Hydroacoustics 101:

How It Works, Why It Matters, and What To Do With It In CEQA
Panelists

Keith Pommerenck, Acoustical and Air Quality Scientist with Illingworth & Rodkin, Inc.

Daniel Chase, Fisheries Biologist with WRA, Inc.

Justin Semion, Aquatic Ecologist with WRA, Inc.
Mr. Pommerenck provides consulting services in the area environmental noise and air quality issues with over 33 years of professional experience (21 years with Caltrans and 12 years with Illingworth and Rodkin) in preparing technical air, noise, and vibration reports for inclusion in CEQA and NEPA environmental documents for transportation projects. Mr. Pommerenck led numerous hydroacoustic field investigations for bridge construction projects. He was the field leader for the Ten Mile River Bridge project that included several months of acoustic measurements and compliance reporting. Mr. Pommerenck’s expertise was routinely relied upon for solutions to reduce underwater sound when construction activities were in jeopardy of exceeding permit underwater noise conditions. Mr. Pommerenck also led Illingworth & Rodkin’s hydroacoustic monitoring efforts on other notable projects that included the Humboldt Bay Bridges Seismic Retrofit, Mad River Bridge replacement, the Klamath River Bridge emergency repair (during salmon migration), Test Pile portion and the construction portion of the Explosive Handling Wharf 2 project for the navy and several other smaller projects in California, Oregon, and Washington. Mr. Pommerenck has also assisted transportation agencies in assessing sound impacts to wildlife in marine environments (both airborne and underwater).
Panel Overview

History of Hydroacoustic Analysis

Technical Specification of Underwater Sound

Biological Effects of Underwater Sound

Regulatory Application of Hydroacoustic Impacts

CEQA Application of Hydroacoustic Impact Evaluation

Questions
Hydroacoustics – Anthropogenic Sounds

Keith Pommerenck
and James Reyff
Illingworth & Rodkin, Inc.
Petaluma * Marysville * Denver
Hydroacoustic Impacts - History

• Pile Driving
• Explosives
• Other construction sounds
SFOBB Pile Installation Demonstration Project - conducted in 2000

- Driving 8ft diameter steel piles
- Over 300 feet long
- Tested two sound attenuation systems
- Fish harmed
New Benicia-Martinez Bridge

- Driving 8ft diameter steel piles
- Some hard substrates
- Fish harmed
- Construction stopped

- Successfully attenuated sound to resume
Fisheries Hydroacoustic Working Group

- Developed to improve and coordinate information on fishery impacts due to underwater sound pressure caused by in-water pile driving
- Developed known information on sound effects on fish
- Identified interim sound thresholds
- Developed guidance
Technical Specification of Underwater Sound

• Fundamentals of hydroacoustics
• Anthropogenic sounds
• Underwater sound control
• Underwater sound measurement systems
• Technical guidance
Fundamentals -
Basic Sound Descriptors

– Peak Pressure (Peak)
  • Over/under pressure

– Root Mean Square (RMS)
  • Pulse
  • Continuous time averaged

– Sound Exposure Level (SEL)
  • Pulse, pile driving event, workday
Decibel to Describe Sound

“A logarithmic measure of the sound strength”

Or in mathematical terms:

The base 10 Logarithmic function of the ratio of the pressure fluctuation to a reference pressure
Calculation of Sound Pressure Level

\[ SPL = 10 \log \left( \frac{p}{p_{\text{ref}}} \right)^2, \text{ dB} \]

or

\[ SPL = 20 \log \left( \frac{p}{p_{\text{ref}}} \right), \text{ dB} \]

where \( p_{\text{ref}} \) is the reference pressure:

- For air, \( p_{\text{ref}} = 20 \mu \text{ Pa} \)
- For water, \( p_{\text{ref}} = 1 \mu \text{ Pa} \)
- As a result:

\[ SPL_{\text{water}} = SPL_{\text{air}} + 26 \text{ dB} \]

\[ 1 \text{ PSI} = 6,895 \text{ Pascals} = 197 \text{ dB re 1}\mu\text{Pa} \]
Sound Level Metrics

