



Soundscape Ecology at Sea

Agency and research initiatives



Jim Cummings, Executive Director

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Soundscape Ecology at Sea



Northwest Fisheries Science Center
NOAA FISHERIES SERVICE



Scientific and regulatory attention largely driven by concerns about effects of anthropogenic noise on marine life



Naval MFA (Mid Frequency Active) Sonar

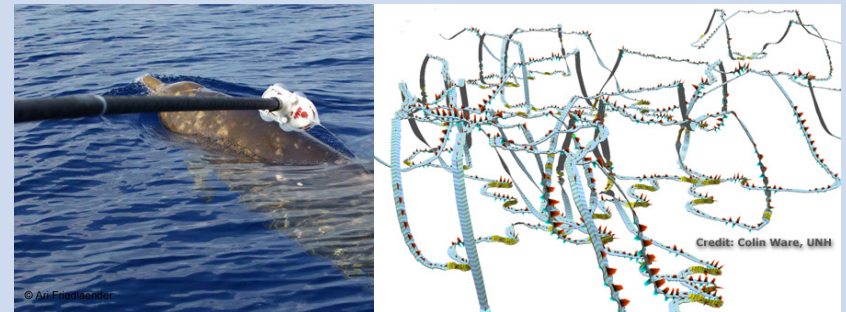
Injuries, deaths — rare
apparently in unusual circumstances



Naval MFA Sonar

Behavioral effects — wide area (10-70 miles)
Avoidance, Foraging disruptions?

Thousands of animals hear sonar when in use
Research underway to determine extent of behavioral changes



<http://aeinews.org/archives/category/ocean/sonar>

See <http://aeinews.org/?s=d-tags>

Seismic surveys

Behavioral effects — chronic in oil/gas regions:
100 +/- ships worldwide



“Make a few whales cross the street”

Yet:

Mid-Atlantic Ridge, survey sounds dominant (from Canada, South America)

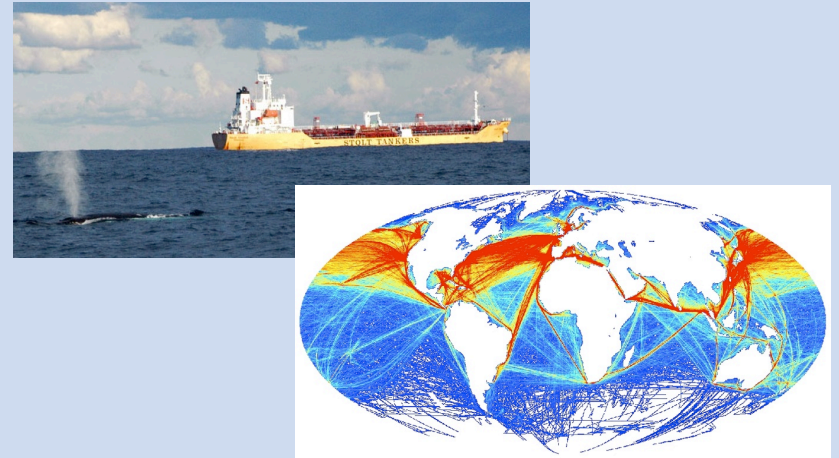
Current:

Resistance to renewed oil/gas exploration along eastern seaboard

See <http://aeinews.org/archives/category/ocean/seismic-surveys>

Global shipping

Chronic exposure — nearly ubiquitous



<http://aeinews.org/archives/category/shipping>

Global shipping

Chronic exposure

Greatly reduced communication space

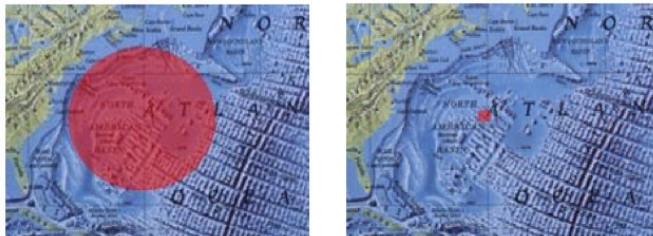
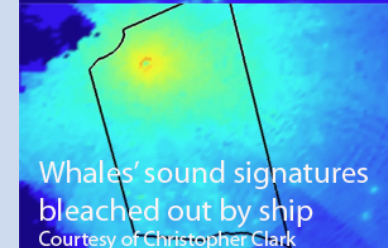
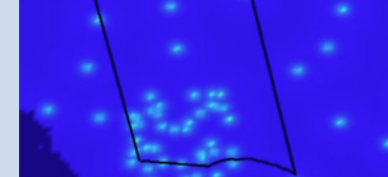


