



Marine Mammal Acoustic Studies: Phase One

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On behalf of Oregon Wave Energy Trust

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Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership funded by the Oregon Innovation Council. Its mission is to support the responsible development of wave energy in Oregon. OWET emphasizes an inclusive, collaborative model to ensure that Oregon maintains its competitive advantage and maximizes the economic development and environmental potential of this emerging industry. Our work includes stakeholder outreach and education, policy development, environmental assessment, applied research and market development.

Introduction

The Oregon coast has been identified as an area with great potential for production of electricity from wave energy. In 2007 the state legislature appropriated funding to create the Oregon Wave Energy Trust (OWET), a non-profit organization composed of stakeholders including representatives from industry, fishing, environmental, government and community groups. OWET has the mission of building and sharing the expertise needed to support and accelerate the responsible development of a wave energy industry in the State of Oregon. Within the last couple of years, applications have been filed for permits to develop wave energy facilities in several locations along the Oregon coast. Those development plans have raised the need to determine potential environmental effects of wave energy parks (Boehlert *et al.* 2008).

Wave energy technology is new and evolving in its applicability, viability, and potential impacts. Very little information is available on environmental effects and, in some cases, no baseline information exists. For example, some wave energy buoy models have never been deployed in the ocean. Since there hasn't been an opportunity to characterize the sound they will generate, it has not been possible to accurately determine the potential acoustic effects on the environment.

The objective of this workshop was to identify studies that should be conducted to properly determine potential effects from power generating buoys on marine mammals of the Oregon coast, with emphasis on cetaceans and focal discussion on gray whales. Special emphasis was put on the acoustic output from both the installation and operation of wave energy buoys (the two phases could be quite different acoustically), monitoring marine mammal behavior with special emphasis on gray whale behavior, detection of buoys by whales, and the use of acoustic deterrence devices to prevent whale collisions and/or entanglements. It was intended that conclusions from the workshop would provide guidance for future studies to support the responsible development of commercial wave energy projects. Workshop participants included marine mammal biologists, marine acousticians, and representatives from the wave energy industry and regulatory agencies (Appendix II).

A variety of technologies are been proposed for generating electricity from ocean waves. OWET is technology neutral and must provide information to all areas – all information is in the public domain. OWET is planning to establish a network database with baseline information that everyone can utilize.

Some discussion during the workshop focused on the project proposed by Ocean Power Technologies (OPT) off Reedsport. The reason for this focus is the more advanced stage of planning for the Reedsport wave energy park – OPT plans to deploy a 150 kW buoy in summer 2009. Nevertheless, discussions during the workshop needed, as much as possible, to address other technologies as well.

Baseline gray whale information

The majority of the eastern gray whale (*Eschrichtius robustus*) population migrates every year from summer foraging grounds in Alaska and the Pacific Northwest to winter reproductive areas in Baja California, Mexico. The gray whale migration path is close to the coast. The average distance from shore for sightings recorded during aerial surveys off the Oregon coast was 9.2 km and the farthest sighting occurred 23 km offshore (Green *et al.* 1995). Shore-based observations within a range of 18 km from shore conducted in 2008 off Yaquina Head, Oregon estimated an average distance from shore of 6.59 km (S.D. = 2.526, $n = 139$) during the southbound migration (Ortega-Ortiz and Mate 2008). During Phase A of the northbound migration (February 26-April 10, 2008), whales were sighted at an average of 5.08 km from shore (S.D. = 2.135, $n = 230$), while during Phase B (April 10-May 29, 2008) the average distance from shore was 4.08 km (S.D. = 2.618, $n = 91$). Average speed of tracked whales was 6.74 km/h (S.D. = 1.382, $n = 37$) during the southbound migration, 6.05 km/h (S.D. = 1.094, $n = 47$) during Phase A of the northbound migration, and 5.42 km/h (S.D. = 1.529, $n = 26$) during Phase B (Ortega-Ortiz and Mate 2008). Average bottom depth of whale locations during scan sampling was 46.3 m (S.D. = 13.70, range=12-75 m; Ortega-Ortiz and Mate 2008). The migration paths of tracked whales in this study seemed to follow a constant depth rather than following the curve of the shoreline.

