A SUMMARY OF RECENT STUDIES THAT EXPOSED CAGED FISH TO PILE DRIVING SOUNDS

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West Coast Fish Cage Studies
2004-09

• San Francisco-Oakland Bay Bridge East Span Replacement, CA 2003-04

• Port of Oakland, CA 2004

• Port of Seattle, WA 2006-07

• Port of Anchorage, AK 2009

• Mad River, CA 2009
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

Principal investigators: Bud Abbott Ph.D., James Reyff, Richard Rodkin PE

Funding and assistance: Caltrans National Marine Fisheries NOAA, and Parson Brinkerhoff (Ivy Edmonds)
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

Project

• Driving 2.4m (8 ft) diameter cast in steel pier foundation piles during production
• Air bubble curtain system used to reduce sound

• Fish exposures in San Francisco Bay during bridge foundation pile driving – two species:
  – Steelhead
  – Shiner perch
• Most fish exposed when bubble curtain operating
• Included bubble curtain on/off exposures
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

Fish holding tanks inside the Greenhouse at Romberg Tiburon Center for Environmental Studies.

Fish in transport bag acclimating to the holding tank water.
Coolers and cages being loaded onto one of the research vessels.
Hydrophones being placed inside the cages.
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

Retrieving cage with fish.
Live fish after exposure to attenuated pile driving operation sound
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

• Study meant to evaluate compliance with Biological Opinion

• Only Peak sound pressure used as acoustic measure
  – Immediate mortality at 69 meters where peak SPL > 204 dB
  – Delayed mortality at 440 meters where peak SPL > 180 dB

• Problems with fish
  – Mostly attributable to transport issues (e.g., low dissolved O₂)
  – Overall fish health (e.g., parasites and elevated bacteria levels)
  – Long days with fish away from lab (transport by boat)
  – Construction delays
  – Construction not accommodating to study
San Francisco-Oakland Bay Bridge East Span Replacement 2003-04

8 days of testing, with 16-17 exposures of Peak SPLs 180 to 206 dB for air bubble curtain and 209 dB unattenuated

Findings:
• No immediate mortalities for fish exposed to pile driving sounds with peak SPLs up to 209 dB. Statistically, delayed mortalities did not occur beyond 69 meters

• Fish exposed to peak SPLs of up to 209 dB. There were some observed mortalities, but cannot be confirmed to result from acoustic-related injuries

• Crude necropsies were conducted, but did not follow appropriate procedures to identify injuries (report suggests barotrauma injuries)
Port of Oakland Wharf Reconstruction
2004

Principal investigators: Bud Abbott Ph.D., James Reyff, Gary Marty Ph.D DVM

Funding and/or assistance: Manson Construction, Carpenters Union 46/AFL-CIO, Dutra Dredging, Levin Richmond Terminals, and Port of Oakland
Project

• Rebuild Ship Berth to accommodate larger ships
• Drive of 0.6m (24-inch) concrete piles (lots of them)
• Part of larger Port expansion/modernization project
Port of Oakland Wharf Reconstruction 2004

Study

• Expose fish to pile driving sounds and identify any near-term effects

• Three species:
  – Steelhead
  – Shiner perch
  – Northern Anchovy

• Unattenuated pile driving, fish exposed at 10 m (33 ft) distance, 8-m (25 ft) depth

• Only Peak sound pressure used as acoustic measure
Port of Oakland Wharf Reconstruction 2004

Cage with hydrophone inserted through the mesh at the top of cage

Retrieving fish from cage
Port of Oakland Wharf Reconstruction
2004

Assessed post exposure behavior

On-site necropsy for external and internal injuries
Port of Oakland Wharf Reconstruction
2004

Four exposures with typical Peak SPLs 185 to 189 dB unattenuated (maximum of 192 dB). Exposures were 200 to 400 pile strikes

Although Cumulative SEL not measured, it could be estimated from per strike data

- Exposure #1 - 400 strikes with typical SEL(strike) of 165 then cumulative SEL = 191 dB
- Exposure #2 - 200 strikes
  Cumulative SEL = 186 dB
- Exposure #3 - 200 strikes
  Cumulative SEL = 188 dB
- Exposure #4 - 200 strikes
  Cumulative SEL = 190 dB
Findings:

• No significant differences in behavior noted after exposure between control and exposed fish were noted

