6th Working Group Meeting on the Multi-study OCean acoustics Human effects Analysis (MOCHA)
Hosted by University of St Andrews, St Andrews, Scotland
2-5 December 2014

1. Summary

This document briefly reports on the sixth, and final, meeting of the US Office of Naval Research sponsored MOCHA working group, held on 2-5 December 2014 and hosted by the University of St Andrews. The overall aim of the group is to develop and implement innovative statistical methodologies for the analysis of behavioral response study (BRS) data. In this final meeting we presented an overview of the status of each of the main areas of methodological development, with the aim of getting feedback from the working group and selected external peers, and guidance on priorities for the remaining months of the project. We also dedicated two days to working in small groups with the BRS project teams on technical methodological development.

2. Background and objectives of working group

The background to the work and the objectives of the working group are described in full in the report of the 1st Working Group Meeting and in the project proposal. Both of these documents are available for download from http://www.creem.st-and.ac.uk/mocha/

The specific objective of the 6th Working Group Meeting was to focus on reporting progress within the main areas of methodological development and in relation to the primary objectives set out in the original MOCHA proposal. We hoped to receive feedback on our efforts to date, and guidance on priorities for the remaining few months of the project.

3. Summary of sixth working group meeting

The format of the first two days of the working group meeting was more structured than recent meetings, with the focus being on presentations of methods and analysis rather than data and results. Following a couple of introductory presentations on behavioural response studies (BRS) and the analytical challenges associated with BRS data, we held more technical sessions on a number of topics. Within each session we introduced an analysis tool/method of interest that has been developed or adapted by MOCHA for application to BRS data. This was followed by presentations by two or three researchers who provided examples of how they have applied the tools to their data, and then we finished each session with open discussion. The main topics presented were:

- Univariate regression (specifically Generalised Estimating Equations) as a tool for detecting changes in key behavioural parameters as a result of sound exposure.
- Multivariate modelling (specifically the application of Mahalanobis distance) as a tool for detecting change-points across multivariate data.

- Detecting horizontal movement responses (e.g. avoidance) using state-based approaches.
- Detecting behavioural states and changes using state-based approaches (specifically semi-Markov and hidden Markov models)
- Dose-response analysis (specifically Bayesian hierarchical models) as a tool for relating responses to dose and investigating the role of contextual variables.
- Dose-response severity analysis (specifically recurrent event survival analysis) as a tool for relating responses of different severities to dose and investigating the role of contextual variables.

Following each series of presentations there was the opportunity for discussion and review of the methods.

On the second day, Harris provided a short overview of the MOCHA objectives and outlined how these have been addressed along with a summary of outputs to date. Thomas and Harris (MOCHA PIs) then invited everyone to give their views on what MOCHA has done over the course of the project so far, and what it should be focussing on in the remaining 10 months.

There was discussion about the efforts to pool results across the studies and conduct meta-analysis. Thus far efforts have been hampered by too many confounding variables across studies. We discussed how this could be improved by BRS researchers considering more overlap in their protocols and experimental set-up. Southall noted an interested in seeing a sensitivity analysis to investigate what would allow data to be more pool-able.

Miksis-Olds noted that MOCHA have developed many analytical tools, but suggested that a comparison of methods would be useful, along with guidance on the methods that could be applied in different situations. There was general support for this suggestion. It also felt that a publication or report outlining how MOCHA have improved methods from what has been done previously would be a useful output, particularly in highlighting what analyses are now possible.

The link between BRSs and biological consequences were discussed in the context of how outputs from BRSs can feed into the likes of the PCoD model. There are opportunities for dose-response functions resulting from BRSs to feed into PCoD models, but making inference about population level consequences from behavioural responses observed on individuals is still difficult. The current focus within PCoD models is on energetics and therefore other data, such as those from naval ranges, may be more appropriate because of the ability to assess recovery times.

There was a discussion about the inclusion of background noise measurements in analysis as there is evidence that the level of background noise affects the probability of response. To date MOCHA have focussed on SPL and cumulative SEL as dose metrics in analysis and there was discussion about whether other dose metrics, such as range or signal-to-noise ratio should also be examined. Currently most of the projects do not have ideal data on background noise levels during exposure and there were discussions about how this could

be measured or derived. It was noted however, that the MOCHA project can conduct analysis with any dose metric provided and the problem remains one of data availability.