Deployment of structures for wave energy facilities (buoys, cables, mooring systems, etc.) in the migratory path of gray whales raises the possibility of collision, entanglement, displacement, or behavioral changes related to sounds associated with their operation and/or their general presence (Boehlert *et al.* 2008). Of particular concern is Phase B of the northbound migration, when there are calves present and the whales travel closer to shore, through areas of currently proposed wave energy development. For example, the marine portion of the proposed OPT project off Reedsport, OR, is to be located within state waters approximately 4.0 km from shore, encompassing a project area of 800 by 800 m, where the water depth is approximately 50-69 m (Proposed Action and Alternative document). The actual footprint of the PowerBuoy array will be deployed in the northwest corner of the project area in approximately 62-69 m water depth.

Other cetacean species

There is also a need to evaluate effects on other whale species. Harbor porpoises are commonly found in nearshore Oregon waters. Minke, humpback, fin, blue, and killer whales also occur in the Oregon territorial sea, but their presence is seasonal and/or not very frequent. Because of this infrequency, it is challenging to design sampling protocols that would yield enough data to provide significant results. Moreover, future development beyond the 3 mile state limit will bring other cetacean species, (sei, sperm, Baird's beaked whale, Cuvier's beaked whale, Stejneger's beaked whale, Mesoplodon species, pygmy sperm whale, short-finned pilot whale, Dall's porpoise, bottlenose dolphin, Pacific white-sided dolphin, common dolphin, Risso's dolphin, Northern right whale dolphin) into consideration.

Characterization of wave energy buoys acoustic output

It was speculated that wave energy buoys will generate continuous noises of considerable variability. Noise will vary (potentially significantly) between different phases of the project (e.g., installation and operation) and will also vary depending on environmental conditions, including wind speed, wave height, and sound velocity profiles, which in turn vary seasonally. Because of the variability it was suggested that acoustic measurements to characterize sound from the buoys should be timed to encompass intra- and inter-annual variation. An autonomous recorder was identified as a viable, practical option with suggested nominal operating parameters. These included a functional frequency detection range of 1 Hz to 10 kHz (sampling rates of 22 kHz and duty cycle of 5 minutes), which will include the auditory range of gray whales, other cetaceans with potential to occur in the project vicinity and most of the expected machinery noise. The deployment of recorders at three monitoring distances was also recommended to better understand sound propagation. The acoustic experts recommended placing recorders along the same water depth contour (isobath) at 100-200 m, 400-500 m, and 1-2 km away from the buoys. It was concluded that placing the acoustic recorders about 10 m from the bottom would reduce background noise associated with waves, while providing a useful measure of received sound within the water column where whales would occur.

Behavioral monitoring

Baseline information is still needed on the habitat use and distribution of summer resident gray whales, and other marine mammals. Knowing where marine mammals occur and how they use the nearshore areas is critical in assessing whether displacement occurs once wave energy buoys are in place. Information on marine mammal behavior near the buoys is also necessary. Several behavioral monitoring methods were discussed to address these questions. Direct monitoring from boats is limited to good weather, is expensive, and the presence of the boat may have a confounding effect on whale behavior. In other words, is the whale reacting to the boat or to the buoy? Aerial surveys are useful for estimating abundance and distribution, but are not generally reliable for studying behavior because aircraft need to fly at a speed faster than would be appropriate for detailed observations. Telemetry can be very valuable for distribution and habitat use questions, particularly in defining the use of near shore areas for summer resident gray whales. Telemetry is capable of providing location, speed, dive profiles, surfacing rates, and pitch and roll on multiple animals simultaneously, day or night, in all weather conditions. Telemetry may not be as useful when looking at immediate effects of a buoy, as the expense prohibits very large sample sizes (large enough to obtain definitive conclusion for some objectives) and there is no guarantee that tagged whales would travel near a buoy. Shore-based observations may be a practical and convenient method to observe large whales if the buoys are located close to shore (<6.5 km) and if there is a high enough (>10 m) observation point. Boat, aerial, and shore-based observations are limited to favorable environmental conditions (wind <29 km/h, Beaufort sea state <5, no rain, and no fog). For species that are vocal (e.g. harbor porpoises), passive acoustic tracking could be a reliable observation method. However, not all cetacean species are good subjects for passive acoustic tracking. For example, migrating gray whales are not very vocal.