Figure 4. Estimated reduction in baleen whale communication range from (left) prior to the advent of commercial shipping to (right) the expected ranges of today. Figure courtesy of C. W. Clark, Cornell University.

<http://aeinews.org/archives/626>

Global shipping

Whales' sound signatures - no ship



Whales' sound signatures
bleached out by ship
Courtesy of Christopher Clark

Shipping in
Stellwagen Bank
reduces the area in
which whales can
hear and be heard:

- Right whales: 84%
- Fin whales: 33%

<http://aeinews.org/?s=stellwagen>

Energetic costs of reduced foraging

Many studies find reduced foraging in whales near *sonar, seismic, and ships*



Energy budget study in PacNW:

Overall energy expenditures are *only negligibly increased* in the presence of boats (2-3% increase)

Total energy taken in was reduced by more than 25% because of lost/disrupted foraging time

Williams, Lusseau, Hammond. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* 133 (2006), 301-311.

<http://aeinews.org/archives/173>

Beyond behavioral . . . Chronic stress?

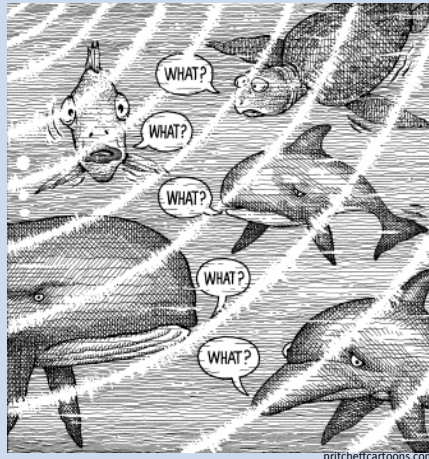
Is a subset of the population more noise-sensitive?
...and if so, being disproportionately affected by repeated exposures to chronic noise sources?



Are animals moving a moderate distance, out of harmful or "annoying" range?
...while experiencing **elevated stress levels** even as they engage in normal activities?

Gradually dawning awareness

We've altered the soundscape of the oceans
The acoustic environment is permeated by human noise



Ocean soundscape ecology

Mostly at stage of understanding the extent of human noise

More apt to chart ambient noise levels
Rather than advanced metrics like % time audible or noise-free intervals

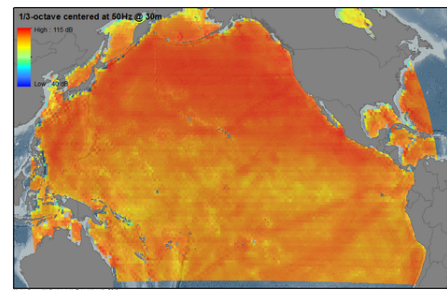
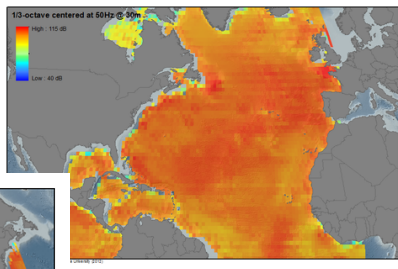
So far, either annual averages or spot-checks
Not much seasonal variability info

Ocean soundscape ecology

NOAA Ocean Noise Mapping

Darker areas 10-20dB over natural ambient

Worst areas up to 60dB over natural ambient



Modeled from shipping data
Mapped for several frequencies and water depths

Some limited ground-truthing (so far, within 5-10dB)

See <http://cetsound.noaa.gov>

<http://aeinews.org/archives/2226>
<http://www.st.nmfs.noaa.gov/cetsound/>

Ocean soundscape ecology

Several research teams:
“soundscapes” / “acoustic ecology”
“acoustic quality” of habitats