Thomas requested feedback on whether MOCHA should carry out more sensitivity analysis relating to future experimental effort as, despite being a core MOCHA objective, it had not been a focus to date. It was felt that it would be useful to have an indication of sample sizes required to identify a response given a certain level of variability. It would also be useful to investigate how many replicate experiments would be required to determine if a difference exists between behavioural responses to a new sonar signal and an existing signal. In general there was a strong interest in doing some more simulation studies to assess future research priorities, however ideas need to be proposed to MOCHA by the project teams and specifications provided.

It was briefly discussed that there is a lack of information relating to duration of response from BRSs, and that a better understanding of a decay function or recovery time would be very useful.

Miller gave a short presentation on his work measuring body density from tag data and discussed the possibility of including body condition in BRS analysis, which would be relevant for linking BRS to PCoD. It was noted that it may also be useful to have prey field information to go along with the body condition as a covariate in any MOCHA-style analysis. Blue whales might provide a good case study for this. The SOCAL project already have qualitative gradings of the condition of tagged blue whales so it may be possible to look at whether there is an apparent relationship between body condition and response.

The third and fourth days of the meeting followed the successful format of the 5th working group meeting. In advance of the meeting we had asked people to propose research questions and come along equipped with ready-prepared datasets. The meeting was structured into multiple small working group sessions, which allowed time for significant development of a number of research questions and analyses. The following were the primary groupings over the two days, with brief descriptions of what each group achieved:

Minke whale change-point analysis
Participants: Stacy DeRuiter, Dina Sadykova, Petter Kvadsheim, Brandon Southall, Jeremy Goldbogen, John Calambokidis.

The goal of this meeting was to make a plan for analysis of the minke whale datasets collected by the 3S and SOCAL projects. The datasets available have different strengths and weaknesses. The 3S data have time-depth-recorder data (no acoustic or accelerometer records, and dive profile data are sampled at lower resolution) and good focal follow positions and surface behaviour observations. The SOCAL data do not have surface positions and focal follow observations, but do include higher-resolution tag data with more sensors (accelerometers, magnetometers and acoustics). Despite the differences in the datasets, there was a strong desire among the team to try to combine the various datasets, and prepare a single publication summarising the baseline dive data as well as assessing the responses to the two CEEs. During the meeting a plan was put together for analyses for a joint paper summarising all the data.

Pilot whale baseline analysis using generalised estimating equations (GEEs)
Participants: Catriona Harris, Charlotte Cure, Saana Isojunno, Nicola Quick, Laela Sayigh, Lindesay Scott-Hayward, Fleur Visser

The aim of this meeting was to update everyone on the work being done by different groups on pilot whales, specifically using GEE-based methods. The idea was to increase awareness of efforts, share ideas and prioritise MOCHA efforts within this topic. It was agreed that valuable outputs from MOCHA would include a generic methods paper describing the application of GEEs to pilot whale call rate data, generic R functions available to the group via the MOCHA website, and a review paper on the application of GEEs within ecology.

Blue whale hidden Markov model (HMM)
Participants: Stacy DeRuiter, Roland Langrock, Brandon Southall, John Calambokidis, Jeremy Goldbogen

The group reviewed the technical specification of a dive-by-dive HMM with discrete random effect, as well as the results of fitting 2- and 3-state versions of this model to the SOCAL blue whale data. The group discussed the blue whale results, and how they should be prepared for publication.

