Artificial Lighting of Bridges – The Potential Effects on Juvenile Chinook Salmon Passage

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# **Presentation Overview**

- Potential effects artificial night lighting may have on biological organisms
- Highlight research
   performed to assess
   impacts of artificial light
- Overview of Winter-run Chinook population
- Brief overview of Sundial Bridge and Cypress Road Bridge and recent efforts to reduce illumination from both
- Highway 44 Bridge
- Possible solutions and next steps



#### **Potential Effects of Artificial Lighting**

- Natural light plays fundamental role in the biology of organisms,
- Artificial light has the potential to disrupt the biology of many species,
- Rich and Longcore (2006) concluded that artificial night lighting may alter the spatial distribution, diel movements, demography, and overwintering success of some freshwater organisms,
- Light is one of the most potent agents interacting with our biological systems,
- Artificial lighting present on over-water structures may:
  - result in a fish passage impediment,
  - disorient migrating juvenile salmonids,
  - compromise their ability to avoid nocturnal predators.



# **Lighting Effects Continued**



- Due to complex nature of light in water, fish have evolved welldeveloped and highly specialized eyes,
- The Oncorhynchus spp. eye contains large number of rods and cones adapted for vision in both bright and dim light,
- When light levels change abruptly, the eye adapts quickly in order to distinguish objects in the background,
- When artificial light is bright, the eye will not respond to a dim light,
- Makes it difficult for juvenile salmon to visually detect predators in the areas beyond the brightly lit area.

# Scientific Research - The Effects of Artificial Lighting on Salmonids

- Scientific research on effects of artificial lighting on salmonid populations has been limited,
- However, studies have been conducted to address this issue
  - results indicate that increased light intensity appears to slow or stop out-migrating salmon fry, and increase feeding patterns, making them more vulnerable to predation (McDonald 1960; Patten 1971; Ginetz and Larkin 1976; Tabor et al. 2004).,



Roger Tabor - USFWS

 Juvenile salmonids reduce their vulnerability to predators by emigrating at night (McDonald 1960),

- Juvenile salmonids feed primarily on drifting invertebrates during sunrise and dusk, but typically do not feed during complete darkness (Brett and Groot 1963; Fraser et al. 1997),
- The presence of artificial lighting and illumination of the water may facilitate juvenile salmonid feeding = increase their vulnerability to predation at night (Rondorf et al. 2010),
- Ginetz and Larkin (1976) found predation of sockeye salmon (*Oncorhynchus nerka*) fry by rainbow trout increased as light intensity increased in the artificial streams they used during their research.

### **Research on Salmonids - Continued**

- Nighttime lighting of bridges = possible predator trap for juvenile salmonids migrating downstream from spawning and rearing areas above the illuminated bridge,
- Celedonia et al. (2011) found:
  - At night, Chinook were attracted to areas where street lamps on a bridge cast light into the water = increased risk to predation,
  - Negative consequences to Chinook might be minimized by reducing the intensity of light reaching the water surface.
- Tabor et al. (2004) found:
  - In the Cedar River in Washington, predation of migrating sockeye salmon fry increased as a result of artificial nighttime lighting, a
  - The lighting may be one of the factors in the overall decline of the Cedar River sockeye salmon population.
  - With no predators present, sockeye fry migrated at a faster rate under complete darkness (0.001 Lux)) than in the other two light intensities assessed (1.08 and 5.4 Lux).



#### Sac River and Tributaries

- Studies have been conducted to assess seasonal, spatial and diel distribution patterns of juvenile chinook,
- In Clear Creek From Dec 2011 June 30, 2012 USFWS found that 80% of fish caught in RST occurred from 1800 to 2300. Peaks took place from 2000 to 2100.
- During same time sunset times ranged from 1629 (Dec 2011) to 2031 (June 2012).
- Similar results were observed in two trials in May and June 2011.
- Mainstem Sac Gaines and Martin (2002) found relative abundance of juvenile Chinook in RST's below Red Bluff Diversion Dam was greatest during nocturnal periods.
- It appears most juvenile Chinook outmigrate under cover of darkness. Recent data show cyclical patterns of migration that correspond to the lunar cycle pulses of outmigration with new moon, decreasing as moon becomes full.
- Artificial lighting could inhibit out-migration, resulting in delays and increased predation.
- Tabor et al. (2004) results show that sockeye fry that encountered artificially lit areas held position in low velocity and migration was delayed. Migration resumed shortly after lights were turned off.

