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BEHAVIORAL RESPONSES OF CETACEANS TO ANTHROPOGENIC SOUND: A COMMUNITY PERSPECTIVE ON RESEARCH PRIORITIES AND FUTURE STEPS



Duke NICHOLAS SCHOOL OF THE ENVIRONMENT

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SUMMARY: Over the last decade BRSs have resulted in a number of key findings that have significantly increased the knowledge base of responsive behavior to anthropogenic noise and also baseline behavior of many species. However as we learn more we continually face more questions. For sonar studies we are at a juncture where efforts to date have been evaluated and future research priorities considered by a group of experts. We took the opportunity to poll the wider marine mammal and sound community on their thoughts for future priorities and present the outcomes here.

BEHAVIOURAL RESPONSE STUDIES

Behavioral Response Studies (BRS) aim to determine the relationship between the dose of a stressor (which can be represented by many different metrics) and behavioral response. BRSs have investigated the effect of a wide range of sound sources on cetacean behavior including various naval sonar signals, seismic airguns, pile driving, marine construction and acoustic deterrent devices. A number of different approaches have been adopted (Fig 1).

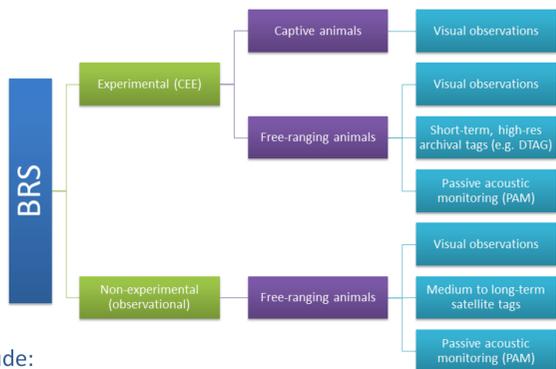


Figure 1: The basic categories of BRSs and the primary methodologies used.

Some key findings across studies include:

- Many species respond at lower noise levels than currently predicted by impact assessment models.
- Huge variation in response type and level being driven by intrinsic and extrinsic factors
- Signal characteristics matter
- Received level possibly not the most important dose parameter

There are many, many outstanding questions, we name a few below:

- Can we extrapolate our findings within and between sound types, i.e. how can we group species?
- Cumulative effects of repeated exposure on individuals
- Population consequences of acoustic disturbance.
- Behavioral responses of small cetaceans and pinnipeds to many sound sources.

STATUS AND FUTURE OF RESEARCH

In 2015 the US ONR, LMR and NOAA commissioned a Behavioral Response study Evaluation Workshop (the BRREW project) with the aim of evaluating past and current research efforts and recommending future research priorities in relation to naval sonar sources. The project report (Harris & Thomas (2015)) is available here: <http://hdl.handle.net/10023/7741>



The workshop consisted of key representatives of US Navy-funded BRSs and three invited external experts. The following research approaches were reviewed:

- Controlled exposure experiments (CEEs) on captive animals using simulated sources of Navy sonar
- CEEs on free-ranging animals using simulated Navy sources or real, but scaled, Navy sources on research vessels
- CEEs on free-ranging animals using real Navy sources deployed by Navy vessels
- Observational studies (primarily using tags, PAM and visual observation) in relation to exposure to real Navy sources and Navy vessels
- Predator playback studies

The external experts each provided an independent evaluation of the research to date and recommendations for future research efforts. In summary the external experts:

- Recommended that BRS research be continued and extended to increase sample sizes and experimental replication, and temporal duration and spatial scale.
- Noted that future investigations would benefit from combining experimentation and observation to enable linkage of short-term behavioral response to long-term fitness consequences of repeated exposure.
- Emphasized the importance of baseline studies and longer-term monitoring of animals before and after exposure.
- Ranked beaked whales highest in terms of research priority.

Specifically the experts made 31 recommendations regarding future research priorities. Below we highlight the highest ranked recommendations (Table 1). Please see report for full listing.

Table 1: Top-ranked future research priorities

Recommendation	Approach	Priority score
Increase collection of baseline data (improve both spatial and temporal extent of data)	Free-ranging CEEs and observational with sat tags	1-1-1
Conducting CEEs with real Navy vessels and sources to generate dose-response functions for real sonar sources	Free-ranging CEEs with real sources	
Investigate the relationship between source-whale distance and received level	Free-ranging CEEs with real sources	
Development of a medium-long term Fastloc GPS tag that can measure sound exposure	Technology	1-1-2
Development of attachment mechanism to fit GPS tag to porpoises and small dolphins	Technology	
Development of long-term tag attachment mechanism for large species that cannot be captured for attachment.	Technology	
Improve understanding of link between dose and severity of response to better understand consequences	Observational and free-ranging CEE	

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References: Harris & Thomas (2015) CREEM Technical Report 2015-3. Background information on all of the above can be found on the MOCHA project website - <http://www.creem.st-and.ac.uk/mocha/>
Acknowledgements: We would like to thank the SMM organisers for allowing us to hold the pre-conference workshop and to all those who attended, presented and participated in the polling sessions.