- Peak
- Average (abs)
- RMS
- Peak-to-peak
## Typical Sound Levels

<table>
<thead>
<tr>
<th>Sound Source</th>
<th>Sound Pressure Level</th>
<th>Pascals</th>
</tr>
</thead>
<tbody>
<tr>
<td>High explosive at 100m</td>
<td>220</td>
<td>100,000</td>
</tr>
<tr>
<td>Airgun array at 100m</td>
<td>200</td>
<td>10,000</td>
</tr>
<tr>
<td>Unattenuated Pile Strike at 100m (SFOB, Benicia)</td>
<td>180</td>
<td>1,000</td>
</tr>
<tr>
<td>Large ship at 100m</td>
<td>160</td>
<td>100</td>
</tr>
<tr>
<td>Fish Trawler passby (low speed) at 20m</td>
<td>140</td>
<td>10</td>
</tr>
<tr>
<td>Background with boat traffic</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Continuous Pure Tone (400 Hz) at 190 dB Peak

Sound Pressure Amplitude, μPa

Time, sec.
Explosive – Underwater Blast
Single Pile Driving Impulse
From SFOBB
Blast (25 PSI, 225 dB), Pile Drive Impulse (203 dB Peak) and 400 Hz Pure Tone (190 dB Peak)
Impact Pile Driving Sounds

30 Inch Pile

Pressure (I)

Time (sec)

5/12/2002 - 10:52 PM
Single Pile Driving Pulse

Peak Sound Pressure Level: *Maximum absolute value of the instantaneous sound pressure that occurs during a specified time interval* (ANSI S12.7)
RMS Sound Pressure Level

\[ p_{\text{rms}} = \sqrt{\frac{1}{T_f - T_i} \int_{T_i}^{T_f} p^2(t) \, dt} \]

**Sound Pressure Level**: Decibel measure of the square root of mean square (RMS) pressure. For impulses, the average of the squared pressures over some time period.
Sound Exposure Level (SEL)

Sound Exposure: time integral of frequency weighted squared instantaneous sound pressure (ANSI S12.7).

Proportional to Acoustic Energy

(Richardson, et al. 1995).
Sound Propagation

• Complicated problem
  – Well bounded environment
  – Extended source
  – Ground borne sound
  – Sound propagating through saturated soils

• Use of 15 Log drop off (4.5 dB/dd)

• Measured drop off rates
  – 10 Log to 30 Log – considerable range
Anthropogenic Sound Sources

- Pile driving
  - Impact driving (loudest)
  - Vibratory driving
  - Impact near water
- Demolition/explosives
- Continuous sources
Impact Pile Driving
Different Types of Conditions

On Land Near Water
Vibratory Pile Driving

- Much lower amplitude sounds than impact pile driving (20 to 30 dB lower)
- Sounds tend to be more continuous
- Higher Frequency sounds
Minimization Measures

• Air bubble curtains
  – Confined / unconfined

• Dewatered cofferdams

• Avoid in water driving
  – Move footings out of water

• Construction windows
  – Avoid times when species are present
Measurement Systems

- Hydrophones
- Signal conditioning
- Signal processing
- Recording
- Descriptors
Basic Hydrophone System

- Analyzer, SLM, recorder
- Power Supply
- Charge Converter
- Hydrophone Cables
- Hydrophone (piezoelectric)
Pressure Sensors

Blast Transducer

Hydrophones
Caltrans Guidance Manual

Provides biologists, engineers and consultants guidance related to environmental permitting of pile driving projects in or near water

- Fundamentals of hydroacoustics
- Fundamentals of noise effects to fish
- Guidance to assess pile driving impacts to fish (hydroacoustic)
- Appendices

Caltrans Guidance Manual appendices

- Compendium of Pile Driving Sound Data
- Procedures for Measuring Pile Driving Sound
  - Hydrophone and equipment selection
  - Data analysis/Quality control
  - Reporting

Biological Effects of Underwater Sound:
Overview for Fish and Marine Mammals

Presented By:
Daniel Chase, MS
Fisheries Biologist
WRA, Inc.
Talk Outline

Fish
- What and how sound is perceived
- Two Hearing Groups
- Hydroacoustic Effects

Marine Mammals
- What sound is used for
- Five Hearing Groups
- Hydroacoustic Effects
What do fish use sound for?