#### Chinook Salmon Populations in the Mainstem Sacramento River

Total Main-stem Sac River Population				% Spawning above Sundial Brg.		
Year	Late-fall	Winter	Fall-Run	Late-fall	Winter	Fall-Run
2000	8702	1,350	96,688	0%	6%	6%
2001	19276	8,224	75,168	26%	35%	7%
2002	36004	7,441	65,690	27%	49%	9%
2003	5532	8,218	89,229	58%	66%	6%
2004	8884	7,869	43,604	84%	16%	10%
2005	10603	15,839	57,012	47%	52%	27%
2006	10175	17,290	55,468	35%	35%	14%
2007	15340	2,541	17,061	57%	52%	20%
2008	3979	2,830	24,743	48%	51%	1%
2009	3424	4,537	5,827	73%	16%	25%
2010	4365	1,596	16,372	72%	48%	16%
2011	3725	824	11,592	73%	6%	34%

Table 1. Adult populations of Chinook salmon runs in the main-stem Sacramento River for years 2000 to 2011, (from Princeton to Keswick Dam). Grey area indicates populations whose juveniles could not have been impacted by Sundial Bridge lighting.

- As shown above winter-run population in 2004 when Sundial Bridge was completed was 7,869.
- In 2005 and 2006 population topped out at 15,839 and 17,290, respectively.
- In 2007 3 yrs. after Bridge opened and night lighting first occurred population declined to 2,541 (2004 Year Class).
- In 2008 and 2009 (05' and 06' year classes) populations were 2,830 and 4,537.
- \*while declines cannot be specifically attributed to the lighting of the bridge, it is an interesting correlation.

- Causes of declines can be many and no one cause likely solely responsible,
- However with correlation of timing between Bridge completion and corresponding declines in returning adults, <u>and</u>
- Research has demonstrated artificial light has detrimental effects on emigrating juvenile salmonids,
- This issue warranted further discussion to find solutions to avoid and minimize impacts from sources of artificial light.

#### White Paper Outlines Research and Effects

- Prepared a White Paper Potential Effects of Artificial Light from the Sundial Bridge on Juvenile Chinook Salmon Migratory Behavior and Predation by Predatory Fishes in the Sacramento River, Redding, Shasta County.
- Outlines the research and issues related to artificial lighting and effects on fish.
- Copies are available upon request.



# **Sundial Bridge**

- Designed by renowned Spanish architect Santiago Calatrava,
- A cantilever spar cable-stayed bridge for bicycle and pedestrian access that spans the Sacramento River in Redding, Shasta County, California,
- Suspended by steel cables from a single 217-foot tall pylon and spans more than 700 feet across the river without touching the water,
- Design criterion to avoid instream impacts to protect the salmon spawning areas in the vicinity of the Bridge,
- Twenty three feet wide and weighs more than three million pounds,
- Construction began in 1999 was completed in 2004, officially opening on July 4, 2004.



## **Bridge Design Continued**



- Calatrava's design called for a pedestrian walkway of nonskid glass illuminated at night from underneath by 210 lights,
- Glass deck is illuminated from underneath with 1/3 of the lights pointing downstream, 1/3 facing upstream, and the remaining 1/3 facing up towards the Bridge deck,
- From dusk to dawn the Bridge and the Sacramento River in the vicinity of the Bridge are illuminated,
- Bridge is undoubtedly an architectural masterpiece, a local icon, a major tourist attraction, and designed to be environmentally sensitive in many ways,
- However night time lighting of the Bridge and Sacramento River may be causing detrimental effects to salmon populations that spawn and rear upstream and in the vicinity of the Bridge.