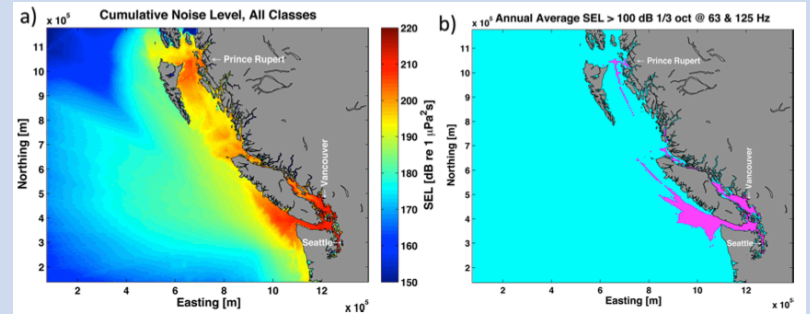


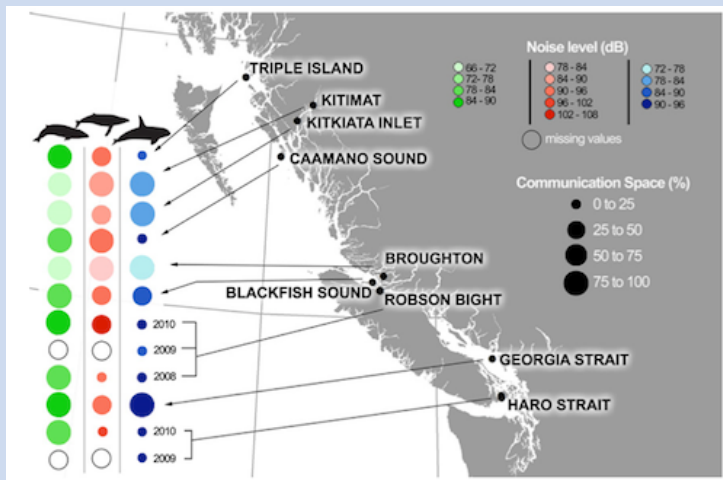
Fig. 2. (Color online) (a) Cumulative sound exposure level from vessel traffic from Jan to Dec 2008. (b) Areas where the estimated annual average sound pressure level (*SPL_{rms}*) exceeded the EU Marine Strategy Framework Directive of 100 dB (*SPL_{rms}*) in 1/3-octave bands centered on 63 or 125 Hz.

Erbe, MacGillivray, Williams. Mapping cumulative noise from shipping to inform marine spatial planning. *J. Acoust. Soc. Am.* 132 (5), November 2012

<http://aeinews.org/archives/2240>

Ocean soundscape ecology

Current communication space on BC coast

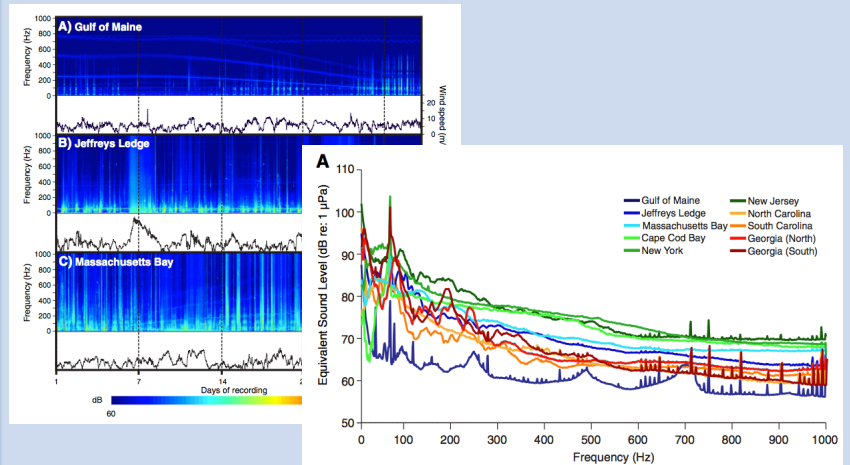


Williams, Clark, Ponirakas, Ashe. Acoustic quality of critical habitats for three threatened whale populations. *Animal Conservation* (2013)

