8th DCLDE Workshop

Marine Mammals and Acoustics

4 – 8 June 2018

FRANCE

http://sabiod.univ-tln.fr/DCLDE/

Photo credit Cetamada

Photo of the 2018 DCLDE participants

(Photo credit: P. Kitmacher –Sorbonne Université – June 8, 2018)

Editorial

Dear Colleagues,

As you know now, since 2003, the International Workshop on Detection, Classification, Localization, and Density Estimation of marine mammals using passive acoustics (DCLDE) is the scientific meeting to show and share research on all aspects of acoustics, signal processing, pattern recognition, mathematics, and computer sciences applied to the study of the biology, ethology and ecology of marine mammals and also their environment and the potential effects of anthropogenic activities!

From June 4-8, the Sorbonne University in the center of Paris, France, is the setting for the 8th session of the DCLDE Conference. Our University has more than 6000 researchers, 130 laboratories, and 50000 students including 4400 PhD candidates. The Faculty of Sciences and Engineering covers all the theoretical and applied scientific topics: ecology, biology, geosciences, chemistry, mathematics, engineering, physics and computer science.

Research programs are made to cultivate new knowledge and to develop methods and materials. It is also the opportunity to collaborate and to exchange multidisciplinary skills at the international level. This DCLDE conference is part of this process, bringing together researchers, engineers and students from around the world to share their recent work on the use of passive acoustics to study marine mammals and their environment. Our results will serve as a contribution to improving underwater life and the conserving and protecting the marine world. And how timely is this conference, which falls just before the International Day of the Ocean 2018!

We also are very proud to welcome the amazing choreographer Camille Hanson whose research, creativity, and ambitions are aligned with those of our scientific community.

Thank you for taking part in this conference. This is your conference… so enjoy it.

Olivier ADAM
Institut d'Alembert
Sorbonne Université

Dear DCLDE Participants,

The d'Alembert Institute (www.dalembert.upmc.fr) is a public French laboratory of Sorbonne University with 100 researchers specialized in acoustics working in 5 different teams:

- Complex Fluids and Hydrodynamic (keywords: Instabilities Fluid mechanics in complex configurations, instabilities, two-phase flows, granular media)
- Reactive Fluids and Turbulence (keywords: Large eddy simulation, combustion devices, pollution control, uncertainty propagation)
- Lutheries, Acoustics, Music (keywords: Multidisciplinary research on musical instruments and sound)
- Modelling, Propagation and Acoustic Imaging (keywords: Mechanical waves, aeroacoustic, biomechanics, inverse problems, acoustic control/imaging)
- Mechanics and Engineering of Solids & Structures (keywords: Modelling and optimization of structures, behavior of heterogeneous materials)

We are involved on different scientific projects dealing with underwater acoustics, especially the study of sonars, the analysis of the underwater acoustic propagations, and the description of underwater soundscapes. You can see that these topics are part of those who describe the DCLDE conference.

Then, welcome among us to the 8th International Workshop on Detection, Classification, Localization, and Density Estimation of marine mammals using passive acoustics!

Stéphane ZALESKI
Directeur
Institut d'Alembert
Sorbonne Université

CONTENTS

DCLDE 2018 Program

The 8th International Workshop on Detection, Classification, Localization, and Density Estimation of marine mammals using passive acoustics will take place at Sorbonne University in Paris, France, from the 4th to the 8th of June 2018.

The DCLDE Workshop brings together researchers and engineers from universities, research institutes, government organizations, and industry, dealing with all aspects of acoustics, signal processing, pattern recognition, mathematics, and computer sciences applied to the study of the biology, ethology and ecology of marine mammals and also their environment and the potential effects of anthropogenic activities. The goal is to provide a forum for exchange of new results obtained from the latest advances in instrumentation and from the recent methods. Also this workshop will clearly encourage interdisciplinary approaches to create more knowledge on these species.

The DCLDE Workshop will comprise a prominent series of thematic sessions of oral and poster presentations. Abstracts will be published in proceedings to be made available to all registered participants on the first day of the Workshop.

As the previous sessions of the DCLDE workshops, a challenge is offered to compare methods, algorithms, and results. This time will be awarded the team that will best detect and classify the underwater acoustic environment including sounds emitted by mysticeti and odontoceti species among other biological, natural and anthropogenic noises.

The workshop will deal with engineering sciences including acoustics, signal processing, pattern recognition, mathematics, and computer sciences, dedicated to studies of marine mammals:

- detection of pulsed and harmonic sounds
- classification of diverse sounds including clicks, whisles and vocalizations
- localization of marine mammals
- estimation of population density
- acoustic propagation models
- innovative engineering including new materials and tools
- big data analytics
- study of sound generator of marine mammals
- underwater soundscapes: description of environmental acoustics and sounds from human activities

Welcome to Sorbonne University!

Address: 4 place Jussieu, 75005 Paris, France

To access

- Subway station: line #7 or line #10 (stop "Jussieu")
- Bus: Line #67 or line #89 (stop "Jussieu") or line #24 or line #63 (stop "Université Paris 6")
- By car: be careful, you have to pay to park your car all around the University.

Info on http://www.locations.espaces.upmc.fr/fr/campus.html

Committees

Scientific Committee
(alphabetic order):

Underwater acoustics
ASCH Mark, LAMFA, Université de Picardie, France
CRISTINI Paul, LMA, Marseille, France
FRASIER Kait Frasier, Scripps Whale Acoustic Lab, San Diego, USA
GERVAISE Cédric, GIPSA-Lab, Grenoble, France
KINDA Bazile, SHOM, Brest, France
LE COURTOIS Florent, SHOM, Brest, France
NOVAK Antonin, LAUM, Le Mans, France
SILVA Fabrice, LMA, Marseille, France
ŠIROVIĆ Ana, Scripps, UCSD, USA
STEPHAN Yann, SHOM, Brest, France
THODE Aaron, Scripps, USA
VAN PARIJS Sofie, NOAA Federal, USA

Signal Processing
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MARS Jérôme, GIPSA-Lab, Grenoble, France
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MORETTI David, NUWC NWPT, USA
MORRISSEY Ronald, NUWC, Newport, USA
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STAFFORD Kate, APL, University of Washington, USA
WHITE Paul, ISVR, University of Southampton, UK
ZARADER Jean-Luc, Sorbonne University ISIR, Paris, France

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GLOTIN Hervé, LIS, Toulon, France
KLINCK Holger, Cornell, USA
MERCADO Eduardo, University at Buffalo, New York, USA
MOUY Xavier, Jasco, School of Earth and Ocean Sciences, Univ. of Victoria, Canada
OBIN Nicolas, Ircam, Paris, France
ROCH Marie, San Diego State University, USA

Density Estimation
HARRIS Danielle, CREEM, University of St Andrews, UK
MARQUES Tiago, CREEM, University of St Andrews, UK
THOMAS Len, CREEM, University of St Andrews, UK

Soundscapes
BAUMGARTNER Mark, Biology Department, Woods Hole, USA
CAZAU Dorian, ENSTA Bretagne, Brest, France
GLOTIN Hervé, LIS, Toulon, France
PAVAN Gianni, CIBRA, Pavia, Italy
SUEUR Jérôme, MNHN, Paris, France

Biology, ethology, ecology, genetics of marine mammals
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CURÉ Charlotte, CEREMA, France
DELFOUR Fabienne, LEEC, Paris, France
JUNG Jean-Luc, BioGeMME, Brest, France

Challenge committee

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HILDEBRAND John, Scripps, San Diego
RICARD Julien, LIS, Toulon

Organizing committee

ADAM Olivier, Sorbonne Université, Paris
DOH Yann, Association Dirac, Paris
PRÉVOT Jean-Marc, UTLN, Toulon (web pages)

Credit photo: Joël Detcheverry – association SPM Terre Vivante

Monday 4 June : 8:30 – 5:00pm Thematic tutorial sessions on Machine Learning and Density Estimation