Pilot whale partially-observed hidden Markov model (HMM)
Participants: Nicola Quick, Laela Sayigh, Ruth King, Roland Langrock, Saana Isojunno, Stacy DeRuiter

This group focussed on focal follow data from the Duke-led BRS (on pilot whale baseline behaviour, as well as CEEs of pilot whales to echosounders), although any progress made on analysis would likely be applicable to a broad range of focal follow datasets. The issue being discussed was that focal follow data often contain many missing observations and there is a desire to develop methods to fill in the gaps in an appropriate way. To date MOCHA have used rather naïve methods like linear or nearest-neighbour interpolation, but a number of other options were discussed during this meeting. The main option discussed was to fit a partially-observed HMM, where the "states" are the behaviour states from the focal follow data. When focal follow data have been collected, the states would be observed (known, not hidden); when focal follow data on behaviour were missing, this method would allow filling them in, with some measure of uncertainty. Many of the technical details were outlined and this analysis will be taken forward as a collaboration between Duke and MOCHA.

Dose-response analysis using generalised estimating equations (GEEs)
Participants: Catriona Harris, Lindesay Scott-Hayward, Monique Mackenzie, Bec Dunlop

This meeting was to discuss a way forward with the dose-response analysis of data from the BRAHSS project that was initiated at the meeting in Olympia. An analysis plan was put together and a joint publication between BRAHSS and MOCHA is expected from this work.

4. Acknowledgements

Appendix 1 – 6th working group meeting attendees

Louise **Burt**, CREEM
John **Calambokidis**, CRC
Charlotte **Cure**, CEREMA
Rene **Dekeling** , NLDMO
Stacy **DeRuiter**, CREEM
Kristianne **Dreteler**, TNO
Glenn **Gailey**, CRC
Odile **Gannier**, French MoD
Jeremy **Goldbogen**, Stanford University
Catriona **Harris**, CREEM
John **Harwood**, CREEM
Dorian **Houser**, NMMF
Saana **Isojunno**, SMRU
Vincent **Janik**, SMRU
Frants **Jensen**, Princeton University
Ruth **King**, CREEM,
Petter **Kvadsheim**, FFI
Roland **Langrock**, CREEM
Frans-Peter **Lam**, TNO
Monique **MacKenzie**, CREEM
Jennifer **Miksis-Olds**, PSU
Patrick **Miller**, SMRU
Doug **Nowacek**, DUML
Nicola **Quick**, DUML
Filipa **Samarra**, MRI
Laela **Sayigh**, WHOI
Lindesay **Scott-Hayward**, CREEM
Brandon **Southall**, SEA Inc.
Len **Thomas**, CREEM
Peter **Tyack**, SMRU
Dina **Sadykova**, CREEM
Fleur **Visser**, KMR
Paul **Wensveen**, SMRU
Erica **Ye**, SCS

Institutional addresses:

CEREMA	Centre For Studies and Expertise on Risks, Environment, Mobility, and Urban and Country planning, Strasbourg, France
CRC	Cascadia Research Collective, 218 1/2 W. 4th Avenue, Olympia, WA 98501, USA
CREEM	Centre for Research into Ecological and Environmental Modelling, University of St Andrews, St Andrews KY16 9LZ, UK.
DUML	Duke University Marine Lab, 135 Duke Marine Lab Rd, Beaufort, NC 28516, USA
FFI	Maritime Systems Division, Norwegian Defence Research Establishment (FFI), NO-3191 Horten, Norway
French MoD	French Ministry of Defence
KMR	Kelp Marine Research, Amsterdam, The Netherlands

MRI	Marine Research Institute, Iceland
NLDMO	NL Defence Materiel Organisation, Postbus 90822, 2509 LV Den Haag, Netherlands
NMMF	National Marine Mammal Foundation, 2240 Shelter Island Drive Suite 200 San Diego, California 92106, USA
Princeton	Ecology and Evolutionary Biology Department, Princeton University, NJ, USA
PSU	The Pennsylvania State University, PO Box 30, Mailstop 3510D, State College, PA 16804, USA
SCS	School of Computer Science, University of St Andrews, St Andrews, UK
SEA Inc.	Southall Environmental Associates, Inc., 9099 Soquel Drive, Suite 8 Aptos, CA 95003, USA
SMRU	Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews KY16 8LB, UK
Stanford	Hopkins Marine Station, University of Stanford, California, USA
WHOI	Woods Hole Oceanographic Institution, MA, USA
TNO	Observation Systems, TNO, Defence, Security and Safety, The Hague, The Netherlands