## Seismic surveys: Potential impacts and ideas for mitigation, monitoring and management

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## Take home messages

- Demonstrated effects
  - Including those that can be incorporated into population level impact calculations
  - Important to consider turtles and fish
- Mitigation
  - Numerous options ranging from observing animals to alternative gear
  - Feedback on effectiveness
  - The next generation of managing noise
- PSSAs, e.g., Cape Hatteras Point
  - Almost complete lack of information about animal use
  - PAM is great, but not without cue rates

# Change in sperm whale foraging rate vs distance to seismic survey



Miller et al 2009

# Change in humpback whale singing behavior in the presence of seismic

Seismic Surveys Affect Humpback Whale Singing



**Figure 4. Impact of seismic survey pulse RL on humpback whale singing activity for the full dataset.** Generalized Additive Mixed Models of the number of humpback whale singers with smooth terms for the dependence on Survey Day, Hour, Moon Phase and Peak Power fitted for each of the MARUs; plots show the estimated conditional dependence of humpback whale singer numbers on Peak Power for (A) MARU 1 and (B) MARU 2. The x-axis in each plot shows Peak Power, describing received level of seismic survey pulse (in dB re: 1 µPa<sup>2</sup> in a 1 Hz frequency bin) with a rug plot (short vertical bars) indicating the Peak Power values of observations. The y-axis, with scale selected optimally for each plot, shows the contribution of the smooth of Peak Power to the fitted values of singer number. Estimates (solid lines) are shown with 95% confidence bands (dashed lines), indicating a significant downward trend in singer number with increasing pulse RL. doi:10.1371/journal.pone.0086464.g004

### Right whale mother-calf countercalling

# Effects on cetaceans, fish and turtles(?)

Species	Location	<b>Response/ Effect</b>	<b>Received Level</b>	Reference
Bowhead whale	Arctic	Change surface- respiration; Avoidance	120-130 dB re 1 μPa RMS	Richardson et al. 1999; Robertson et al. 2013
Sperm whale	Gulf of Mexico	Buzz (feeding) rate decline	135-147 dB re 1 μPa RMS	Miller et al. 2009
Harbor porpoise	North Sea	Temporary displacement	145-151  dB re  1 $\mu Pa^2 \text{ s}^{-1}$	Thompson et al. 2013
Humpback whale	Angola	Singing and singers declined	120-150 dB re 1 μPa peak	Cerchio et al. 2014
Fin whale	Mediterranean	Altered singing and abandon habitat	ca. 15 dB 1 μPa above background	Castellote et al. 2012
Fish (herring, blue whiting)	Norway	Displacement, horizontal and vertical	Unknown	Slotte et al. 2004
Fish (Cod, Pollock)	Scotland	Short-term startle, no long term effects	variable	Wardle et al. 2001
Fish (Pink snapper)	Captive	Hearing system damage	Variable 150-180 dB re 1 µPa RMS	McCauley et al. 2003

### Responsible Practices for Minimizing and Monitoring Environmental Impacts of Marine Seismic Surveys with an Emphasis on Marine Mammals

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Douglas P. Nowacek, Christopher W. Clark, David Mann, Patrick J.O. Miller, Howard C. Rosenbaum, Jay S. Golden, Michael Jasny, James Kraska and Brandon L. Southall – In Press *Frontiers in Ecology and Env* 

### Marine Seismic Surveys and Ocean Noise: Time for coordinated and prudent planning

Figure 1. A practical roadmap for planning, executing, evaluating, and improving the design of a responsible seismic survey; the numbers in parentheses throughout the figure refer to other elements within the figure.

ASSESS ENVIRONMENT and PROPOSED ACTIONS (1) Baseline environmental and biological data collection In situ measurements of the biological environment with sufficient characterization of sources of natural variability. Key parameters include ecosystem features and their influence on spatial and temporal variability in density, distribution, and behavior of key species. NEEDED FOR: Risk assessment (3); Mitigation design (4a); Monitoring program design (4b); Assessment of mitigation efficacy (7)

### (2) De

(2) Describe proposed development actions and alternatives Provide detailed characterization of key operational parameters (e.g., sound output parameters from seismic sources, vessels, and other sources) and quantitative modeling of their propagation in the environment. All process stages and alternative strategies should be described, regardless of economic feasibility. NEEDED FOR: Risk assessment (3); Mitigation design (4a)

### **EVALUATE and IMPROVE**

(7) Evaluate effectiveness of mitigation measures Evaluation of monitoring results to determine if mitigation measures as implemented were adequate to meet agreed objectives in (4a). NEEDED FOR: Future mitigation design (8)

(8) Evaluate effectiveness of monitoring program Determine if monitoring results were sufficient to adequately address (7) and identify any residual risk to species of concern. NEEDED FOR: Future mitigation and monitoring design

(9) Prompt analysis and publication of results Ensure that analyses are completed promptly and results published (ideally in open, peer-reviewed literature) to inform future risk assessments and mitigation and monitoring actions.