<http://aeinews.org/archives/2520>

Ocean soundscape ecology

Variations in soundscape of North Atlantic



Rice, et al. Variation of ocean acoustic environments along the western North Atlantic coast: A case study in context of the right whale migration route. *Ecological Informatics* 21 (2014) 89-99

No AEI summary yet...see reference on slide

Ocean soundscape ecology

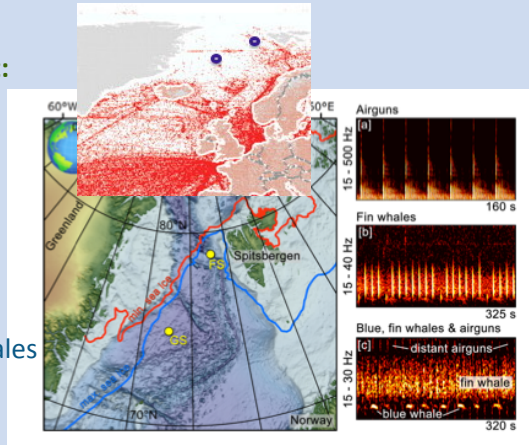
Seismic survey sounds in remote polar Atlantic

Increases to ambient:

Airguns
5-10dB, up to 20dB

Stormy winter waves
up to 10dB

Calls of 1000's of whales
up to 10dB

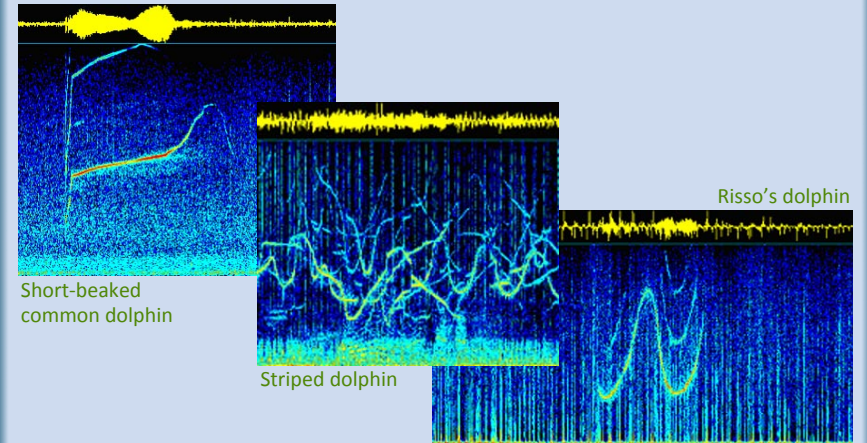


Klink et al, Seasonal presence of cetaceans and ambient noise levels in polar waters of the North Atlantic. J. Acoust. Soc. Am. 132 (3), September 2012

<http://aeinews.org/archives/2599>

Ocean soundscape ecology

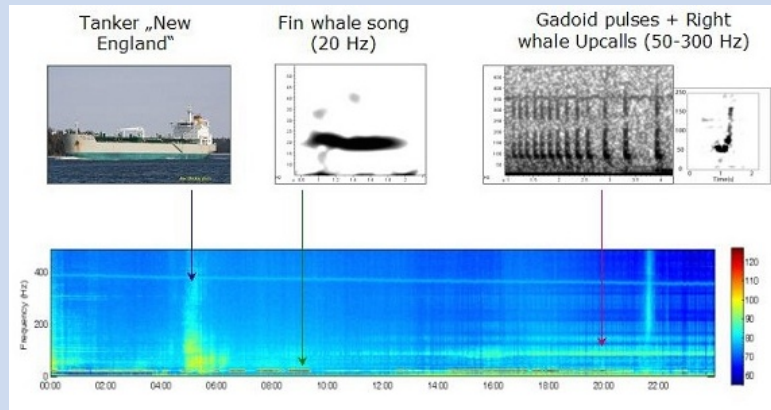
Automated detection



Oceanus-Explorers.com (2009; no longer online)