# Light Measurement Results

- For reference moonless clear night = 0.002 lux, and family living room = 50 lux.,
- Took measurements on June 14, 2012 in 6 different locations beginning at 1012 P.M., including under Cypress Bridge as comparison:
  - Location 1 Under Sundial at EOW = 25.55 lux
  - Location 2 100' downstream @EOW = 1.34 lux
  - Location 3 400' downstream @EOW = 0.01 lux
  - Location 4 In parking lot 6.95 lux
  - Location 5 Directly under street lamp
     = 19.56 lux
  - Location 6 Cypress Road Bridge 3.47 and 7.14 lux



#### CEQA Mitigated Neg. Dec. – Mitigation Monitoring Program

- Issue of potential biological impacts from artificial lighting of the Bridge was acknowledged and addressed during the environmental review and approval process pursuant to CEQA,
- Mitigation measures were identified/included in *Mitigation Monitoring Program* for the Pedestrian Bridge at Turtle Bay, Redding, California, Addendum to the Mitigated Negative Declaration (Use Permit 43-97, SCH 1995023013).
- Impact: Biological Resources BR-9 Fisheries Impacts Due to Lighting of Surface Waters, states:
  - "Artificial flood lighting along surface waters is known to attract fry and juvenile salmonids, and other predator fish species."
- **Mit. Meas.:** *BR-9m*: "No direct lighting onto the river shall occur at either approach or from the bridge." The City of Redding Community Services Department is responsible for monitoring and implementing the above mitigation measure.

#### Steps Taken to Reduce Lighting on the Sundial and Cypress Bridges

Numerous meetings with the City of Redding
Several lighting assessments over the last year – including joint assessments with the City

Collaborative efforts to find agreeable solutions

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#### Management Changes to Lighting of the Sundial Bridge

- Through the numerous assessments conducted, and testing various circuit configurations, and a goal of reducing intensity to as close to 1 LUX as possible, light levels were reduced from the original levels of 25 LUX to 3 LUX,
- The agreed upon circuit configuration meets the concerns the City had for safety on the bridge deck, as well as resulting in significant reductions in illumination of the river,
- The City and CDFW have reached an interim agreement (long-term solution of LED retrofit is being developed),
- From Aug 15 Nov 1 (peak Winter-run outmigration period), from sundown till 12 a.m. lighting on the Sundial will remain significantly reduced through implementing the agreed upon circuit configuration.
- Between 12 a.m. and sunrise lighting will be further reduced to a minimum safety level.



# **Cypress Bridge**

- There are 40 under-deck lights (70 watt bulbs) per bridge span, 5 spans, for total of 200 under-deck lights,
- Results in significant levels of artificial light reaching the river,
- Recent assessment on July 30, 2013, we took light level measurements and recorded 10.6 LUX,
- Turned off second span and recorded 0.73 LUX,
- Significant reduction by turning off spans.



#### Management Changes to Lighting of Cypress Bridge

- City agreed to change lighting on the Cypress Bridge to:
  - During critical outmigration period of Aug 15 Nov 1, beginning on Sun Thurs, from sundown to 11 p.m. – all under-deck lights off, after Nov 2 lights will be operated as det. By City
  - Everyday between 11 p.m. and sunrise all under-deck lights will be off. This will continue indefinitely.
- Changes result in significant reductions of levels of artificial light reaching the river.



#### Highway 44 Bridge

- Street lamps on both sides of the bridge, approximately every 100 feet,
- Results in illumination of the river:
  - During assessment in January 2013 we recorded light levels of 6.5 LUX at the waters edge.
- Possibly simple changes to light fixtures will result in significant reductions of levels of artificial light reaching the river.
- Currently working with Caltrans to find an agreeable solution to reduce light levels.



### **Possible Solutions and Next Steps**

- To reduce the illumination of the Sac River from the 44
   Bridge possible changes could include:
  - Install shields on lights directly over the river,
  - Turn off portion of lights if not needed,
  - Set lighting on timers,
  - Change the type of bulb used,
  - ???? Other possibilities
- Consider efforts to reduce artificial light pollution in your area, to reduce impacts to our fishery resources.



Shield added to cobra-head streetlight.



# Additional Resources Available

- UC Davis Lighting Technology Center
  - <u>http://cltc.ucdavis.edu/</u>
- The Urban Wildlands Group
  - <u>http://www.urbanwildlands.org/</u>
- Darksky
  - <u>http://www.darksky.org/assets/media/MMPG.pdf</u>
- Skykeepers
  - <u>http://www.skykeepers.org/vancalsal.html#Vanishing</u>
- Other websites:
  - <u>http://physics.fau.edu/observatory/lightpol-environ.html</u>

# **Questions / Discussion**

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