In summer 2009, OPT will deploy a test buoy about 4.0 km off Reedsport. There is a sand dune about 25 m high and within 5 km of the location where the test buoy will be deployed. Theodolite tracking may be possible from that dune to monitor the behavior of gray whales and other

opportunistically sighted large whales near the buoy. Previous shore-based observations off the California coast indicate that southbound gray whales detected a 21 kHz signal and were deflected offshore when the sound source was turned on (Frankel 2005). The study by Frankel (2005) had two theodolite stations, 2 km apart, which enabled gathering longer tracks – further north and south than with just a single station. Tracks had to be at least 1 km long to yield usable data. Handing off a whale from one station to the other was complicated but possible. Something like that would be applicable to the Reedsport OPT installation – if the dunes allow a shore station adjacent to the buoy location and one further north or south to pick up animals movements, and detect a deflection if there is one. Metrics have been developed to statistically detect effects of stimulus that observers cannot identify in the field. Observation stations off California were higher and the sound source was closer to shore than the Reedsport site. Observations at Reedsport will have less accuracy but they may still be reliable, and quite useful. On site observations of whales around wave energy buoys are preferable to play-back experiments using buoy sounds because of differences in environmental conditions, acoustic propagation field, and general context.

Deterrence devices

The development of a deterrence device to alert animals to the presence of wave energy structures and deflect them around such structures was discussed. Such a device could be brought into play in the event that buoys are seen to have an adverse effect on animals, in terms of collision and/or entanglement.

The design of pingers used in fisheries favors low intensity signals so the devices don't ensnare a larger area than necessary. Pingers authorized by NOAA to reduce cetacean bycatch in gillnets have a frequency of 10 kHz at 132 dB re 1 μ Pa at 1 m for 300 milliseconds, and a pulse period of 4 seconds (Barlow and Cameron 2003). Many large whales, including gray whales, have lower frequency hearing compared to odontocetes for which off-the-shelf pingers are designed. There are no pingers on the market specifically designed for the auditory capabilities of large whales, or gray whales specifically. A 130 dB pinger at 10 kHz on an obstacle is not loud enough for large whales – from our limited understanding of their auditory capabilities we would expect that they could hear it but likely over too short a range to avoid the obstacle. A pinger that can be detected by whales 500 m away from the buoy would probably be enough to deflect their migratory path so they do not come near the buoy. Design of a pinger has power constraints and must consider ambient noise level and the hearing abilities of gray whales and other large whales. It takes a larger device to generate sound at low frequencies than at high ones. A balance between these factors may be possible at about 3 kHz. A device that can detect ambient noise level and adjust the output to approximately 60 dB above ambient noise would be desirable. Levels of ambient noise have been modeled and noise curves are available (*e.g.* Richardson *et al.* 1995).

Consultation with NMFS will determine if a low output level device would develop sufficient source levels to rise to the level of take under current or future acoustic policy. The NMFS current threshold for behavioral disturbance of cetaceans from impulsive sound is 160 dB re 1 μ Pa. If deterrence measures are deemed to result in the take by harassment (from sound exposure) then authorization under the MMPA/ESA or both may be required. Effects to ESA-

listed marine mammal species from acoustic exposure during installation or operation of the buoy or from deterrence measures would be analyzed in ESA section 7 consultation with NMFS during the permitting process.