COMMUNITY PERSPECTIVE

A workshop was held prior to the 2015 SMM conference to present and discuss the status and future of marine mammal BRSs. The workshop included presentations and discussions on:

- results from studies investigating the effects of naval sonar
- how predictions from these studies can be (and are being) tested at broader spatial and temporal scales
- naval sonar studies in the broader context of anthropogenic sound in the ocean
- taking the step from individual to population-level consequences.

Throughout the workshop we polled participants to gain a community perspective on future research priorities. We present some of the results below.

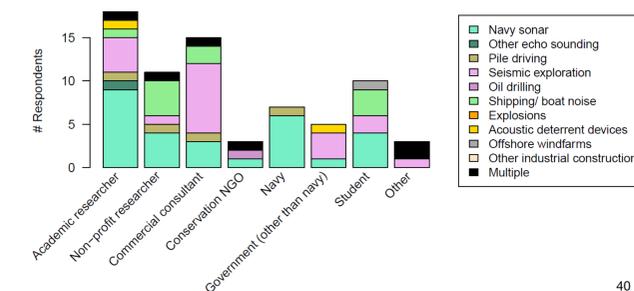


Figure 2: Composition of participants and an indication of their primary interest.

Participants were asked their opinion on which sound source is of greatest concern for marine mammals globally, and then which source they believe has the best science base. There was a disparity between what participants believed to be of greatest concern (shipping noise) and where there has been most research effort (Navy sonar) (Fig 3). This was discussed and was thought to be driven by regulatory requirements, funding and the difficulty of studying impacts that are more likely to be chronic than acute.

The workshop had representation from all the major stakeholder groups with a range of interests across sound types (Fig 2).

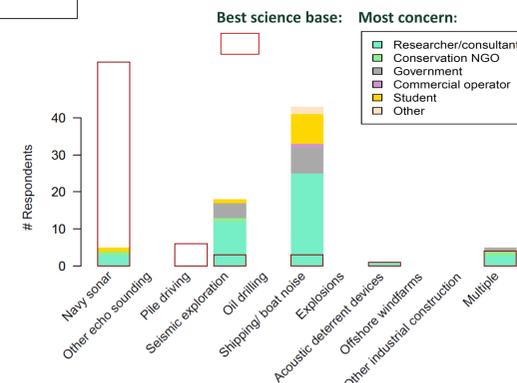


Figure 3: Comparison of sound source of greatest concern and sound source thought to have best science base.

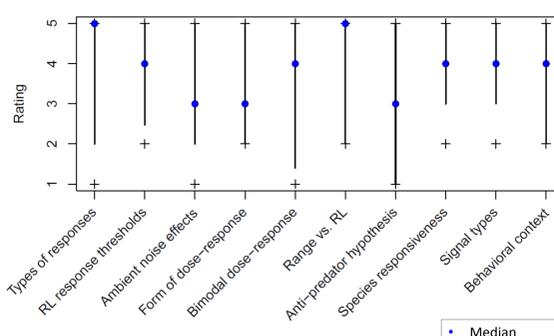


Figure 4: Median priority ratings of research topics for testing/validating in a non-experimental setting. 1=low priority, 5=high priority.



We asked participants to prioritise species, firstly for studying in relation to sonar but also in relation to their own sound source of interest. There was general agreement that beaked whales should be the highest priority for BRSs on sonar, however priorities differed across sources. For example, ESA-listed baleen whales were selected as the priority species by the majority of those interested in seismic and shipping.



Participants were asked to indicate their level of agreement with four of the top research priorities identified by the BRREW report. There was general agreement that these recommendations should be priorities for future research funding. In particular there was strong agreement that the collection of baseline data should be a high priority for future research efforts.

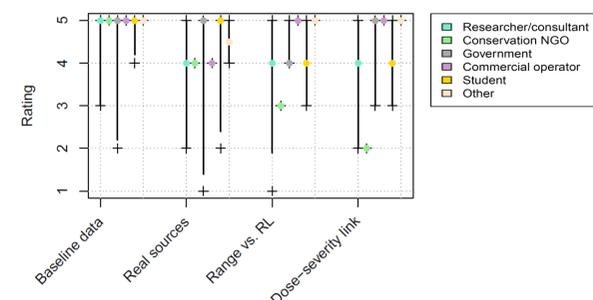


Figure 5: Median ratings for agreement that four of the top research recommendations from the BRREW report should be highly prioritised. Further information in Table 1. 1 = low level of agreement, 5=high level of agreement.