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IMPLEMENT MITIGATION and MONITORING

(5) Implement mitigation and monitoring Systems must be in place in the field to ensure that agreed mitigation measures and agreed monitoring actions are correctly and effectively implemented in a timely manner. Written protocols, based on anticipated scenarios, must be understood and practiced ahead of time by all involved parties. Clear chains of command and communication are essential as is honest assessment of the value and limitation of all observing systems. NEEDED FOR: Mitigation and monitoring

(6) Implement data collection, validation, and archiving Must have systems in place to ensure that data are properly treated (QA/QC) and redundantly archived. NEEDED FOR: Mitigation evaluation (7); Future mitigation design (8)

### EVALUATE RISK and DEVELOP PLANS (3) Evaluate risks of proposed development actions and alternatives

Conduct a quantitative risk assessment based on information from (1) and (2), including extrapolation and/or models derived from other species/areas if required. This should be precautionary but practical in the potential impacts formally assessed. NEEDED FOR: Mitigation design (4a)

### (4a) Design effective mitigation actions

Agree on key objectives with all stakeholders. Measures must be shown to be likely to succeed in light of information on (1)–(3). When feasible, use time/areas when susceptible animals are absent/ low density. Develop full protocols including command chain and real-time actions required if measures not working. Integrate with (4b) and (5). Make plans publicly available. NEEDED FOR: Mitigation implementation (5)

### (4b) Design effective monitoring methods for before, during, and following operations

Integrated (with 4a) monitoring technologies and protocols using real-time and archival elements are required. These methods should be adaptable and with sufficient power to detect changes in key parameters (1), determine if mitigation measures (see 4a) are working, address data and information gaps, and contribute to long-term monitoring. Make plans publicly available. NEEDED FOR: Mitigation implementation (5); Mitigation evaluation (7); Future mitigation design (8)



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Acoustic Zoom: The Future of Offshore Exploration

- Mitigation measures
  - Baseline data
  - Minimize survey area
  - Minimize airgun array
  - Propagation modeling
  - Exposure criteria
  - Real time acoustic monitoring
  - Visual monitoring
  - Timing survey to separate from animals
  - Multi-client surveys
  - Provisions for poor visibility conditions
  - Shut-downs
  - Dissemination of results
  - Alternative sources

## Time for planning

- Appropriate impact thresholds
  - Managing with a single number...currently regulated to avoid exposure >180 dB for injury and 160 dB for behavioral disruption...needs to be revisited
  - Revisions to impact criteria are underway
  - Probabilistic risk function
- The need for baseline data
  - Lessons from DWH
- Cumulative effects
  - Inherent and pragmatic challenges
  - Still, need to press ahead, tools are improving
    - Estimating health, e.g., PCOD
    - Estimating masking, e.g., Clark et al. 2009
    - Risk assessment frameworks, e.g., value of individual habitats
- A way forward...

## A Way Forward...

- Precedents for international and trans boundary 'pollutants'
  - Cartegena Protocol for Biosafety (UN 2000)
  - Convention on Long-range Transboundary Air Pollution (UN ECE 1979)
  - EU, CBD, CMS, etc., all recognize noise as a problem or even a pollutant
- Options??
  - IMO member states could pursue a new annex to MARPOL 73/78 through Marine Env Protection Comm
    - » Definition of 'harmful substances'? Maybe use 'discharge'
  - New Convention regulating all non-military noise sources

### Measures to include in a convention

- 1. Empirically-based restrictions on time, duration and/or area of activities in biologically important habitats
- 2. Require sustained monitoring of acoustic habitat indicators, including establishing limits and targets
- 3. Promote development and requiring use of methods and technologies that reduce acoustic footprints
- 4. Creation of intergovernmental science organization to coordinate, promote and advance efforts to improve assessment of impacts
- Requirements for preparation of EISs and 'strategic' or 'programmatic' EAs that meaningfully analyze cumulative effects









Atlantic Pending Surveys



Seismic permit applications

- Speculative surveys – 2D
- 3D preproduction
- 4D during production