Passive acoustics monitoring (PAM) for habitat use studies

Odontocetes and pinnipeds may not have the same risk as large whales for collision or entanglement on cables and mooring system, given the increased sensory capabilities of echolocating odontocetes and the small size and maneuverability of pinnipeds. Nevertheless, the physical presence of the buoys may cause displacement from (or in the case of pinnipeds, potential attraction to) the immediate project vicinity. However, because of the small scale of the Reedsport project, any potential displacement would be localized. There is concern about the potential cumulative effect of displacement across a broader spatial scale as more wave energy facilities become developed in the future.

Shore-based tracking is not an effective observation method for small species (dolphins, porpoises, seals, and sea lions). For behavioral studies, even being out on a boat visually tracking porpoises is not practical. A passive acoustic monitoring (PAM) system may work for porpoises, dolphins, and perhaps seals. This system could be done simultaneously to the acoustic characterization of wave buoys by adding recording capabilities in the 20-150 kHz range (porpoise clicks are centered at ~120 kHz). Automated acoustic detectors are available and could keep data analysis costs reasonable.

PAM methods can be used to record habitat use and compare changes before/during/after deployment of buoys. Ideally, PAM should start a full annual cycle of observation pre-deployment and continue one year post-deployment to account for seasonal variation. On-site and off-site control observations with separation based on habitat heterogeneity at the buoy deployment site would also be recommended.

It could be possible to set up a system by deploying a series of hydrophones running through the subsea pod of the proposed OPT buoy and sending data back through the subsea transmission cable. The array of hydrophones could allow tracking of vocal animals through the wave park. Any survey protocol will follow the NOAA guidelines for use of passive acoustic listening systems for monitoring in mitigation programs (NOAA, NMFS internal memorandum of October 8, 2008).

Summary of conclusions:

Characterization of wave energy buoy acoustic output

- Automated acoustic recorders
- 1 Hz to 10 kHz (up to 60 kHz for concurrent monitoring of marine mammals, or up to 150 kHz for harbor porpoise monitoring, specifically)
- Adaptive sampling scheme based on initial measurements
- Sampling rate 22 kHz (sampling rate of 120 kHz for marine mammal monitoring, or 300 kHz for harbor porpoises, specifically)
- 10 m off the bottom
- Three monitoring distances – 100-200 m, 400-500 m, 1-2 km
- Long-term (e.g. 1 year) measurements needed to assess environmental variability
- Optimize sampling design (e.g. 5 min every hour)

Behavioral monitoring

- Shore-based theodolite tracking for large whales
- Passive acoustic monitoring for odontocetes and pinnipeds and for offshore observations and habitat use
- Some baseline data may be applicable for future larger-scale development (e.g. habitat displacement of porpoises)
- Tagging studies can be conducted to determine distribution and habitat use of summer resident gray whales

Passive acoustics monitoring (PAM) for habitat use studies

- PAM methods to record habitat use and compare changes before/during/after deployment of buoys
- Ideally one full annual cycle of observation pre-deployment and one year post-deployment
- On-site and off-site (control) observations with separation based on habitat heterogeneity at area of deployment
- 100-150 kHz for harbor porpoises
- Up to 60 kHz for dolphins
- 10 kHz for pinnipeds
- 5 min every hour
- Devices are available for this sampling

Deterrence devices

- Porpoise pingers are available
- May not work at enough distance for gray and other large whales
- Fisheries pinger specifications (for porpoises to detect nets at close distance): broadcasts a sound frequency range of approximately 10 kHz at 132 dB re 1 μ Pa at 1 m with pulse duration of 300 milliseconds and a pulse period of 4 seconds.
- Optimization problem for gray whales
- May be between 3-5 kHz and 60 dB above ambient noise but further calculations needed

- Ideally output level should adjust to ambient noise level. Ambient noise curves are available
- It may be advantageous to have a system capable of varying the sound signal over time to prevent habituation by gray and other large whales.