Tuesday 5 June

8:00 – 8:50am	Registration
8:50 – 9:00am	Welcome from Prof Olivier Adam, Organizer, Sorbonne University, France
Oral session #1	**Topic: New Technology Chair: Marie Roch**
9:00 – 9:20am	Florent Le Courtois: *Sparse hypothesis for time-frequency representation: application to the detection of the vocalization of marine mammals*
9:20 – 9:40am	Dave Mellinger: *Enhancements to Software for Detection, Classification, and Localization*
9:40 – 10:00am	Douglas Gillespie: *PAMGuard: New features and future directions*
10:00 – 10:20am	Peter Dugan: *The Raven-X Software Package: A scalable high performance computing framework for the analysis of large bioacoustic sound archives*
10:20 – 10:40am	*Coffee break*
Oral session #2	**Topic: Detection Chair: Flore Samaran**
10:40 – 11:00am	Ana Širović: *Detection of blue whale D calls from long-term recordings in southern California*
11:00 – 11:20am	Maëlle Torterotot: *Automated detection of non-stereotyped whale calls using dictionary-based representations: application to blue whale D-calls*
11:20 – 11:40am	Lea Bouffaut: *Passive Stochastic Matched Filter for Antarctic Blue Whale call detection: performance analysis on highly variable SNR ground-truth dataset*
11:40 – 12:00pm	Franck Malige: *Joint analysis of pulsation and peak frequency : a model for examining frequency decrease in pulsed blue whale song*
12:00 – 12:20pm	Rose Hilmo: *Characterizing Blue and Fin Whale Populations Using a Large Ocean-Bottom Seismometer Array*
Poster session #1	**Topic: Detection and communication** (Authors have 2 min to orally pitch their poster)
12:20 – 12:22pm	Elena Papale: *Year-round acoustic patterns of bottlenose dolphins and interaction with anthropogenic activities in the Central Mediterranean Sea*
12:22 – 12:24pm	Juliana Lopez Marulanda: *Who is vocalizing? an innovative detection-localization system to study dolphins communications and social behaviours*
12:24 – 12:26pm	Marion Poupard: *Ethoacoustics: a new model based on automatic clustering, applications on Pantropical Spotted dolphin whistles during whale watching*
12:26 – 12:28pm	Tess Gridley: *Acoustic signalling predicts surface behaviour in common bottlenose dolphins (Tursiops truncatus)*
12:28 – 12:30pm	Fabio Cassiano: *Introducing DeteClic: a user-friendly and comprehensive automated click detector to monitor odontocetes*
12:30 – 12:32pm	Julien Ricard: *DyniClick: open-source toolbox for stereo click detection, analysis and tracking*
12:32 – 12:34pm	Jennifer Wladichuk: *Ambient soundscape of grey whale feeding grounds in British Columbia, Canada*
12:34 – 1:50pm	*Lunch*
Oral session #3	**Topic: Density Estimation Chair: Len Thomas**
1:50 – 2:10pm	Len Thomas: *Evaluation of methods for estimating call density from static acoustic sensors: bowheads in the Beaufort*
2:10 – 2:30pm	Tiago Marques: *Estimating density of fin whales and beaked whales outside Navy Ranges*
2:30 – 2:50pm	Danielle Harris: *Estimating cetacean detection probabilities using slow-moving autonomous ocean vehicles: an example with Blainville's beaked whales*
2:50 – 3:10pm	Kalliopi Gkikopoulou: *Go Deep to get High – Depth dependent detectability of Blainville's beaked whales and the use of underwater autonomous vehicles as an acoustic platform for density estimation – A simulation approach*
3:10 – 3:30pm	Gerald D'Spain: *Environmental Calibration for Density Estimation using Directional Sensor Systems*
3:30 – 3:50pm	*Coffee break*
Oral session #4	**Topic: Classification Chair: Dorian Cazau**
3:50 – 4:10pm	Mark Thomas: *Marine mammal species classification using Convolutional Neural Networks*
4:10 – 4:30pm	Randall Balestriero: *WaveLetNet: Deep learning of chirplet and other wavelet for optimal marine mammals bioacoustical representation*
4:30 – 4:50pm	Daniel Wolff: *Heuristic Classification of Hydrophone Recordings*
4:50 – 5:10pm	Tyler Helble: *Improving marine mammal classification using context from multiple hydrophones*
5:10 – 5:30pm	Peter Achi: *Using Gaussian Discriminative Analysis and Neural Networks to Classify Odontocete Acoustic Encounters*
IceBreaking evening 7:00 – 10:00pm	Invitation to the IceBreaking evening at Sorbonne University, Jussieu, Zamansky Tower, floor 24th

Wednesday 6 June

Oral session #5	**Topic: Localization** **Chair: Hervé Glotin**
9:00 – 9:20am	Alexander Conrad: *Use of the Double-Difference Method to Improve Bowhead Whale Localizations from Autonomous Vector Sensor Recorders*
9:20 – 9:40am	Ludovic Tenorio-Hallé: *A double-difference method for high-resolution acoustic tracking using a deep-water vertical array*
9:40 – 10:00am	Alfie Anthony Treloar: *Towed array shape estimation for passive acoustic monitoring from a wave-propelled USV*
10:00 – 10:20am	David Lechner: *Comparison of Error Sources in TDOA Algorithms*
10:20 – 10:40am	Hervé Glotin: *1 MHz SR high definition 3D tracking of wild amazon river dolphins with JASON tiny array, results and perspectives*
10:40 – 11:00am	Yvonne Barkley: *Improving location estimates for sperm whales from towed linear array data*
11:00 – 11:20am	*Coffee break*
Oral session #6	**Topic: Baleen whales** **Chair: Kate Stafford**
11:20 – 11:40am	Denise Risch: *Acoustic detections of minke whales in Northeast Scotland*
11:40 – 12:00pm	Mark Baumgartner: *Near real-time delivery of baleen whale acoustic presence information collected with long-endurance autonomous platforms*
12:00 – 12:20pm	Thomas Guilment: *Joint detection-classification of baleen whale sounds using sparse representations*
12:20 – 12:40pm	Michelle Tanalega: *Application of machine learning techniques to identify foraging calls of baleen whales*
Poster session #2	**Topics: Detection, Classification, Soundscapes** (Authors have 2 min to orally pitch their poster)
12:40 – 12:42pm	Aaron Thode: *Using nonlinear time warping to estimate North Pacific Right Whale calling depths in the Bering Sea*
12:42 – 12:44pm	Ann Allen: *Optimization of a general power law algorithm for detection of humpback whale calls in heterogeneous acoustic datasets*
12:44 – 12:46pm	Vincent Roger: *AutoEncoder for Marine Mammal Bioacoustics*
12:46 – 12:48pm	Divna Djokic: *Humpback whale song theme recognition tool*
12:48 – 12:50pm	Dorian Cazau: *Bi-class classification of humpback whale sound units against complex background noise with deep convolution neural network*
12:50 – 12:52pm	Charles Vanwynsberghe: *Labeling method of the South Indian Ocean marine soundscape and associated database*
12:52 – 12:54pm	Franck Malige: *Acoustical analyses of submarine explosions in northern Chile on long term continuous recordings*
12:54 – 1:50pm	*Lunch*
Oral Session #7	**Topic: Beaked whales** **Chair: Odile Gérard**
1:50 – 2:10pm	Shannon Rankin: *Beaker BANTER: Application of Compound Classification to Beaked Whales*
2:10 – 2:30pm	Natalia Sidorovskaia: *Unsupervised clustering approach to classify beaked whale's clicks*
2:30 – 2:50pm	Susan Jarvis: *The Spatio-Temporal Distribution of Cuvier's Beaked Whale Buzz Detections off San Clemente Island, California*
2:50 – 3:10pm	Alba Solsona Berga: *Gaussian mixture models for automatic classification of Cuvier's beaked whale echolocation clicks*
3:10 – 3:30pm	Jay Barlow: *3D acoustic dive tracking of Cuvier's beaked whales using a nested array of drifting hydrophone recorders*
3:30 – 3:50pm	Simone Baumann-Pickering: *Geographic differences in Blainville's beaked whale echolocation clicks*
3:50 – 4:10pm	*Coffee break*
Oral Session #8	**Topic: Odontocete clicks** **Chair: Yann Doh**
4:10 – 4:30pm	Jennifer Keating: *An acoustic survey of beaked whale and Kogia in the main Hawaiian Islands using drifting recorders*
4:30 – 4:50pm	Karlina Merkens: *Kogia click characteristics: new recordings, new locations, new instruments, new detectors*
4:50 – 5:10pm	Jens Koblitz: *Toothed whale classification- incorporating echolocation click properties and global distribution*
5:10 – 5:30pm	John Hildebrand: *A method for annotation of odontocete echolocation clicks*
5:30 – 5:50pm	Kaitlin Frasier: *Machine learning methods to guide odontocete echolocation insights from large datasets*
5:50 – 6:10pm	Tina Yack: *Inter and Intra Specific Variation in Echolocation Signals Among Odontocete Species in Hawaii, the Northwest Atlantic and the Temperate Pacific*

