying combinations of LED spectra and those with different strobing frequencies found that the behavioral response of Chinook salmon smolts depended on the light spectra and time of day (Hansen et al. 2018). While red light repelled fishes during the day, there was no effect of any light spectra at night. Strobing did not alter fish behavior at night or during the day (Hansen et al. 2018). A follow up study focusing specifically on the ability to use LED strobes of emitting different spectral signatures to divert migrating Chinook salmon smolts found that strobing lights of all wavelengths increased entrainment compared to the absence of light, and entrainment increased at night, with blue and white strobing lights having a stronger effect than strobing red LEDs (Hansen et al. 2019).

Despite the need for ongoing research to identify species-specific responses to dynamic LEDs of varying spectra and temperature, conditions for the proposed Project are not expected to be different from the existing conditions.

Avian Assessment

This section of the document reviews scientific information that has been published since the existing project was installed and provides updated information on the potential effects of the proposed The Bay Lights 360 Project on avian species. As detailed below, adverse impacts to avian groups are not anticipated, except for the potential to affect avian species during installation if nests are impacted during breeding season.

Direct effects of light installation and removal

In general, the installation of the lights should not disturb breeding birds to the point of abandonment, unless the work is to occur in such a way as to directly impact the nests of breeding individuals. If the lights are installed between late fall and early winter, the installation will fall outside the primary breeding season and not be a potential issue. If the lights are installed during the breeding season, it should not significantly increase human activity levels relative to existing conditions with respect to local birds, which are habituated to the traffic and other anthropogenic activities associated with the bridge. If installation is to occur during the breeding season (February-September), it is recommended that a biological monitor be present. If an active nest that might be directly impacted (including disturbing adults to the point of nest abandonment) is detected, the Regulatory Resource Agencies (California Department of Fish and Game / United States Fish and Wildlife Service) should be contacted to consult on avoidance measures. Potentially breeding birds on the Bay Bridge include cormorants and peregrine falcons, however these birds primarily breed below the traffic bearing portions of bridge structures, which lie below the Project activity.

The removal of the lights should involve the same considerations as the installation. If the lights are removed after the avian breeding season (i.e., "late in 2023"), there would be no impacts to breeding birds.

Indirect effects of installed lighting

The lighting should not have a significant impact on birds. Nocturnal migrants collide primarily with towers and other structures that are lit with constant white light (Gauthreaux and Belser 2006). These birds also collide with buildings that have lit windows at night during migration. This phenomenon is most pronounced in eastern and central North America (likely due to increased numbers of migrant birds relative to western North America; Horton et al. 2019) and, with respect to towers, collision typically occurs when guy wires secure the towers. Strobe lights and colored lights (especially green) substantially reduce the collision rates of migrants with lit structures (Gauthreaux and Belser 2006). A field study in the in the North Sea found that nocturnally migrating birds were disoriented and attracted by red and white light, whereas they were "clearly less disoriented by blue and green light" (Poot et al. 2008). Multiple studies have found that flashing or blinking lights are less attractive to migrating birds relative to continuous light (Gauthreaux and Belser 2006; Gehring et al. 2009) and several have found that numbers of birds around blinking modes (intermittent, continuous) did not differ from numbers of birds under darkness conditions (Rebke et al. 2019). In the case of The Bay Lights 360 Project, the lights on display are not single-source, nor static. The movement patterns associated with the lighting scheme should not attract or disorient (leading to collision of) migrants. The addition of constant white lighting sources to the existing light installation on the bridge during nighttime construction could slightly increase the likelihood of collision for nocturnally migrating birds, especially during foggy or stormy nights. However, the bridge is already well lit at night for safety reasons.

As indicated above, higher CCTs generally have greater effects on wildlife (Longcore et al. 2018a). Currently, recommendations for reducing effects on biota vary from less than or equal to 3000 to 2700 (e.g., Longcore et al 2018; International Dark Sky Association: https://www.darksky.org/). In the case of potentially attracting nocturnally migrating birds, we know of no research on the effects of differential light temperature in blinking versus static LED lights. However, research indicates no difference in the attractiveness of dynamic lights that are of different colors (which translates into varying temperature) (Rebke et al. 2019).

Nocturnal migrants (especially passerines or songbirds), may be attracted to the horizon glow and overall lighting of populated areas in general. However, no negative effects of such attraction have been demonstrated. Under current conditions, given the amount of artificial light associated with development in the San Francisco Bay Area (including the current lighting on the Bay Bridge itself), the installation of new LED lights would not significantly add to the overall lighting in the region.

Similarly, the lighting should not affect waterbirds or shorebirds associated with the Bay, including birds breeding on the bridge. These birds are well below portions of the bridge that will be lit by this Project, and are associated with water as opposed to structures. Migrant shorebirds flying at bridge height should be able to easily detect and avoid the bridge in most conditions. Under foggy conditions, the lighting may even increase the probability of detection and avoidance by these birds.

In summary, while higher temperature lights may have an increased effect on birds and other wildlife, research reviewing the attractiveness of blinking lights versus static lights indicates that impacts of static lighting are not associated with dynamic lighting of the same color temperatures.

Overall Summary

The Bay Bridge and vicinity in San Francisco Bay is currently extremely well-lit with artificial light at night. Based on our analysis of the proposed Project and updated scientific information since the original project memo, the additional lighting from the Bay Bridge 360 Project is not anticipated to have additional effects on listed fish or avian species, except for the potential to affect avian species directly during installation if nests are impacted during breeding season. A San Francisco Bay Conservation and Development Commission (BCDC) permit will be required, as the scope of the proposed Project represents a minor repair or improvement, and there are potential listed species in the area

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