References

- BARLOW, J. and G. A. CAMERON. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. *Marine Mammal Science* 19:265-283.
- BOEHLERT, G. W., G. R. McMURRAY and C. E. TORTORICI, Eds. 2008. Ecological effects of wave energy in the Pacific Northwest. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-92.
- FRANKEL, A. S. 2005. Gray whales hear and respond to a 21-25 kHz high-frequency whale-finding sonar. *16th Biennial Conference on the Biology of Marine Mammals*, San Diego, CA: 97.
- GREEN, G. A., J. J. BRUEGGEMAN, R. A. GROTEFENDT and C. E. BOWLBY. 1995. Offshore distances of gray whales migrating along the Oregon and Washington coasts, 1990. *Northwest Science* 69:223-227.
- ORTEGA-ORTIZ, J. G. and B. R. MATE. 2008. Distribution and movement patterns of gray whales migrating by Oregon: Shore-based observations off Yaquina Head, Oregon, December 2007-May 2008. Report submitted to the Oregon Wave Energy Trust. 34 pp. Available from Oregon State University Marine Mammal Institute, 2030 SE Marine Science Drive, Newport, OR 97365.
- RICHARDSON, W. J., C. R. GREENE, JR., C. I. MALME and D. H. THOMSON. 1995. *Marine Mammals and Noise*. Academic Press, San Diego, CA.

Appendix I

Workshop Agenda

Thursday, October 9th

Presentations:

- 9:00-9:15 Welcome and review of meeting agenda and objectives (OSU and OWET)
- 9:15-10:00 Description of power generating buoys, wave energy farms, mooring, location, number of buoys, etc. (Wave Energy Industry representative)
- 10:00-10:20 Environmental description of proposed wave energy farm sites: depth, bottom type, prevailing currents (Wave Energy Industry representative)
- 10:20-11:00 Distribution of gray whales along the Oregon coast (OSU)
 - Previous studies (1978-81 Yaquina Head observations and 1990 aerial surveys)
 - Summary of 2007-08 Yaquina Head observations.

Panel Discussion with experts:

- 11:10-11:40 Review Recommendations from Marine Mammal group of the Ecological Effects Workshop and discussion
- 11:40-12:00 Need to Evaluate Effects on Other Whale Species
- 12:00-13:00 Lunch
- 13:00-14:30 Characterization of sound from wave energy buoys
 - Review Ocean Power Technologies (OPT) protocol for measuring sound at project site
 - Sound propagation models
 - Estimating of exposure of whales
- 14:30-17:00 Assessment of potential effects of sound from wave energy farms on whales
 - Review OPT's proposed methods for post-deployment monitoring and determine adequacy of approach
 - Behavioral observations and methodology for monitoring whale behavior near wave energy systems (study design characteristics and requirements)
 - Device options for active deterrence
 - Control Exposure Experiments (CEE's)

Friday, October 10th

Roundtable:

- 8:00-9:45 Mitigation Options
- How to determine the need for mitigation? (Monitoring protocols)
 - Potential need for and effectiveness of active deterrence, as well as other potential effects on marine resources
 - Location and techniques for observations
- 9:50-10:00 Coffee break
- 10:00-12:00 Final remarks and mitigation plan summary
- Summary of information and research needs
 - Priorities and methods for monitoring plan
 - Recommendation on strategies to avoid whale entanglements and collisions
 - Considerations on timing and scheduling future work and research

Appendix II

Workshop List of Participants

Alison Agness*, NOAA, NMFS, Northwest Region Protected Resources Division
Peter Browne, Devine Tarbell and Associates
Adam Frankel, Marine Acoustics, Inc.
Charles R. Greene, Greeneridge Sciences, Inc.
Jim Hastreiter, Federal Energy Regulatory Commission
Justin Klure, Oregon Wave Energy Trust
Steve Kopf, Ocean Power Technologies, Inc.
Bruce Mate, Oregon State University
Dave Mellinger, Oregon State University/NOAA Fisheries
Brent Norberg*, NOAA, NMFS, Northwest Region Protected Resources Division
Joel Ortega-Ortiz, Oregon State University
Brandon Southall*, Ocean Acoustics Program, NOAA Fisheries
Rick Williams, SAIC/OWET
George Wolff, Ocean Power Technologies, Inc.
Sheri Woods, Oregon State University

* Attended by teleconference