Ocean soundscape ecology

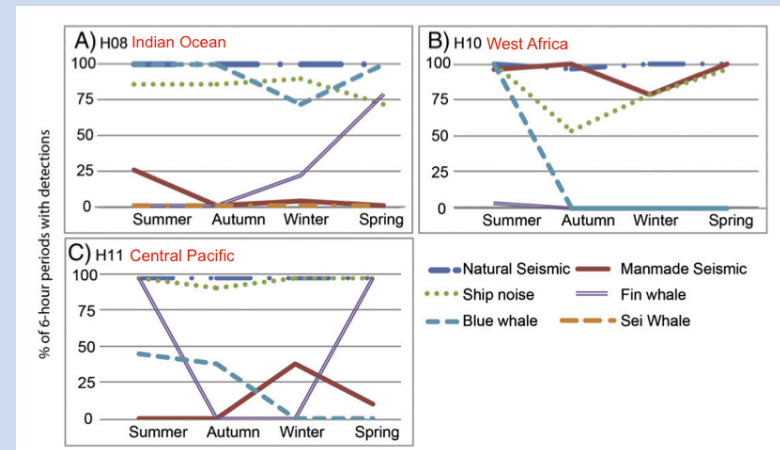
Sound budgets



Denise Risch, Northeast Fisheries Science Center. 2007 data, Stellwagen Bank National Marine Sanctuary

Ocean soundscape ecology

Sound budgets — seasonal

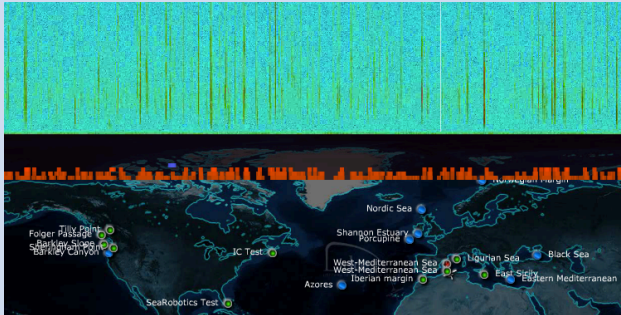


Parks, Miklos-Olds, Denes. Assessing marine acoustic diversity across ocean basins. Ecological Informatics 21 (2014) 81-88
SEE ALSO: Sirovic, Wiggins, Oleson. Ocean noise in the tropical and subtropical Pacific Ocean. J. Acoust. Soc. Am. 134 (4), October 2013

No AEI summary yet...see reference on slide

Ocean soundscape ecology

Real-time acoustic monitoring



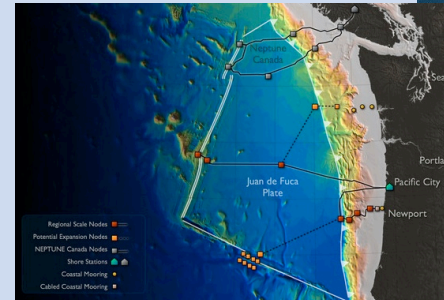
LIDO: Listening to the Deep Ocean Environment
Real-time listening and initial classification
Data archiving

<http://aeinews.org/archives/1763>

Ocean soundscape ecology

Ocean observatories (some with acoustic sensors)

US Ocean Observatories Initiative (OOI)
Papa, Pioneer, Endurance, more

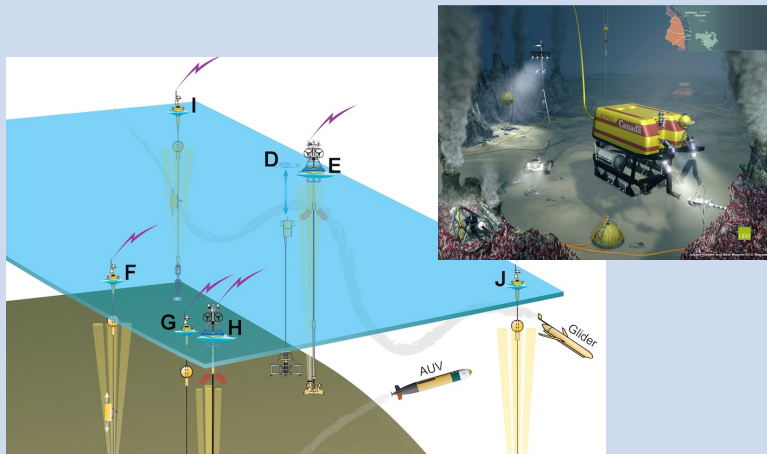


Ocean Networks Canada
NEPTUNE (regionally linked with US sites)
VENUS (BC), Arctic