Thursday 7 June

Oral session #9	**Topic: Detection** **Chair: Julie Patris**
9:00 – 9:20am	Harald Yurk: *The effects of ambient noise and propagation loss on the acoustic detection of killer whales in inshore waters in British Columbia, Canada*
9:20 – 9:40am	Julien Ricard: *Long term Cachalot and noise monitoring on stereo sonobuoy Bombyx*
9:40 – 10:00am	Kristian Beedholm: *Finding a needle in a whole bunch of needles: targeted species discrimination based on differential template outputs*
10:00 – 10:20am	Pina Gruden: *Automated extraction of dolphin whistles in the presence of missed detections and false alarms*
10:20 – 10:40am	*Coffee break*
Oral session #10	**Topic: Humpback whales Chair: Isabelle Charrier**
10:40 – 11:00am	Olivier Adam: *From anatomy to sounds: description of the sound generator*
11:00 – 11:20am	Anjara Saloma: *Humpback whale calves' vocal repertoire in the Sainte Marie channel breeding ground*
11:20 – 11:40am	Eduardo Mercado: *Spectral spacing by singing humpback whales*
Poster session #3	**Topics: Methods, Detection, Localization** (Authors have 2 min to orally pitch their poster)
11:40 – 11:42am	Abel Ho: *Sound Source Separation of Overlapping Signals through High-resolution Beamforming*
11:42 – 11:44am	Paul Nguyen: *Using Deep Learning method to classify marine mammals*
11:44 – 11:46am	Valentin Gies: *Qualilife-JASON 1 MHz SR multichannel recorder, luxmeter and low power wake-up detector*
11:46 – 11:48am	Taiki Sakai: *Automated burst pulse detection using Pamguard Whistle & Moan Detectors*
11:48 – 11:50am	Flore Samaran: *Using acoustic glider to explore seamont in western Indian Ocean and looking for baleen whales*
11:50 – 11:52am	Ilse Van Opzeeland: *On the reliability of acoustic annotation and automatic detections of Antarctic blue whale calls under different acoustic condition*
11:52 – 11:54am	Sonia Español Jiménez: *An automatic method for a detection of blue whale calls*
11:54 – 11:56am	Marie Sauvêtre: *Acoustic analyses of Sperm whales vocalizations: indication of vocal signature and cultural transmission of vocal repertoire*
11:56 – 11:58am	Maxence Ferrari: *Cachalot ultra high frequency near field multichannel analysis*
11:58 – 12:00pm	Pierre Cauchy: *Monitoring of the distribution of sperm whales using PAM gliders*
12:00 – 1:30pm	*Lunch*
Oral Session #11	**Topic: Density estimation Chair: Danielle Harris**
1:30 – 1:50pm	Carlos de Obaldía: *Abundance Estimation for Passive Acoustic Monitoring of Cetaceans using Click-based Correspondence Analysis*
1:50 – 2:10pm	Erin Oleson: *Progress in phases: using passive acoustics to estimate false killer whale abundance in Hawaiian waters*
2:10 – 2:30pm	Jamie Macaulay: *Fine scale harbour porpoise distribution and density in a tidal rapid habit using PAM*
2:30 – 2:50pm	Goldie Phillips: *Estimating the density of blue whales in the Southern California Bight: reducing uncertainty in cue rate and detection probability*
2:50 – 3:10pm	*Coffee break*
Oral Session #12	**Topic: Right whales Chair: Tiago Marques**
3:10 – 3:30pm	Hansen Johnson: *Probability of passive acoustic detection of right whales from autonomous platforms equipped with a real-time monitoring system*
3:30 – 3:50pm	Kaitlin Palmer: *WhaLeNet: Using a standard neural network to improve the generalisability of a right whale upcall detector*
3:50 – 4:10pm	Christopher Chin: *Supervised vs unsupervised feature learning for right whale upcall detection in convolutional neural networks*
Challenge Session #1	**Topic: Challenge Chair: Hervé Glotin**
4:10 – 5:30pm	Presentation of the results obtained by the participants to the challenge
Banquet evening	
7:00 – 1am	Cruise on the Seine river. Come on board (before 7:45pm) on the *Louisiane Belle* boat, on *Quai St Bernard, in front of the rue Cuvier*

Friday 8 June

Oral session #12	**Topic: Behavior** **Chair: Olivier Adam**
9:00 – 9:20am	Karin Dolan: *Beaked whale group deep dive behavior from passive acoustic monitoring*
9:20 – 9:40am	Jennifer Wladichuk: *Active communication space for beluga whales in Cook Inlet, Alaska*
9:40 – 10:00am	Mathilde Massenet: *Acoustic discrimination of fish versus mammal-eating killer whales by long-finned pilot whales: evidence with playback experiments*
10:00 – 10:20am	Lucie de Barluet: *Discrimination of conspecific sounds in Risso's dolphins (Grampus griseus)*
10:20 – 10:40am	Matthias Hoffmann-Kuhnt: *Whistling By – Issues with Identifying Moving Vocalising Dolphin*
10:40 – 11:00am	Xavier Mouy: *Sequential pattern mining of Pacific walrus sounds*
11:00 – 11:20am	*Coffee break*
Oral session #13	**Topic: human activities** **Chair: Jérôme Sueur**
11:20 – 11:40am	Amanda Debich: *Contributions of shipping and seismic survey noise to the underwater soundscape of the northern Gulf of Mexico*
11:40 – 12:00am	Nancy Di Marzio: *Temporal distribution and abundance of Cuvier's beaked whales with and without mid-frequency active sonar (MFAS) off San Clemente Island, California*
12:00 – 12:20am	Sander von Benda-Beckmann: *Using acoustic recorders and satellite tags in controlled sonar exposure experiments – estimating the acoustic dose in relation to behavioural responses*
Poster session #4	**Topics: Methods, Detection, Localization** (Authors have 2 min to orally pitch their poster)
12:20 – 12:22pm	Aaron Thode: *How the spacing between distributed sensors biases source level distribution and call density estimates, and how to correct for it*
12:22 – 12:24pm	Simon Vallez: *Automatic Localization of Sperm Whales and Sei Whales during Marine Seismic Survey*
12:24 – 12:26pm	Maxence Mercier: *Dynimax: a browser to stretch, to scrub and to visualize bioacoustical structures*
12:26 – 12:28pm	Thomas Norris: *The 3-D-V Array: A volumetric, digital towed hydrophone array system capable of bearing and location estimation in 3-D space*
12:28 – 12:30pm	Michael Reinwald: *Bone conducted sound in a dolphins' mandible: Experimental investigation of elastic waves mediating information on source localization*
12:30 – 12:32pm	Jim Theriault: *Catching more than lobsters in traps: Can citizen science be used to protect the North Atlantic right whale? human activities*
12:32 – 12:34pm	Jennifer Trickey: *Beaked whales use alternating echolocation regimes at the start of foraging dives*
12:34 – 1:50pm	*Lunch*
Oral Session #14	**Topic: Localization** **Chair: Bazile Kinda**
1:50 – 2:10pm	Aaron Thode: *Using 'azigrams' to display directional information from DIFAR sonobuoys*
2:10 – 2:30pm	Jim Theriault: *Correlogram processing for Odontocete click tracking using multiple independent autonomous acoustic sensors*
2:30 – 2:50pm	Dean Hawthorne: *Validation of a near-field beamforming acoustic localization algorithm for large baseline marine arrays using in-situ playbacks*
2:50 – 3:10pm	Julie Patris: *Monohydrophone 3D localization of baleen whales*
3:10 – 3:30pm	Richard Dréo: *Tracking Antarctic Blue Whales over a mountainous area with an Ocean Bottom Seismometers array: dealing with 3D propagation effects*
3:30 – 4:00pm	*Coffee break*
Closing session	**Topic: Discussion** **Chair: Olivier Adam**
4:00 – 5:00pm	Closing discussion: *Results, next session*


Credit photo: Joël Detcheverry – association SPM Terre Vivante

Thematic Tutorial Sessions

Two thematic tutorial sessions will be organized on Monday 4th. The objective is to present the new theory, the current methods and the software used by the researchers. During the whole day, overall presentation and examples on real recorded sounds will illustrate the knowledge, the advantages/inconvenient, and the use of these methods.

The sessions are simultaneously held on Monday, June 4th from 8:30 am to 5 pm.

Machine learning (Deep learning) for Bioacoustics:
This 1-day session the Dyni team of Toulon university (Hervé Glotin, Ferrari Maxence, Julien Ricard, Vincent Roger, Marion Poupard, Julie Patris, Franck Malige) will introduce workshop participants to the paradigm of deep learning of acoustic regresentation, from raw audio, and taking advantages of stereophony to elaborate new objective and efficient loss function for transient encoding. We will present usual signal stereophony processing for detection of Physeter from the BOMBYX long term submarine stereo dataset (http://sis.univ-tln.fr/~glotin/SABIOD/VAMOS/). We'll mostly focus on weak transients (distant Physeter and others) on long term whale tracks (up to 10 hours long).
We will conduct scripts in Tensorflow deep learning to train Autoencoder and show the advantages of stereophonic learned representation. Practical examples and exercises will be discussed, and shall open long term discussion on this new paradigm.
The material, scripts (GPL), and slides, for this session are available here:
https://github.com/dynilib/DCLDE

Density Estimation
In this 1-day session, we (Len Thomas, Tiago Marques and Danielle Harris) will introduce workshop participants to the concepts behind estimating animal density (and abundance) from acoustic data. We will start the day with two lectures that will cover all the basics. We assume no prior knowledge, so the first lecture will cover animal density estimation methods and the second lecture will focus on specifically using acoustic data. Through these lectures, participants will also learn about current research topics and recent case studies.
In the afternoon, we will conduct some discussion-based group exercises. Participants will be split into small groups and will be presented with realistic monitoring scenarios and asked to design an acoustic survey to estimate density. Groups will present a summary of their case study to the other groups at the end of this session. We will also have time in the afternoon session to demonstrate the software that can be used for density analyses (both in R and using Program Distance).
Finally, we plan to join with the other tutorial session at the end of the day, to explore how their acoustic monitoring survey might be used for density estimation.
Questions and discussions are encouraged throughout the whole workshop – by the end, we hope that participants will be familiar with the main methods available for density estimation, as well as having an appreciation of the various pros and cons of each approach.