Determine the direction of a sound source

- Communicate
- Locate prey
- Avoid predators
- Perceive their environment
Fish Anatomy– How Fish Perceive Sound

1. Otoliths - inner ear structure

Source: thefisheriesblog.com
Fish Anatomy—How Fish Perceive Sound

1. Otoliths - inner ear structure
2. Swim bladder
Fish Anatomy – How Fish Perceive Sound

1. Otoliths - inner ear structure
2. Swim bladder
3. Lateral Line
Fish Hearing Groups

Hearing thresholds of representative species

- Atlantic salmon (Salmo salar)
- Plaice (Pleuronectes platessa)
- Atlantic cod (Gadus morhua)
- Scaled Sardine
- Goby (Gobius niger)
- Bull shark (Carcharhinus leucas)

Fish species have different hearing thresholds

Source: Hastings & Popper 2005 Effects of Sound on Fish
Fish Hearing Groups

Hearing Specialists

Connection between ear and swim bladder
Capable of hearing over a wide range of frequencies

Example Species

American Shad

Fathead minnow
Fish Hearing Groups

**Hearing Generalists**

No connection between ear and swim bladder
Narrower range of frequencies

**Example Species**

- Chinook salmon
- Steelhead/Rainbow trout
How Hydroacoustics Can Effect Fish

Behavioral Effects

*Examples:*

- Causing fish to vacate or leave an area,
- Move or leave cover or territories,
- Exposure to predators,
- Interfere with foraging and prey capture,
- Elevated stress response
How Hydroacoustics Can Effect Fish

Behavioral Effects

Examples:

Injury

• Temporary threshold shifts (TTS)
• Permanent threshold shifts (PTS)
• Auditory tissue damage
• Capillary ruptures
• Reduces individuals fitness
How Hydroacoustics Can Effect Fish

Behavioral Effects

Examples:

- Barotrauma
  - Swim bladder and tissue rupture
  - Traumatic brain injury
  - Neurotrauma

Injury

Mortality
Marine Mammals use sound for:

- Communication
- Perceive their environment
- Locate prey
- Avoid predators/protection
Marine Mammal Hearing Groups

Because not all marine mammals use sound or hear the same…

Five basic hearing groups have been established
Marine Mammal Hearing Groups

3 Cetacean Groups

Low-Frequency [humpback whale, blue whale]
Marine Mammal Hearing Groups

3 Cetacean Groups

Low-Frequency [humpback whale, blue whale]

Mid-Frequency [killer whale, bottlenose dolphin]
Marine Mammal Hearing Groups

3 Cetacean Groups

Low-Frequency  [humpback whale, blue whale]

Mid-Frequency  [killer whale, bottlenose dolphin]

High-Frequency [harbor porpoise]
Marine Mammal Hearing Groups

3 Cetacean Groups: Low-Frequency; Mid-Frequency; High-Frequency

2 Pinniped Groups: Phocids [elephant seal, harbor seal]
Marine Mammal Hearing Groups

3 Cetacean Groups:  Low-Frequency; Mid-Frequency; High-Frequency

2 Pinniped Groups:

Phocids  [elephant seal, harbor seal]

Otariids  [sea lions, sea otters]
How Hydroacoustics Can Effect Marine Mammals

Behavioral Effects

Examples:

• Vacate or leave an area – haul out locations
• Auditory masking,
• Interfere with communication,
• Distress and elevated stress response,
• Interfere with foraging and prey capture
How Hydroacoustics Can Effect Marine Mammals

Behavioral Effects

Examples:

Injury

- Temporary threshold shifts (TTS)
- Permanent threshold shifts (PTS)
- Auditory tissue damage
- Lung or gastrointestinal tract injury
- Reduces individuals fitness
How Hydroacoustics Can Effect Marine Mammals

Behavioral Effects

Examples:

Injury

• Stranding
• Barotrauma
  • Traumatic brain injury
  • Neurotrauma

Mortality
Summary

Fish and Marine Mammals

• Underwater sound important for perceiving and interacting with the environment

• Species hear and use sound different – hearing group categories

• Elevated hydroacoustic levels can cause harmful effects – behavioral, injurious, and/or potentially fatal
Thank you!

Contact:

Dan Chase
Fisheries Biologist
WRA, Inc.
Email: Chase@wra-ca.com
Phone: 415-454-8868
Regulatory Application of Hydroacoustic Impacts

Keith Pommerenck
and James Reyff
Illingworth & Rodkin, Inc.
Petaluma * Marysville * Denver
Thresholds for Fish

Interim acoustic criteria – 2008

• Onset of injury expected:
  – Peak pressure $>206$ dB
  – $SEL_{12hr} = 187$ dB (fish $>2$ grams)*
  – $SEL_{12hr} = 183$ dB (fish $<2$ grams)*
    *150dB $SEL_{strike}$ = effective quiet

• Effect area = $>150$ dB RMS (Behavioral)

Except for very short events, SEL is dominant threshold
Assessing Effect Areas - Fish

• Determine near source sound levels
  – Use compendium – type, size, environment, etc...