<http://www.oceannetworks.ca>
<http://oceanobservatories.org>

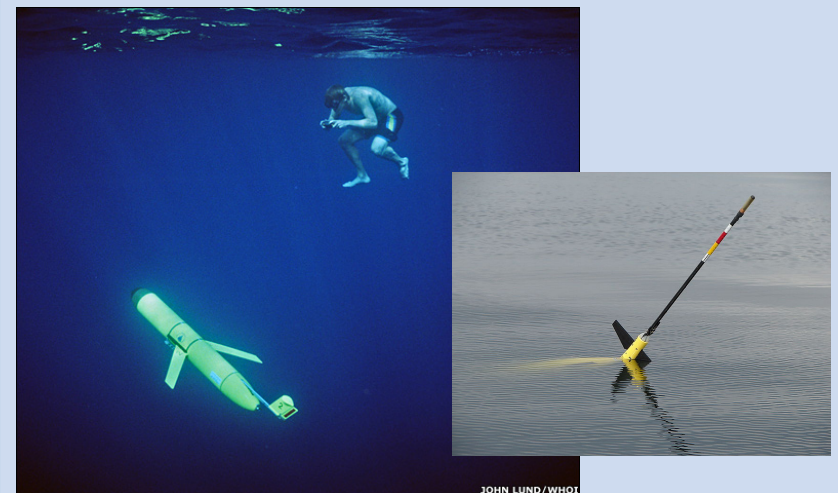
Ocean soundscape ecology

Ocean observatories (some with acoustic sensors)



Ocean soundscape ecology

On tap: acoustic monitoring from autonomous gliders



<http://aeinews.org/archives/826> (section in AEI report)
<http://aeinews.org/?s=gliders>

Ocean soundscape ecology

Goal: Identifying areas of relative natural quiet



Protection Noise Management Ocean wilderness?

Ocean soundscape ecology

Goal: Managing (reducing?) anthropogenic noise in the sea



Ship noise reduction

NOAA > Int'l Maritime Organization
US Chamber of Shipping

Loudest 10-15% of ships in each class
creating 40-80% of ship noise?

NOAA Sanctuaries/MPAs

Increasing interest in sound
Still shy from speaking of "wilderness"

Environmental assessments

Noise footprint routinely assessed
Navy / oil and gas exploration
offshore wind / tidal, wave energy

Ocean soundscape ecology

Goal: expanding the use of acoustics

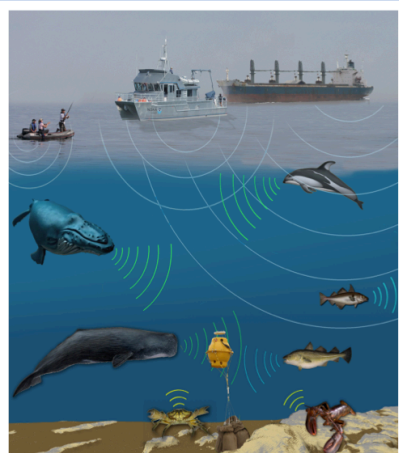


Figure: Michael A. Thompson

Move beyond:

- Monitoring for specific species
- Focus on average noise levels
- Identifying local geophony/biophony/anthrophony

Expand into:

- Assessing species composition & habitat health
- Individual animal responses to soundscape and changes
- Better modeling of noise outside of monitored areas

Ocean soundscape ecology

Links to learn more

AEInews.org: sound-related environmental news, science

Peruse main page, or poke around in categories and do searches

See categories list on each page, eg:

ocean / shipping / seismic surveys

Create searches, eg:

IMO+shipping / "communication+space" / navy+sonar

Good post on acoustic tagging of whales (including links to related articles)

<http://aeinews.org/archives/2531>

Excellent ocean noise presentation from NOAA's Leila Hatch:

<http://aeinews.org/archives/2585>

<http://openchannels.org/webinars/2014/listening-our-sanctuaries-understanding-and-reducing-impacts-underwater-noise-marine>

<https://vimeo.com/94543099>

AcousticEcology.org

AEInews.org

Resources/information on all manner of sound-related environmental issues and science

science summaries | special reports | news updates

Thanks to Bryan, Meredith, and cohorts for making this event happen!