<u>Oral sessions</u>

Photo: credit Cetamada

Abstracts

(*alphabetic order*)

Comparing Five Machine Learning Techniques for the Classification of Odontocete Acoustic Encounters

Peter Achi, Jay D. Dias, Sonny O. Osunkwo, Henry Udeogu, Hossein Zandipour, and Natalia Sidorovskaia

Department of Physics, University of Louisiana at Lafayette, Lafayette, LA 70504-3680

The goal of this study is to compare the performance of five machine learning algorithms in classifying acoustic encounters with various odontocetes, using a common set of features. First, we analyse the high frequency acoustic data provided for the workshop. To extract classification features, we apply a high-pass filter with a 20 kHz cutoff frequency to the raw data. We identify individual clicks by analysing, in the time domain, the filtered signals associated with annotated time intervals, after which we extract features. The chosen features are the inter-click interval and spectral banding patterns. These features are chosen as they present little overlap between the species at hand, and their mean values are published in the literature (Soldevilla et al. 2017, and Zimmer et al. 2005). These features are then used to train five machine learning algorithms: logistic regression, Gaussian discriminative analysis, support vector machines, k-nearest neighbours and neural networks. Each model's ability to classify test clicks is evaluated using performance metrics such as accuracy and F1 score. This study is a part of the students' group project for the graduate Machine Learning course at the University of Louisiana at Lafayette.

Soldevilla, M. S., Baumann-Pickering, S., Cholewiak, D., Hodge, L. E., Oleson, E. M., and Rankin, S. (2017). Geographic variation in Risso's dolphin echolocation click spectra. The Journal of the Acoustical Society of America, 142(2), 599-617.

Zimmer, W. M., Johnson, M. P., Madsen, P. T., and Tyack, P. L. (2005). Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). The Journal of the Acoustical Society of America, 117(6), 3919-3927.

From anatomy to sounds: description of the sound generator

Olivier Adam[1,2], Dorian Cazau[3], Juliette Damien[4], Nadège Gandilhon[5], Paul White[4], Jeffrey T. Laitman[6] and Joy S. Reidenberg[6]

[1] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France
[2] Institute of Neurosciences Paris-Saclay, Bioacoustics Team, CNRS UMR 9197, Université Paris Sud, Orsay, France
[3] ENSTA Bretagne Lab-STICC, CNRS UMR 6285, Université Européenne de Bretagne, Brest France
[4] Institute of Sound and Vibration Research, University of Southampton, UK
[5] Gandilhon, Aix-en-Provence, France
[6] Center for Anatomy and Functional Morphology, Mount Sinai School of Medicine, New York, USA

The humpback whale is one of the most well-known of cetacean species, probably because of their complex songs emitted during the breeding seasons. However, we still do not how humpback whales produce their vocalizations. While it has been suggested that the larynx is the source of these sounds, it is unclear which laryngeal structure is the actual sound generator. The objective of our work is to describe a potential sound generating tissue, and link its characteristics to the acoustic features of the sound units these whales produce. Twelve humpback whale laryngeal specimens were dissected. Their anatomy includes air chambers, a vocal fold homolog, and corniculate flaps that are opposed against each other Anatomical complexity is mostly centered on respiratory protection (from incursions of water). However, movements of the arytenoids appear able to control the vocal folds, and thus regulate their ability to vibrate during generation of sounds. This work also brought our attention on some specific acoustic non-linearities, as frequency jumps and chaos in some successive sound units. These sounds may be associated with specific whale behaviors.

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WaveLetNet : end to end DeepNet Learning of chirplet and other Wavelet optimal marine mammals bioacoustical representation

Balestriero R.[1,3,4], Glotin H.[2,3,4], Roger V.[2,3,4,5], Spong P.[6,4], Symonds H.[6,4], Marxer R.[2,3,4], and Baraniuk R.[1]

[1] Rice Univ, USA ; [2] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France ; [3] EADM GDR CNRS MADICS, France ; [4] SABIOD.org ; [5] Nortek Med, France ; [6] OrcaLab, Canada

Convolutional Neural Net (CNN) can be seen as an optimal kernel decomposition, nevertheless it requires large amount of training data to learn its kernels. An alternative using pre-imposed kernels and thus not requiring any amount of data is the scattering framework which imposes as kernels wavelet filters. Due to this rigidity one has to know a priori what wavelet family to use which is not just dataset dependent but also task dependent. We thus propose two trade-off between these two approaches. Via spline functionals we offer analytics kernels with learnable coefficients with much less degrees of freedom as opposed to standard CNN. Due to this, we do not require a large amount of dataset for learning, and the method is robust to noise and to poor optimization schemes. Another benefit of the proposed analytical filters is their use to derive rich filter-banks. The most common is the wavelet filter-bank. In this case, our formulation [2,5,6] allows to learn the analytical mother wavelet which is then dilated to form a Q-constant filter bank used to represent the input signal.

The use of chirp is demonstrated [3] to offer an efficient Q constant bioacoustic representation to pretrain CNN. First we motivate Chirplet bioinspired auditory representation. We give the first algorithm (and code) of a Fast Chirplet Transform (FCT). We demonstrate the computation efficiency of FCT on large environmental database with online transform on months of Orca orcinus recordings from Orcalab ONG [1,3].

This wavelet filter bank learning demonstrated [3,6] crucial improves in bioacoustic analysis on a bird activity detection task. This forms the basis of the spline filter learning formulation. Another augmented filter-bank uses in addition of dilation a chirpness operator, that could represent marine mammals transients.

Future work will consider to learn in addition of the filters, the exact chirpness operator [4]. We propose to directly learn the wavelet support from scratch, based on a gradient descend on the parameters of cubic splines [6], with application to mysticetes and odontocetes (transients of *Inia g*. or *Physeter m.*).

We particularly thank Orcalab (Spong P., Symonds H.) for their long term recordings and collaboration allowing FCT decomposition that opens avenues for future research on cetacean communication system. We thank BRILAM AmSud 17-STIC-01, EADM CNRS MADICS. We thank Region PACA & NortekMed for Roger's Phd grant.

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Improving location estimates for sperm whales from towed linear array data

Yvonne Barkley[1], Eva-Marie Nosal[1], and Erin M. Oleson[2]

[1] University of Hawaii at Manoa
[2] NOAA, NMFS, Pacific Islands Fisheries Science Center

Between 2010 and 2017, the Pacific Islands Fisheries Science Center conducted four ship-based line-transect surveys designed to collect visual and acoustic data for assessing cetacean populations in the Hawaiian Island Exclusive Economic Zone. Perpendicular distances from the transect line to the animals are one component documented by visual observers for estimating animal density and abundance. Limitations exist for integrating passive acoustic monitoring data into these estimates due to uncertainties in perpendicular distances that arise for deep-diving animals using two-dimensional towed linear array data. Vocalizing animals at depth are commonly localized under the assumptions that the sound speed profile is constant, and the animals occur at the same depth as the array. This is problematic for deep-diving species due to the vertical components of their positions and leads to biased location estimates. This study aims to improve location estimates derived from towed linear array acoustic data by implementing a localization technique that accounts for animal depth and sound speed profiles, and that quantifies errors introduced by uncertainties in the hydrophone positions and time delay measurements. The dataset includes over 250 acoustic events of sperm whales collected via towed linear array. Automated methods estimate the time delays of echolocation clicks between hydrophone pairs, which are used to form ambiguity surfaces that give an estimate of three-dimensional animal position with error estimates. Improving the localization of towed linear array data will provide better information for abundance estimates and enable more appropriate scaling of environmental data for species distribution models.