• Estimate sound propagation rate (use 15 Log if unknown)

• Identify amount of activity
  – #piles, pile strikes, locations

• Effect of sound control measures
**NMFS Fish Calculator**

- Simple model relying on available data
- Uniform spreading loss
- Applies effective quiet to SEL levels

**Spreadsheet inputs in Green Cells**

<table>
<thead>
<tr>
<th>Project Title</th>
<th>AEP Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile information (size, type, number, pile strikes, etc.)</td>
<td>36-inch diameter steel shell pile, 1 hour pile driving 1 strike every 1.5 seconds = 2,400 strikes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acoustic Metric</th>
<th>Peak</th>
<th>SEL</th>
<th>RMS</th>
<th>Effective Quiet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured single strike level (dB)</td>
<td>211</td>
<td>184</td>
<td>192</td>
<td>150</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

- Estimated number of strikes: 2400

| Cumulative SEL at measured distance | 217.80 |

<table>
<thead>
<tr>
<th>Distance (m) to threshold</th>
<th>Onset of Physical Injury</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak dB</td>
<td>Cumulative SEL dB**</td>
<td>RMS dB</td>
</tr>
<tr>
<td>Fish ≥ 2 g</td>
<td>206</td>
<td>187</td>
</tr>
<tr>
<td>Fish &lt; 2 g</td>
<td>15</td>
<td>22</td>
</tr>
</tbody>
</table>

**This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)**

Notes (source for estimates, etc.)
### Project Title

Pile information (size, type, number, pile strikes, etc.)

#### Peak SEL RMS Effective Quiet

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<th>Distance (m)</th>
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#### Fish Behavior

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<th>dB</th>
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<tr>
<td>206</td>
<td>187</td>
<td>183</td>
<td>150</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>331</td>
<td>541</td>
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</table>

#### Notes (source for estimates, etc.)

AEP Project

36-inch diameter steel shell pile, 1 hour pile driving 1 strike every 1.5 seconds = 2,400 strikes

** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)

- **Same as previous**
- **Air Bubble Curtain -8 dB**
# Sensitivity of Transmission Loss Constant

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<td></td>
<td></td>
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<tr>
<td>Cumulative SEL at measured distance</td>
<td>218</td>
<td></td>
<td></td>
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</table>

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<thead>
<tr>
<th>Distance (m) to threshold</th>
<th>Peak</th>
<th>Cumulative SEL**</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission loss constant (15 if unknown)</td>
<td>208 dB</td>
<td>187 dB</td>
<td>183 dB</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>22</td>
<td>1131</td>
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</table>

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</tr>
<tr>
<td></td>
<td>17</td>
<td>20</td>
<td>648</td>
</tr>
</tbody>
</table>
Thresholds for Marine Mammals

PTS Onset Criteria (used for Level A)

• Continuous and impulsive thresholds
• Peak and SEL thresholds
• Functional hearing groups
  – Low-frequency cetaceans (7 Hz to 35 kHz)
  – Mid-frequency cetaceans (150 Hz to 160 kHz)
  – High-frequency cetaceans (275 Hz to 160 kHz)
  – Phocid pinnipeds (e.g., harbor seals) (50 Hz to 86 kHz)
  – Otariid pinnipeds (e.g., sea lions) (60 Hz to 39 kHz)
Thresholds for Marine Mammals