• No significant differences in near-term mortality rate between control and exposed fish (delayed mortality not studied)
  – All steelhead and perch survived
  – Some mortality with anchovies (control and exposed fish)

• No significant differences in tissue damage between control and exposed fish
Port of Seattle, Fishermen’s Terminal
2006-07

Principal investigators: Gregory Ruggerone, PhD, Scott Goodman, Robert Miner

Funding and/or assistance: Port of Seattle, American Construction Company, Salmon Bay Boat Works, and Washington Dept. of Fish and Wildlife
Port of Seattle, Fishermen’s Terminal 2006-07

Study

• Driving of 0.5m (20-inch) diameter steel pipe piles
• Expose juvenile coho salmon to 1 and 14 pile driving events during a single workday
• Observe and video record fish response
• Hold fish for 10 to 19 days after exposure and periodically observe behavior
• Fish feeding began 4 days after exposure and observe feeding habits
• Perform non-histological necropsies on fish either 10 or 19 days after exposure
Port of Seattle, Fishermen’s Terminal
2006-07

Exposure

- Juvenile coho salmon exposed to 1 pile driving event (97 pile strikes)
  - Max. Peak SPL = 194 dB
  - Cumulative SEL = 186 dB

- Juvenile coho salmon exposed to 14 pile driving events in one work day (1,627 pile strikes)
  - Max. Peak SPL = 208 dB
  - Cumulative SEL = 207 dB
Port of Seattle, Fishermen’s Terminal
2006-07

Findings

• All juvenile coho salmon exposed to 97 pile strikes (cumulative SEL 186 dB) survived for the 10 and 19 day holding periods

• All juvenile coho salmon exposed to 1,627 pile strikes (cumulative SEL 207 dB) survived for the 10 day holding period

• Necropsies for 200 fish exposed to all 14 pile driving events revealed no external or internal injuries related to pile driving sound exposure

• Subtle behavioral changes of fish were noted in response to pile strikes

• Fish readily consumed hatchery food during the first and subsequent feeding trials (5 to 19 days after exposure)
Port of Anchorage Marine Terminal Redevelopment Project - 2009

Principal investigators: Hart Crowser/Pentech, Illingworth & Rodkin, URS

Funding and/or assistance: Port of Anchorage, ICRC, U.S. DOT Maritime Administration
Mad River Bridges Replacement Project
Arcata, CA  2009

Principal investigators:  ICF Jones & Stokes and Illingworth & Rodkin
Funding and/or assistance:  Caltrans, FHWA
Mad River Bridges Replacement Project
Arcata, CA  2009
Mad River Bridges Replacement Project
Arcata, CA  2009

Multiple cages simultaneously placed in river
Mad River Bridges Replacement Project
Arcata, CA 2009

Project

• Construction of new replacement bridge

• Pile drive 2.2m (7.2 ft) diameter cast in steel shell piles next to the Mad River

• Study conducted in summer when river is shallow ~ 1.5 m (5 ft) or less
Mad River Bridges Replacement Project
Arcata, CA 2009

Study
• Expose steelhead (2 to 17 grams) to impact pile driving sounds and identify any physical injuries.

Method
• In-situ exposure of fish during impact pile driving at Pier closest to river
  – Exposures at 4 positions (35 to 150 m)
  – Reference exposure (350 m)

• Simultaneously measure peak sound pressure and sound exposure levels

• Monitor fish for immediate physical effects of pile driving sound exposure
  – Observations of mortality
  – Gross observations and necropsy
Mad River Bridges Replacement Project
Arcata, CA  2009
Mad River Bridges Replacement Project
Arcata, CA  2009
Findings

- Exposures were conducted on 4 separate days of pile driving where number of pile strikes ranged from 1,100 to 4,306

- Measured sound pressures varied by position, with loudest levels at closest positions:
  - Peak SPLs ranged from 165 to 188 dB
  - Cumulative SEL levels ranged from <150 dB to 194 dB

- SEL levels per strike exceeded 150 dB only at positions 50 m or closer to pile driving

- Sound pressure levels were detectable at Reference position, but well below NOAA Interim criteria.

- On-site necropsies of all exposed and control fish conducted following each trial, as well as histopathology of the fish from the cages closest to the pile-driving and control fish, showed no physical trauma that could be related to exposure to underwater noise from pile-driving

- Similarly, hematocrit and plasma cortisol levels were not significantly related to exposure to noise generated by pile-driving.
Questions

James Reyff