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3D acoustic dive tracking of Cuvier's beaked whales using a nested array of drifting hydrophone recorders

Jay Barlow[1], Emily Griffths[1], Holger Klink[2] and Danielle Harris[3]

[1]NOAA Southwest Fisheries Science Center
[2]Cornell University
[3]University of St. Andrews

A time series of 3D localizations for Cuvier's beaked whales is estimated from their echolocation clicks using a nested array of drifting autonomous recorders. Each of five drifting instruments in a spatial array recorded stereo signals from a vertical 2-element hydrophone array. Localizations were based on vertical bearing angles estimated from the spatial array drifting in the Catalina Basin, California. Ten of 38 detected Cuvier's beaked whale foraging dives were suitable for tracking. A Bayesian state-space model is developed to estimate the time series of locations during the clicking portion of these ten foraging dives. Declination angles estimated from occasional surface reflections are not subject to array tilt and are used in fitting the model to correct for small degrees of tilt in the vertical arrays. Mean clicking depths were 955 m, but some whales were foraging on or near the bottom of this 1250-m deep basin. Mean swimming speeds were 1.2 m/s. Swim speeds during foraging dives have not been estimated previously for this species, but other aspects of their foraging dives were similar to those measured for this species with tagging studies. Localizations from this study will be used to quantify the detection range of other recording instruments. This method can be used to study that diving behaviour of other species that cannot be easily tagged.

Discrimination of conspecific sounds in Risso's dolphins (*Grampus griseus*)

Lucie Barluet de Beauchesne[1], Mathilde Massenet[1], Fleur Visser[2], and Charlotte Curé[1]

[1]Cerema, Dter Est, Acoustics Group, Strasbourg – France
[2]Kelp Marine Research – Pays-Bas

Risso's dolphin (RD) is a highly social odontocete species. Groups composed of females and calves remain usually apart, particularly from associations between males that form alliance likely to compete with other male groups for female and/or territory access (Hartman *et al.*, 2008). The vocal repertoire of RD includes various social sounds and foraging echolocation clicks (Arranz *et al.*, 2016). By detecting unintended signals coming from conspecifics, we hypothesized that RD can gather information at reduced cost, enabling them to adjust their behavior according to the perceived context (Valone, 2007). To do so, we conducted sound playback experiments on free-ranging RD in North Atlantic Ocean (Azores, Portugal). We investigated whether RD can eavesdrop on conspecific foraging sounds that might facilitate prey localization, and on conspecific social sounds that might indicate a potential disturbance context (e.g. presence of male groups). To do so, we exposed animals to conspecific 1) foraging sounds (FO, n=7), 2) male social sounds simulating a potential risk of interaction with territorial males (SO+, n=5) and 3) female-calf social sounds representing likely a non-threatening context (SO-, n=4). We quantified RD's behavioral responses by using acoustic-and-motion tags (Dtag) and visual observations of the surface tagged whale's behavior and its group. We showed that RD increased their horizontal swimming speed and maintained their social cohesion in response to all conspecific sounds. Animals were horizontally attracted to both FO and SO-, probably to investigate the sound source and to gather for additional information, whereas they avoided SO+. Moreover, FO did not elicit a start nor increase of prey searching, suggesting that RD might not rely on detecting conspecific clicks to locate a food patch. The contrast between avoidance reaction to male social sounds and approach response to foraging and female-calf sounds indicate that RD can discriminate between male sounds likely perceived as a threatening context and other conspecific sounds.

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Geographic differences in Blainville's beaked whale echolocation clicks

S. Baumann-Pickering[1], J. S. Trickey[1], and E. M. Oleson[2]

[1] Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0205, USA
[2] Pacific Islands Fisheries Science Center, NOAA, 1845 Wasp Blvd., Building 176, Honolulu, Hawaii 96818, USA

Understanding the distribution of cetacean species and their populations over space and time is relevant to conservation, management and mitigation goals. We investigate geographic differences in Blainville's beaked whale (*Mesoplodon densirostris*) frequency-modulated (FM) echolocation signals as a potential tool for population-level discrimination.

Blainville's beaked whales have a cosmopolitan distribution from temperate to tropical waters. They produce species-specific FM pulses with a steep energy onset at around 25 kHz, a small energy peak at 22 kHz, a peak frequency of 30 to 34 kHz, and an inter-click interval of 280 ms. We have identified several FM signals at recording sites across the North Pacific and North Atlantic that have spectral shapes and temporal characteristics quite similar to Blainville's beaked whale FM pulses, and unlike known signals produced by other beaked whale species. These pulses were either shifted upward or downward in frequency by up to 5 kHz and generally occurred instead of the usual Blainville's beaked whale FM pulse type. We observed differences between ocean basins when comparing all Blainville's beaked whale-like signals. There were lower peak frequencies and longer signal durations detected in the North Atlantic than the North Pacific. Additionally, we identified a latitudinal cline with higher peak frequencies occurring in lower latitudes. Further quantification of the variability in spectral shapes and inter-click intervals measured within and between encounters will be achieved through weighted network clustering.

The observed variability may have several possible origins. Body size has been shown to influence signal frequency, in which lower frequencies are produced by larger animals. In turn, larger animals tend to be found in higher latitudes for some species, but this has not been investigated in beaked whales. Furthermore, prey size may shape the frequency content of echolocation signals and larger prey items may possibly occur in higher latitudes. The observed differences in echolocation signal frequency may be first indications for delineation of population-level boundaries of Blainville's beaked whales that have not been identified previously.

Near real-time delivery of baleen whale acoustic presence information collected with long-endurance autonomous platforms

Mark Baumgartner[1], Julianne Bonnell[2], Cara Hotchkin[3], Sofie Van Parijs[2], Kimberley Davies[4], and Christopher Taggart[4]

[1] Woods Hole Oceanographic Institution
[2] NOAA Northeast Fisheries Science Center
[3] NAVFAC Atlantic
[4] Dalhousie University

Effective mitigation of human-caused threats to whales often depends on a near real-time assessment of animal occurrence. Conventional approaches to this assessment have relied on visual surveys, but such surveys are typically costly and infrequent. We are using the digital acoustic monitoring (DMON) instrument and the low-frequency detection and classification system (LFDCS) to record, detect, classify, and transmit to shore information about the low-frequency tonal sounds of baleen whales in near real time from both Slocum gliders and moored buoys. A human analyst reviews this information to determine if whales are acoustically present. The results are automatically posted to a publically accessible website, sent directly to stakeholders via email or text message, and served on both public and private applications (e.g., Whale Alert iOS/Android app, U.S. Coast Guard CG1 View). Daily email notifications are sent to scientists, state/provincial/federal regulators (NOAA, DFO), Coast Guard, Navy, conservationists, and industry. We evaluated the performance of this system for humpback, fin, sei, and North Atlantic right whales during 2015-2017. Daily false occurrence rates were less than 1%, indicating that the analyst is nearly always correct when estimating the presence of whales in near real time on daily time scales. Daily missed occurrence rates were modest, ranging from 7 to 44%; however, these rates were affected by subsampling (duty cycling) implemented to minimize transmission and analyst costs, and can be improved by transmitting more data in near real time. The system is being used to monitor baleen whales, particularly the seriously endangered North Atlantic right whale, on the east coasts of the United States and Canada. Applications include reconnaissance for research activities, mitigating ship strikes from commercial and Coast Guard vessels, mitigating impacts of wind farm construction (ship strikes and sound exposure), dynamic fisheries management to reduce entanglement risks, and public outreach.

Finding a needle in a whole bunch of needles: targeted species discrimination based on differential template outputs

Kristian Beedholm[1], Jamie MacAulay[2], Peter Teglberg Madsen[1] and Mark Johnson[2]

[1] Bioscience, Aarhus University, DK
[2] SMRU, Univ. of St Andrews, UK

Any detector/classifier dealing with rare, evasive or silent species must face the fact that the target species is likely to be found in areas with more abundant vocalising animals, or other sources of acoustic transients that – if not dealt with – will generate a high number of false alarms, necessitating time consuming manual post hoc analysis of the detected events.

Specifically, we consider an acoustic beaked whale detector, where confounding transients are likely to be generated by broad band delphinids. As a remedy for the false alarm problem, we propose that a relatively conservative classification and discrimination stage follows a simple transient detector stage. We find that the most robust way of doing this is passing the signals through two (or more) filters derived from informed hypotheses about the properties of both the confounding and the target species, and then comparing the output amplitudes. We present here a demonstration implemented as a PAMGuard module.

Among the lessons learned is that the detection performance depends on the sampling rate of the recordings being sufficiently large to encompass the bandwidth also of the sounds from the confounding species.

Empirical evaluations using data sets of detected sounds from identified species revealed that for the discrimination performance to be comparable to the theoretically attainable, the SNR would have to be around 6 dB higher. We find it likely that the bulk of this difference is due to biological variation that cannot be predicted reliably.