The point of this slide is that these are complex! Dual thresholds, different types of sounds and frequency weightings.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>PTS Onset Acoustic Thresholds*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Received Level)</td>
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<tr>
<td></td>
<td>Impulsive</td>
</tr>
<tr>
<td>Low-Frequency (LF)</td>
<td><strong>Cell 1</strong></td>
</tr>
<tr>
<td>Cetaceans</td>
<td>$L_{pk,flat}$: 219 dB</td>
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<tr>
<td></td>
<td>$L_{E,LF,24h}$: 183 dB</td>
</tr>
<tr>
<td>Mid-Frequency (MF)</td>
<td><strong>Cell 3</strong></td>
</tr>
<tr>
<td>Cetaceans</td>
<td>$L_{pk,flat}$: 230 dB</td>
</tr>
<tr>
<td></td>
<td>$L_{E,MF,24h}$: 185 dB</td>
</tr>
<tr>
<td>High-Frequency (HF)</td>
<td><strong>Cell 5</strong></td>
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<tr>
<td>Cetaceans</td>
<td>$L_{pk,flat}$: 202 dB</td>
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<tr>
<td></td>
<td>$L_{E,HF,24h}$: 155 dB</td>
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<tr>
<td>Phocid Pinnipeds (PW)</td>
<td><strong>Cell 7</strong></td>
</tr>
<tr>
<td>(Underwater)</td>
<td>$L_{pk,flat}$: 218 dB</td>
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<tr>
<td></td>
<td>$L_{E,PW,24h}$: 185 dB</td>
</tr>
<tr>
<td>Otariid Pinnipeds (OW)</td>
<td><strong>Cell 9</strong></td>
</tr>
<tr>
<td>(Underwater)</td>
<td>$L_{pk,flat}$: 232 dB</td>
</tr>
<tr>
<td></td>
<td>$L_{E,OW,24h}$: 203 dB</td>
</tr>
</tbody>
</table>

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
Thresholds for Marine Mammals

Behavioral Criteria (used for Level B)

- Continuous and impulsive thresholds
- RMS thresholds
  - Time averaged for continuous
  - Pulse averaged for impulses
- No applicable frequency weightings
  - next step for NMFS??

Continuous Sounds (e.g., vibratory driving) = 120 dB (time avg)
Impulsive Sounds (e.g., impact driving) = 160 dB (pulse avg)
Thresholds for Marine Mammals

In Air Disturbance (used for Level B)

• RMS thresholds (time averaged)
  – 90 dB phocid pinnipeds (harbor seals)
  – 100 dB otariid pinnipeds (sea lions)

• Typically applied at haul outs

Explosives (Level A)

• Several types for injury
NMFS User Spreadsheet

- Simple model relying on available data
- Uniform spreading loss
- Computes duty cycle for SEL computations
- **NO** effective quiet applied to SEL levels

**Frequency adjustments are key inputs**
NMFS User Spreadsheet

5 different types

- Non-impulsive stationary continuous
- Non-impulsive stationary intermittent
- Non-impulsive mobile continuous
- Non-impulsive mobile intermittent
- Impulsive – Stationary
- Impact Pile Driving
- Impulsive mobile

- WFA – Weighting Factor Adjustments
  - Default single factors
  - Develop factors or weighted levels using guidance weighting functions applied to signal
CEQA and Permitting Impacts Analysis

Hydroacoustic Effects
Overview Hydroacoustics Impacts Analysis

- CEQA and Permitting Thresholds
- Factors and Uncertainties Affecting Thresholds
- Impacts Analysis
- Mitigation Approach
Appendix G Biological Resources

- a) Have a **substantial adverse effect**, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?

- d) **Interfere substantially** with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?
CEQA Significance Thresholds

Substantial Adverse Effect

- substantially reduce the habitat of a fish or wildlife species
- cause a fish or wildlife population to drop below self-sustaining levels
- threaten to eliminate a plant or animal community
- reduce the number or restrict the range of a rare or endangered plant or animal
## Regulatory Background

### Endangered Species Act

<table>
<thead>
<tr>
<th>Federal</th>
<th>State</th>
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</thead>
<tbody>
<tr>
<td><strong>No effect</strong></td>
<td><strong>Pursue, injure or harm to</strong></td>
</tr>
<tr>
<td>No consultation</td>
<td><strong>2081 Incidental Take Permit</strong></td>
</tr>
<tr>
<td><strong>Not likely to adversely affect</strong></td>
<td><strong>State</strong></td>
</tr>
<tr>
<td>Letter of concurrence, no “take” coverage</td>
<td><strong>Incidental Take Permit</strong></td>
</tr>
<tr>
<td><strong>Likely to adversely affect</strong></td>
<td><strong>Incidental Take Permit</strong></td>
</tr>
<tr>
<td>Biological Opinion, “take” coverage</td>
<td><strong>2081 Incidental Take Permit</strong></td>
</tr>
</tbody>
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## Regulatory Background

### Marine Mammal Protection Act

<table>
<thead>
<tr>
<th>Federal</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level A Harassment, “serious” injury or mortality</td>
<td>Letter of Authorization (federal rulemaking process)</td>
</tr>
<tr>
<td>Level B Harassment, non-serious injury and/or disturbance</td>
<td>Letter of concurrence, no “take” coverage</td>
</tr>
<tr>
<td>Fish and Game Code, no permit process except for listed marine mammal species</td>
<td></td>
</tr>
</tbody>
</table>
Hydroacoustic Thresholds

