G&G Surveys Benthic

- What do they tell us about fish habitat?
- What are potential effects?
- What monitoring is planned?

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Groundtruth Geophysical Data

• Methods in BOEM Guidelines
  • Grab for grain size (sieving and lab analysis)
  • Grab + Video (addition of surface features)
  • SPI/PV (Visual grain size, layering, and surface features)

• Visual data also useful for benthic habitat characterization
  • Benthic habitats are combination of physical and biological characteristics
  • Coastal & Marine Ecological Classification System (CMECS)
Visual groundtruth

Operation of SPI/PV Imaging System

1. System is Lowered to Seabed
2. Plan View Camera is Triggered
3. Profile Camera is Triggered

SPI Image Captured
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Sound cues are used by fishes and invertebrates for many important biological functions:

- Communication within species
  Reproductive activities account for the majority of sounds produced by fishes
- Avoidance of predators
- Detection of prey

Anthropogenic noise can have negative ecological, behavioral and physiological impacts

Sound travels as a wave through a medium, such as liquid (water), solid (seafloor), or gas (air).

- Sound pressure = compression and expansion of the medium as sound energy moves through it
- Particle motion = back-and-forth motion of the particles of the medium

https://dosits.org/science/sound/what-is-sound/

https://dosits.org/animals/advanced-topics-animals/components-of-sound/
Specific resources for Decision Makers

- Tutorials
  - Science of sound
  - Effects of sounds
  - How do you determine effects
  - Specific sound sources and their potential effects
- Instructional videos
  - Science of sound
  - Hearing in fishes, marine mammals
  - Ecological risk assessment process
- Webinars

For more background: Discovery of Sound in the Sea (dosits.org)
How do Fish Detect Sound?
Without sensors, the sound pressure moves through body without effects

**Inner ear**
- Otoliths are denser than water and fish’s body
- Move more slowly in response to sound wave, displacing the cilia on hair cells
  - Respond to particle motion
- For those fishes that have been studied, greatest sensitivity from 100 to 200 Hz up to 800 Hz (.1-.8 kHz)

**Swim bladders**
- Respond to sound pressure, creating particle motion that inner ear can detect
- Proximity to inner ear influences sensitivity to sound (Hawkins et al. 2020), resulting in four basic groups of fishes

**Groupings based on presumed hearing ability**
1. Fishes with no swim bladder or other gas chamber (e.g., flatfish, elasmobranchs): hearing limited to well below 1 kHz
2. Fishes with swim bladder not involved in hearing (e.g., Atlantic salmon, sturgeons): hearing limited to 1 kHz
3. Fishes with swim bladder close to the ear but no specialized physical connection (e.g., Atlantic cod): can detect sound up to a few kHz
4. Fishes with swim bladder connected to the ear (e.g., herrings, Atlantic menhaden): can detect sound above 2-3 kHz, some to over 100 kHz

**Lateral Line**
- System of flow sensors distributed throughout the body of a fish
- Neuromasts are hair cell receptors
- Receptors on the lateral line can detect sounds that are very close to the source (within a few body lengths of the fish) at frequencies up to approximately 200 Hz

Range Groups 1-3: <3 kHz; Group 4: 3-100 kHz
Acute criteria (recoverable injury) > 210 dB rms or 207 dB peak

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How do Marine Invertebrates Detect Sound?

**Sensory hairs**
- Found in most marine crustaceans (e.g., lobster, crab, shrimp)
- Extensive array covering their bodies
- Detect particle motion (vibrations)
  - American lobster: sounds from 20 to 300 Hz

**Chordotonal organs**
- Found in the joints of flexible appendages (e.g., walking legs, antennae), connected to the central nervous system
- Detect particle motion (vibrations)
  - Fiddler, ghost crabs: sounds to 300 Hz
  - Common prawn: 100-3,000 Hz

**Statocyst**
- Found in most marine invertebrates, including cephalopods and crustaceans
- Organ with dense structure (statolith) associated with hair-like cells
- Primarily provides orientation cues; may detect particle motion
  - Longfin squid: 30-500 Hz
  - Common octopus: 400-1,000 Hz

Range 0.02 – 3 kHz

No established acute criteria

Limited experimental studies
<table>
<thead>
<tr>
<th>G&amp;G Source</th>
<th>Type of sound source</th>
<th>Operating Frequency</th>
<th>Source Level (1 m from source)</th>
<th>Fish Acoustic Threshold Groups 1-3</th>
<th>Fish Acoustic Threshold Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multibeam echosounder</td>
<td>Non-impulsive</td>
<td>200-400 kHz Primarily 400 kHz</td>
<td>220 dB rms</td>
<td>&gt;210 dB rms 0.01 – 3 kHz</td>
<td>&gt;210 dB rms 3 – 100 kHz</td>
</tr>
<tr>
<td>Chirp sub-bottom profiler</td>
<td>Non-impulsive</td>
<td>2-16 kHz Primarily 9 kHz</td>
<td>176-197 dB rms</td>
<td>&gt;210 dB rms 0.01 – 3 kHz</td>
<td>&gt;210 dB rms 3 – 100 kHz</td>
</tr>
<tr>
<td>Parametric sub-bottom profiler</td>
<td>Non-impulsive</td>
<td>6-12 kHz Primarily 10 kHz</td>
<td>220-232 dB rms</td>
<td>&gt;210 dB rms 0.01 – 3 kHz</td>
<td>&gt;210 dB rms 3 – 100 kHz</td>
</tr>
<tr>
<td>Ambient RI Sound (Kraus et al. 2016)</td>
<td>Non-impulsive</td>
<td>&lt; 1 kHz</td>
<td>130 dB rms</td>
<td>&gt;210 dB rms 0.01 – 3 kHz</td>
<td>&gt;210 dB rms 3 – 100 kHz</td>
</tr>
<tr>
<td>Fish finder (single beam echosounder/sonar)</td>
<td>Non-impulsive</td>
<td>3 to 200 kHz</td>
<td>150 – 235 dB rms</td>
<td>&gt;210 dB rms 0.01 – 3 kHz</td>
<td>&gt;210 dB rms 3 – 100 kHz</td>
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<tr>
<td>Sparker sub-bottom profiler</td>
<td>Impulsive</td>
<td>0.2-5 kHz Primarily 2 kHz</td>
<td>211 dB peak (203 dB rms)</td>
<td>&gt;207 dB peak 0.01 – 3 kHz</td>
<td>&gt;207 dB peak 3 – 100 kHz</td>
</tr>
<tr>
<td>Boomer sub-bottom profiler</td>
<td>Impulsive</td>
<td>0.2-8 kHz Primarily 0.6 kHz</td>
<td>211 dB peak (203 dB rms)</td>
<td>&gt;207 dB peak 0.01 – 3 kHz</td>
<td>&gt;207 dB peak 3 – 100 kHz</td>
</tr>
</tbody>
</table>
Monitoring of G&G

Collect baseline data in areas with survey activities
  Lease Areas
  Cable Corridors
Collect baseline data in areas outside survey activities

Example of proposed reference areas for ventless trap surveys