Using acoustic recorders and satellite tags in controlled sonar exposure experiments – estimating the acoustic dose in relation to behavioural responses

A.M. (Sander) von Benda-Beckmann[1], P.J. Wensveen[2,6], M. Prior[1], M. A. Ainslie [1,5], R.R. Hansen[3], S.P. v. IJsselmuide[1], S. Isojunno[2], F.P.A. Lam[1], P.H. Kvadsheim[3], P.L.T. Tyack[1], and P.J.O. Miller[2]

[1] Netherlands Organisation for Applied Scientific Research (TNO), The Hague, The Netherlands.
[2] Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, UK.
[3] University of Oslo, Department of Biosciences
[4] Norwegian Defence Research Establishment (FFI), Maritime Systems, Horten, Norway.
[5] JASCO Applied Sciences (Deutschland) GmbH, Mergenthaler Allee 15-21, 65760 Eschborn, Germany.
[6] Life and Environmental Sciences, University of Iceland, Reykjavik, Iceland

In order to understand the consequences of behavioural responses to underwater noise, there is a push to test for responses over increased spatial and temporal coverage. Fixed acoustic recorders and satellite tags provide more long-term, and larger scale coverage of behavioural response than acoustic-recording tags, at the cost of a decreased resolution of parameters from which the animal response can be quantified. However, these methods currently do not provide a direct measure of the acoustic dose to which animals are exposed. Here we discuss the consequence of the decreased resolution of data from satellite tags and fixed acoustic recorders on the acoustic dose estimated by propagation modelling, and the capability to reliably measure dose-response relationships with these methods. This is illustrated using experimental results obtained during controlled exposures with bottlenose whales exposed to sonar playbacks, carried out around Jan Mayen area. We show that variability and uncertainties in the sound field around the fixed acoustic recorders, as well as decreased resolution in dive profiles, can lead to significant uncertainties in the estimated acoustic dose associated with the behavioural response (in this case cessation of feeding) detected in response to sonar playbacks.

Passive Stochastic Matched Filter for Antarctic Blue Whale call detection: performance analysis on highly variable SNR ground-truth dataset

Léa Bouffaut[1], Richard Dréo[1], Valérie Labat[1], Abdel Boudraa[1], and Guilhem Barruol[2]

[1] Institut de Recherche de l'Ecole Navale, EA3634, Ecole Navale / Arts et Metiers ParisTech - BCRM Brest CC600, 29240 Brest Cedex 9, France
[2] Institut de Physique du Globe de Paris, Sorbonne Paris Cite, UMR 7154 CNRS, 1 rue Jussieu 75238 Paris Cedex 05, France

The Stochastic Matched Filter (SMF) is extended to the passive context and used for Antarctic Blue Whale call detection. This filter strongly attenuates the noise when there is no signal of interest and is well suited for remote call detection. Thus, the SMF's performances at low SNR need to be evaluated. However, such assessment requires the theoretical Probability of False alarm (PFa) and Probability of true detection (Pd), which are not available.

Conducting performance analysis by simulations requires the creation of an artificial dataset with control on each parameter (number and types of events, SNR …). Yet, it is quite challenging to recreate soundscapes diversity and accurate propagation-like filters. This is why the performance assessment often relies on the confrontation between the detector's output and a test dataset. Generally, this dataset is represented in the time-frequency domain and submitted to visual analysis by experimented operators, providing annotations. This process, subjective to the analyst experience, also has a strong inter and intra-analyst variability especially with low SNR signals, essential to assess the SMF performance.

To create and annotate a dataset, multi-sensor observations are used as decision-making information. The tracking of a continuously singing solo ABW, swimming through an OBS array, was realized. Records from the remotest OBS are selected, showing the lowest SNR. The trajectory provides the source-receptor distance and therefore *a priori* information on the signal's condition (complete call or upper part), and the relative SNR. Furthermore, inter -and closer- OBS comparison is used to solve ambiguous call selections. The SMF performance are evaluated on this ground-truth dataset, in comparison with the Matched Filter (MF). The SMF allows the PFa to drastically decrease. The miss detection rate is low and the Pd stays high in comparison to the MF with identical threshold.

Supervised vs Unsupervised Feature Learning for Right Whale Upcall Detection in Convolutional Neural Networks

Christopher Chin

Graduate Program in Acoustics, Pennsylvania State University, Ocean Conservation Research

Neural networks have achieved state-of-the-art results in bioacoustic detection and classification problems, greatly assisting efforts toward conservation and biodiversity determination. Convolutional neural networks (CNNs) in particular have been successful in spectrogram feature extraction due to their optimized receptive fields and consequent reduced set of learned training parameters. However, due to backpropagation and labeling being expensive processes, unsupervised feature learning holds great potential for the development of more robust classification models - its speed (in the case of K-Means-like algorithms) and ability to learn abstract features from readily available unlabeled data make it a powerful tool for future monitoring systems. In this study, the performance of two unsupervised CNNs was compared on the task of differentiating right whale upcalls from ambient noise using a dataset from the 2013 ICML Right Whale Redux Challenge, with the K-Means algorithm used in both cases to learn a dictionary of filters. Concretely, the two CNNs differed in their methods of receptive field reduction, a smaller feature dimensionality having been shown to improve the performance of K-Means: the first model utilized squared-energy correlation grouping while the second employed 1x1 convolution feature- pooling. While a supervised CNN model trained on the same dataset attains an AUC (Area Under ROC Curve) score of 98.29%, the second model's AUC score of 95.37% demonstrates the efficacy of the unsupervised approach in the case of limited labeled data.

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Use of the Double-Difference Method to Improve Bowhead Whale Localizations from Autonomous Vector Sensor Recorders

Alexander Conrad[1], Ludovic Tenorio-Hallé[2], Aaron Thode[2], Katherine Kim[1]

[1] Greeneridge Sciences Inc., Santa Barbara, California, USA
[2] Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA

Directional Autonomous Seafloor Acoustic Recorders (DASARs) were deployed in the Beaufort Sea each open water season from 2007 to 2014 to detect and localize bowhead whale calls. Acoustic particle motion measurements of a detected call were used to estimate the call's bearing, and bearings of a call detected on an array of DASARs were triangulated to estimate the whale call's location. The double-difference method was originally developed for improving the localizations of earthquakes along a fault line (Waldhauser and Ellsworth 2000). The method considers multiple sources detected on an array of receivers and minimizes the residual differences between observed and calculated travel times to pairs of those receivers (double-differences) via an iterative least-squares approach. Although the initial localizations with DASARs are based on bearing alone and do not depend on time-of-arrival, in this work these initial localizations are improved upon by applying the double-difference method based on both time and acoustic bearing. In testing on simulated data, the method successfully corrected for systematic random error added to calculated bearings and arrival times. It was then applied to recorded DASAR data to correct localizations of calibration signals transmitted from known source locations. Results from the three variations of the double-difference method (using bearing, time of arrival, and the combination) are compared, as well as the use of weighting and damping factors.

Finally, preliminary results of applying the techniques to clustered bowhead whale calls are presented, in an effort to discern individual or paired trajectories and, thus, determine calling rates for use in passive acoustic animal abundance estimation.

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Contributions of shipping and seismic survey noise to the underwater soundscape of the northern Gulf of Mexico

Amanda J. Debich[1], Lance P. Garrison[2], John A. Hildebrand[3] , and Melissa S. Soldevilla[2]

[1] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School for Marine and Atmospheric Science, University of Miami

[2] NOAA Southeast Fisheries Science Center

[3] Scripps Institution of Oceanography, University of California, San Diego

The Gulf of Mexico, home to 21 cetacean species, is highly industrialized; the levels of oil and gas exploration and commercial shipping traffic are among the highest in US waters. Noise levels in the Gulf of Mexico are also among the highest in US waters, but the contributions of these two industries to the low frequency anthropogenic soundscapes in this area is not well known. To characterize the natural and anthropogenic noise sources that contribute to the Gulf of Mexico soundscape, calibrated Low-frequency Acoustic Recording Packages (LARPs) were deployed at five sites along the northern Gulf of Mexico continental shelf break from Texas to Florida. The LARPs recorded continuously from July 2016 through May 2017 at a sampling rate of 2 kHz. Site depths ranged from 180 to 264 m. To evaluate the frequency of occurrence of anthropogenic noise sources, a trained analyst manually logged ship noise presence in three frequency bands (0-400 Hz, 400-700 Hz, and >700 Hz) and airgun noise presence in three frequency bands (0-100 Hz, >100 Hz, and >200 Hz). Monthly sound levels were measured and compared within and among sites, and sound levels were compared between periods when anthropogenic activities were present and absent. At one site, the lowest frequencies of seismic survey noise were present 83% of the time, while seismic survey noise extended to higher frequencies 7% of the time. Two large whale species found in the Gulf of Mexico that are acoustically sensitive to low-frequency noise include sperm whales and Gulf of Mexico Bryde's whales which, respectively, are listed and have been proposed for listing under the Endangered Species Act. Measuring and characterizing the anthropogenic contributions to the Gulf of Mexico soundscape can help us better understand how these sounds affect these animals.