• **Fish**
  - Peak pressure $\geq 206$ dB (re: 1$\mu$Pa)
  - SEL
    - $> 2$ grams = 187 dB (re: 1$\mu$Pa$^2$ • sec)
    - $< 2$ grams = 183 dB (re: 1$\mu$Pa$^2$ • sec)

• **Marine Mammals**
  - Level A Harassment (e.g., “Permanent Threshold Shift”)
  - Level B Harassment
  - Temporary Threshold Shift
Hydroacoustic Thresholds

- Model output: distance at which specific decibel levels are reached
Hydroacoustic Impacts

Interpreting hydroacoustic effects modeling:

• “All models are wrong, some models are useful”
• At a distance of 1 foot from the sound source, all thresholds are exceeded in most (but not all) cases
• Decibel level dissipates over distance, fish and marine mammals can be thought of as mobile “sensitive receptors”
• CEQA assumptions for hydroacoustic models are usually wrong, and change, often substantially, as the project progresses toward final design
Factors and Uncertainties

- Context/environmental setting
- Pile size and type
- Number of piles per day
- Number of strikes per pile
- Frequency shift
- Other and unstudied sound sources
  - Different types of sound can affect aquatic resources in different ways
  - Pile driving is relatively well studied
- Gaps in scientific knowledge
- Modeling imperfections
Context/Environmental Setting

San Francisco Bay

Moss Landing
Context/Environmental Setting

- Background noise
- Habituation
- Haul outs
- Migratory corridors
- Spawning and pupping
- Presence of ESA/CESA listed species
Factors Affecting Observed Hydroacoustics

- Sound source
- Physical dynamics of a site
- Background noise
- Type of piles
- Number of piles per day
- Number of strikes per pile
- Currents
- Soil/substrate type
- Distance of measurement
- Attenuation methods
- Type of pile driving equipment (down to model #)
- Other things we may not even be looking for…
Design Factors Affecting Pile Driving Assumptions and Models

- Anticipated use
- Structural load
- Geotechnical factors
- Skill of construction contractor
- Equipment availability
- Site access and maneuverability
- Physical conditions coefficients
- Unknown submerged objects
Factors and Uncertainties

**Your Plan**

**Reality**
Generalized Hierarchy of Pile Types

- Steel Shell or Pipe
- Steel Sheet and “H” Pile
- Concrete
- Wood/Vinyl

Increasing Hydroacoustic Effect

Relative Influence of Pile Size on Effect Level
Hydroacoustic Impacts Analysis

- Individuals’ residence time within the affected area
- Incidental occurrence vs. core habitat
- Species’ status
- Modeling uncertainties
- Background noise and habituation
- Speculative or discountable effects standards

- Substantially reduce the habitat of a fish or wildlife species
- Cause a fish or wildlife population to drop below self-sustaining levels
- Threaten to eliminate a plant or animal community
- Reduce the number or restrict the range of a rare or endangered plant or animal
Mitigation Measures

- Very few cases where a technical solution can avoid all risk to individuals
- Minimization and avoidance
- Similar to many CEQA technical areas: noise, GHG, water quality, traffic
Developing Mitigation Measures

• Avoid deferral
• Avoid being overly prescriptive
  – Not every BMP is feasible for all construction conditions
• Allow for the regulatory process to run its course
• Do not assume that modeling assumptions will hold true for construction
Developing Mitigation Measures

- Implementation of some BMPs can extend the duration that resources are subject to disturbance
- Practicability of field biological monitoring and assigning source of stress or injury
- Consider the level of risk to the resource
Developing Mitigation Measures

- Consider use of an “if…then” framing
- Standard mitigation measures for developing a SWPPP may provide a good conceptual model
  - Develop a hydroacoustic effects analysis for review by NMFS
  - Include list of BMPs “such as…”
- Field measurement of underwater sound can be appropriate to refine and inform modeling results
  - Field hydroacoustic measurement is not a mitigation measure in and of itself
  - Consider the cost in relation to the resource risk
- Biological monitoring is typically effective for marine mammals, less so for fish
  - Site conditions influence efficacy of biological monitoring
Developing Mitigation Measures

Maintain flexibility

There is a physical universe that we cannot always control
Questions?