Jim Cummings, Executive Director
 cummings@acousticecology.org

Considerations for Marine Species

Reduced foraging in response to moderate noise

Sonar and foraging



Dramatic orca foraging disruptions at moderate received levels (160dB) of MFA sonar

Group ceased foraging and moved rapidly away

Unusual dive pattern:

- Twice as deep (60m) as normal (20-45m)
- Reversed ascent at 15m, headed back down to 60m

“Potentially very significant” foraging changes in beaked whales during sonar exercises

“Appear to cease vocalizing and foraging for food in the area around active sonar transmissions”

Orcas: Kvadshem, Benders, Miller, Doksaeter, Knudsen, Tyack, Nordlund, Lam, Samarra, Kleivane, Godo, Herring (slid), killer whales (spekkhogger) and sonar - the 3S-2006 cruise report with preliminary results. Norwegian Defence Research Establishment (FFI), 30 April 2007. Kvadshem, Lam, Miller, Alves, Antunes, Bocconcelli, Ijsselmuide, Kleivane, Olivierse, Visser. Cetaceans and naval sonar - the 3s-2009 cruise report. Norwegian Defence Research Establishment (FFI), 01 July 2009. FFI-rapport 2009/01140. Beaked whales: as reported in Nature, which received the report under a FOIA request, with the author(s) name(s) and location of the study removed. <http://www.nature.com/news/2008/080801/full/news.2008.997.html>

Considerations for Marine Species

Reduced foraging in response to moderate noise

Boats and foraging



Tour boats disrupt foraging common dolphins:

Proportion of time spent foraging dropped by 28% (from 35% to 25% of the time)

Length of each foraging period dropped by 40% (from 10 minutes to 6 minutes)

Time until return to foraging increased 56% (from 9 minutes to 14 minutes)

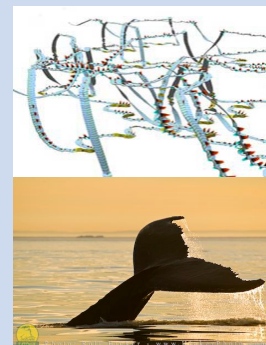
21% decrease in foraging activity observed in orcas when boats are within 400m
 (from 76% to 60% of the time)

Stockin, Lusseau, Binedell, Wiseman, Orams. Tourism affects the behavioural budget of the common dolphin *Delphinus* sp. in the Hauraki Gulf, New Zealand. *Mar Ecol Prog Ser* 355: 287–295, 2008
 Williams, Bain, Smith, Lusseau. Effects of vessels on behavior patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research*, Vol. 6: 199-209, 2009

Considerations for Marine Species

Reduced foraging in response to moderate noise

Seismic and foraging



20% decrease in foraging likely among sperm whales
 SWSS overall conclusion

No tagged whales made a deep foraging dive closer than 4km from active seismic array

Several studies show indications of whales lingering on surface near active arrays

Pilot whales: moved to be 1.2km from survey vessel then “exhibited a behavior best described as milling.”

Humpback whales: increase in number of whales seen within visual observing range (i.e. close to vessel) when airguns are active

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, and B. Wursig. 2008. Sperm whale seismic study in the Gulf of Mexico: Synthesis report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2008-006. 341 pp.
 Caroline Weir. Short-Finned Pilot Whales (*Globicephala macrorhynchus*) Respond to an Airgun Ramp-up Procedure off Gabon. *Aquatic Mammals* 2008, 34(3), 349-354.
 Caroline Weir. Overt Responses of Humpback Whales (*Megaptera novaeangliae*), Sperm Whales (*Physeter macrocephalus*), and Atlantic Spotted Dolphins (*Stellena frontalis*) to Seismic Exploration off Angola. *Aquatic Mammals* 2008, 34 (1), 71-83.