Temporal distribution and abundance of Cuvier's beaked whales with and without mid-frequency active sonar (MFAS) off San Clemente Island, California

Nancy DiMarzio, Susan Jarvis, David Moretti, Ronald Morrissey, Benjamin Jones, and Stephanie Watwood

Naval Undersea Warfare Center Division, Newport, RI USA

Cuvier's beaked whales (*Ziphius cavirostris, Zc*), the primary species involved in a number of mass stranding events linked to the use of naval mid-frequency active sonar (MFAS), appear to be particularly sensitive to MFAS [1],[2]. However, they are regularly detected on the U. S. Navy's Southern California Anti-submarine Warfare Range (SOAR) [4], which routinely uses MFAS during training exercises. The Marine Mammal Monitoring on Navy Ranges (M3R) program began conducting joint field tests at SOAR in 2006 with Cascadia Research Collective and MarEcoTel. Sightings throughout this period indicate that *Zc* display site fidelity to the area [3].

M3R has collected acoustic detections of *Zc* foraging clicks on the SOAR range's 89 broadband hydrophones from 2010 through 2017, along with detections of MFAS. *Zc* groups have been identified from the foraging clicks using an automated process, and MFAS receive level (RL) at the face of the hydrophones has been derived from the peak magnitudes of the MFAS detections. *Zc* temporal distribution and abundance have been analysed. The methods for extracting the data will be reviewed, and an initial diel, monthly and yearly temporal distribution and abundance of *Zc* on SOAR will be presented, both in the absence and presence of MFAS.

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Beaked whale group deep dive behavior from passive acoustic monitoring

Karin Dolan[1], Sarah Blackstock[1], Jessica Shaffer[1], Diane Claridge[2], Charlotte Dunn[2], Len Thomas[3], and Tiago Marques[3]

[1] Naval Undersea Warfare Center (NUWC),
[2] Bahamas Marine Mammal Research Organisation
[3] Centre for Research into Ecological and Environmental Modelling, University of Saint Andrews

While a significant body of knowledge regarding individual beaked whale behavior at depth has been established in the last decade, mostly based on tags deployed on individual animals, little is known about how beaked whales interact as a group while at depth. This project uses Passive Acoustic Monitoring at the Atlantic Undersea Test and Evaluation Center (AUTEC) to simultaneously track multiple individual Blainville's beaked whales (Mesoplodon densirostris) during group foraging dives. These tracks will help establish baseline data for future behavioral response studies by providing insight into group foraging strategy at depth, including: prey capture attempts, spatial relationships among conspecifics, independent or cooperative prey hunting, and foraging strategy.

We enhanced a novel method of Detection, Classification and Localization (DCL) to provide the ability to DCL and track beaked whale clicks from multiple individuals within a diving group. The DCL methodology was validated against 2007 Behavioral Response Study DTAG data for a group of 3 whales (one whale with DTAG). Of the 66 group dives evaluated thus far, 28 groups (57 individuals, 1-3 individuals per group) were sufficiently resolved with nearly continuous individual dive tracks to be included in evaluation of group dive dynamics. Preliminary data exploration suggests beaked whales are capable of coordinating activity while at depth. There seems to be (at least) two types of behaviors, one in which animals travel together in parallel in a given direction, and another in which animals separate while at depth and then return to a common meeting point before their ascent. The primary foraging depth appears to be centered at approximately 900 m with a secondary layer at 1300 m. While individuals and foraging groups of 2 or 3 animals were observed at the shallower depth, primarily animals in a group of 3 were observed at the deeper foraging depth.

Tracking Antarctic Blue Whales over a mountainous area with an Ocean Bottom Seismometers array: dealing with 3D propagation effects

Richard Dréo, Laurent Guillon, Léa Bouffaut, and Valérie Labat

French Naval Academy Research Institute - BCRM CC600, 29240 Brest Cedex 9, France

The RHUM-RUM seismic experiment aimed at imaging the mantle plume beneath La Réunion island using a large ocean bottom seismometers (OBS) network from October, 2012 to November, 2013. As part of this network, a small array of 8 OBSs (70 x 40 km) was deployed around a seamount of the South West Indian Ridge, with depths varying between 2500m and 5500m. The hydrophones' 0-50 Hz bandwidth, allowed the detection of different whale songs such as Fin Whales, Antarctic Blue Whales (ABW) and Madagascan Pygmy Blue Whales. Furthermore, the small dimension of the array provided multi-sensor observations. The localization and tracking of a continuously singing ABW was possible for several hours.

It was carried out using a method based on Time Difference of Arrival (TDOA). However, in this area, a special attention is required to reduce the impact of multipath propagation and the acoustic screen effect induced by the mountainous relief. The theoretical TDOAs were computed using the ray tracing tool BELLHOP for a grid of 20,000 regularly spaced theoretical sources (depth: 20m). To deal with the multipath and screen effect, choice was made to determine TDOAs only considering the first eigenray, which is reasonably supposed to propagate along the source-OBS path and therefore be relevant for TDOA algorithm. ABW call detection and TOA measurements are provided automatically by a passive version of the Stochastic Matched Filter, used both as a noise cancelling technique and a detector. Therefore it provides more accurate and systematic measurements. Experimental TDOAs are then compared to theoretical ones to generate a probability of presence map.

The comparison of our method with an analytic solution (supposing the direct path detection), highlights the impact of the acoustic screen effect induced by the mountainous relief.

Environmental Calibration for Density Estimation using Directional Sensor Systems

Gerald D'Spain[1], Dennis Rimington[1], Regina Guazzo[1], Douglas Gillespie[2], Michael Oswald[3], Liz Ferguson[3], and Tom Norris[3]

[1] Scripps Institution of Oceanography, La Jolla, CA U.S.A. (SIO)
[2] University of St. Andrews, St. Andrews, Scotland (St. Andrews)
[3] Bio-Waves Inc, Encinitas, CA U.S.A. (Bio-Waves)

Methods for detecting and locating marine mammals, and correcting these detections for environmental effects in order to estimate call density, are greatly improved by using directional sensor systems. In a partnership between SIO, Bio-Waves, and St. Andrews, a towed 3D hydrophone array system for real-time passive underwater acoustic monitoring from seismic survey and other vessels is presently undergoing in-water testing. Previously tested detectors based on Nuttall's Power Law processor are being implemented along with a variety of localization algorithms, including both conventional and data-adaptive beamforming approaches. The latter are undergoing quantitative evaluation, primarily by measuring the bias and variance of the localization estimates, with data collected at sea using controlled underwater sources. Methods for dealing with lack of statistically independent realizations in estimating the data cross spectral matrix ("snapshot deficiency") when adaptive beamforming on transient signals will be discussed. Also presented will be the performance of an approach to in situ calibration of the array in order to obtain high-resolution estimates of the directionality of low-frequency baleen whale calls. All algorithms are being integrated into PAMGuard for real-time processing and display. In parallel with this towed array system development, SIO is developing an automated set of algorithms for processing infrared images collected by directional thermal cameras deployed by NOAA during the southbound grey whale migration off the California coast. Correcting the detections of whale blows in these camera images is done in a way directly analogous to that used the underwater passive acoustic detections, except that propagation modelling is based on the conservation of electromagnetic energy (the radiative transfer equation) rather than numerical solutions to the wave equation as in ocean acoustics.

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The Raven-X Software Package
A scalable high performance computing framework for the analysis of large bioacoustic sound archives

Peter Dugan[1], John Zollweg[1], Tyler Helble[2], Marie A. Roch[3], Christopher Clark[1], and Holger Klinck[1]

[1] Bioacoustics Research Program, Cornell Lab of Ornithology, Cornell University, Ithaca, NY 14850, USA
[2] U.S. Navy, SPAWAR Systems Center Pacific, 53560 Hull Street, San Diego, CA 92152, USA
[3] Department of Computer Science, San Diego State University, 5500 Campanile Drive, San Diego, CA 92182, USA

Recent advances in consumer audio technologies are allowing scientists the ability to record and store large archives of acoustic sound data. These sound archives can reach several hundred Terabytes in size, and beyond. The analysis of these large complex data sets remains challenging, time-consuming, and expensive. With funding from the U.S. Navy's Office of Naval Research, we are developing a Matlab-based high performance computing framework, called Raven-X. The software package uses parallel-distributed processing to significantly reduce the time required to process large complex data sets. Raven-X is hardware-independent, capable of running on multi-core desktop computers as well as enterprise-level, and cloud-based, distributed server environments. Raven-X provides a unique processing model that hides the complex nature of parallel distributed computing, allowing the user to focus on creating serialized algorithms for data-mining sounds. Several established detector algorithms; General Power-Law (Helble et al.), Silbido (Roch et al.) and ERMA (Klinck and Mellinger) are bundled with each release. A variety of common methodologies, such as matched-filtering and connected regions, are used in a package for advanced-segmentation-recognition (Dugan et al.) and data-template analysis; example detectors are provided for finding naval mid-frequency sonar signals and vocalizations of fin whales (Balaenoptera physalus), North Atlantic minke whales (Balaenoptera acutorostrata), and North Atlantic right whales (Eubalaena glacialis). Newly developed detection algorithms can be incorporated through an object-oriented interface and acoustic feature measures can be generated for each event using the Acoustat measurement package (Fristrup et al.). Additionally, Raven-X provides the ability to read multiple sound file types (wav, aif, dat, flac) and output detection results using a multitude of formats (Raven Pro, Tethys, HDFv5). We will demonstrate the utility of Raven-X using a variety of U.S. Navy relevant data sources, collected with different types of sensors (e.g. U.S. Navy training range data, moored recorders, and gliders).

For references, see project wiki
https://github.com/Cornell-RavenX/Raven-X/wiki/Related-Papers-for-Raven-X-project

Machine learning methods to guide odontocete echolocation insights from large datasets

Kaitlin E. Frasier[1], Marie A. Roch[2], Lynne E. W. Hodge[3], Sean M. Wiggins[1], and John A. Hildebrand[1]

[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA
[2]San Diego State University, San Diego, CA, USA
[3]Duke University Marine Laboratory, Nicolas School of the Environment, Beaufort, NC, USA

A typical wide-bandwidth passive acoustic seafloor sensor can record tens of millions of echolocation clicks from dozens of odontocete species each year. The volume and variety of detections make human analyst manual classification of these datasets unmanageable without an in-depth knowledge of the overall acoustic context of each monitoring location. To aid analysts, unsupervised clustering tools were used as part of the preparation of the 8th DCLDE challenge dataset to provide an overview of the dominant signal categories and variability across sites and seasons. Computing strategies for efficiently processing and understanding the contents of large acoustic datasets are discussed and illustrated with examples from the western Atlantic and Gulf of Mexico. These tools are critical for helping analysts distinguish within and between type variability for signal classification in these high diversity environments, where multi-species acoustic encounters are common. Processing large datasets using these methods reveals temporal and spatial patterns in click characteristics, and supports consistent pattern recognition across sites.

PAMGuard: New features and future directions

Douglas Gillespie[1], Mike Oswald[1], Jamie Macaulay[1], Gerald D'Spain[2], and Tom Norris[3]

[1] Sea Mammal Research Unit, University of St Andrews, Scotland
[2] Scripps Institution of Oceanography, La Jolla, CA U.S.A.
[3] Bio-waves Inc., 1106 2nd St. #119, Encinitas, CA, USA.

The PAMGuard software was first released in 2006 to perform a variety of Detection Classification and Localisation tasks. PAMGuard has been designed with a highly flexible and interactive user interface, attempting to combine the best of automatic DCL algorithms with a human operators abilities to pick out patterns from noise and to respond to the unexpected.

In this presentation we describe the latest features which have been added, or will soon be added to PAMGuard releases. New features include an improved data labelling system, new displays and improved systems for marking, selecting and localising data interactively. We are currently working on the implementation of a Generalised Power Law Detector and on beam-forming modules which can be used to improve signal detection in noise and to estimate bearings and 3D localisations of a wider variety sound sources than was previously possible. For developers we have increased the levels of standardisation of both internal and file based data storage between modules and have introduced a new plug-in system whereby new modules can be distributed independently of PAMGuard releases. An improved Matlab interface has also been developed so that users can easily further process PAMGuard output using their own bespoke algorithms.

In order to further improve PAMGuard's suitability for the analysis of large multi-study and multi-year data sets we are considering ways to further standardise and improve archival storage and data annotation systems which will make it easier to integrate more advanced machine learning algorithms for species classification. We are also looking at ways in which PAMGuard could be deployed on large cloud based computer platforms.

Developments have been supported by the Joint Industry Programme and the U.S. National Oceanographic and Atmospheric Administration. Ongoing maintenance, bug fixing, and support is being provided through a system of voluntary contributions from industry users.

Go Deep to get High – Depth dependent detectability of Blainville's beaked whales and the use of underwater autonomous vehicles as an acoustic platform for density estimation – A simulation approach

Kalliopi Gkikopoulou[1], Natacha Aguilar de Soto[2], Douglas Gillespie[1], Mark Johnson[1], Sophie Smout[1], and Peter Tyack[1]

[1] University of St Andrews, UK
[2] University of La Laguna, Spain

Autonomous underwater gliders are increasingly used for sampling ocean data because of their low relative cost and persistent coverage of most of the water column. Beaked whales perform deep foraging dives echolocating almost continuously for 20% of their full dive cycle. Gliders can sample at depths of at least up to 1000m which covers most of the depth range in which beaked whales are available for acoustic detection. However the suitability of gliders as platforms for density estimation of these deep-diving species, and the sensitivity of detection probability to mission design, remain to be evaluated. We present a density estimation method of deep diving echolocating animals from gliders equipped with single channel sound recorders. Using these platforms to estimate density requires an estimate of the probability of detecting a sound made by an individual animal. The rates of calling by individual animals also must be known to convert the number of calls into the number of animals. First, we present a simulation method to estimate the probability of detection as a function of distance and depth of the receiver, using call rates and movement data as recorded on DTAGs (Digital Acoustic Recording Tags) and a theoretical network of receivers. The results show a depth dependent detectability of Blainville's beaked whale calls. Secondly, we modify the cue-counting method to incorporate the moving aspect of gliders and the depth dependent detectability, and we apply this new method in a simulated glider survey. We use real animal movement and click rate production data derived from DTAGs attached with suction-cups to 18 Blainville's beaked whales in El Hierro (Canary Islands) and 6 whales in the Bahamas. The results here, demonstrate the applicability of gliders as platforms for density estimation using acoustic data, though locally derived information for calling rates and movement data is desirable.

1 MHz SR High Definition 3D Tracking of wild Amazon River dolphins with JASON Tiny Array - Results & Perspectives

Glotin H.(1,4,5,6,7), Blakefield G.(4,5,6,8), Trone M.(2,,3,4,5,6), Bonnett D.E.(4,5,6,8), Giraudet P.(1,4,5,6), Giès V.(10,4,5,6,7), Barchasz V.(10,4,5,6,7), Patris J.(1,4,5,6), Malige F. (1,4,5,6), and Balestriero R.(9,5,6)

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France ; [2] Valencia College, Kissimmee, Florida, USA ; [3] CONAPAC, Iquitos, Peru ; [4] BRILAM STICAmSud ; [5] EADM MADICS CNRS, France ; [6] SABIOD.org ; [7] SMIoT, Université de Toulon, France ; [8] Engineer, retired, USA ; [9] Rice University, USA ; [10] Université de Toulon, Aix Marseille Univ, CNRS, IM2NP, Marseille, France

Two species of dolphins (*Inia geoffrensis*, *Sotalia fluviatillis*) inhabit the Amazon River watershed. These populations are difficult to visually assess due to the opaque waters and flooded forests in which they live, as well as the morphology and behavior exhibited by these unique aquatic mammals. As a result, both species are listed as “data deficient” by the IUCN. Thus, these dolphins lack endangered species status and consequently international protection, despite increasing anthropogenic threats. Our research team has been working to develop robust methods to assess river dolphin populations using visually-supplemented, acoustical methods.

Underwater portable arrays housing between 4 and 7 hydrophones have been used in conjunction with a high capacity digital analog converter : JASON DAQ [3] which is capable of sampling at 1 MHz on 5 channels simultaneously to assess dolphin positions relative to the array using time delay of arrivals of the dolphin acoustical signals. JASON has been designed, built for this purpose. It is distributed by SMIoT UTLN department. These data are supplemented with simultaneous video recordings, and sightings are documented using customized code on a tablet. Data have been collected in the Peruvian Amazon using these techniques from 2014 – 2018.

Results demonstrate the efficiency of this advanced low cost scientific instrumentation: it allows with only 4 hydrophones to track in 3D the precise movements of the *I. g.* dolphin, and to determine key behavioral features, like the velocity of its rostrum rotation, while following its highly defined biosonar emissions. This is the first, at our knowledge, that wild amazon dolphin biosonar is described inside its ecosystem. Moreover, we show click emissions up to 450 kHz [1,2]. Perspectives on counting dolphins and individual signatures are given, as well as avenues for future research on other cetaceans.

We thank Explorama Lodge which hosted our expeditions, BRILAM STIC AmSud 17-STIC-01 who grant some of them, and *Scientific Microsystem for Internet of Things SMIoT* http://smiot.univ-tln.fr, and *Cetacean research* for their collaboration on advanced scientific instrumentation.

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Automated extraction of dolphin whistles in the presence of missed detections and false alarms

Pina Gruden, and Paul White

Institute of Sound and Vibration Research, University of Southampton, Southampton, UK

The detection and extraction of marine mammal sounds is a key first step for a range of biological applications, and due to the large quantities of data typically collected, automated techniques are desired. The extraction of dolphin whistles, which are narrowband frequency modulated calls, represents an especially challenging problem for automated extraction.

In this work the whistle extraction is considered from the perspective of frequency tracking, and is cast in the context of the Random Finite Sets (RFS)[1] framework. The RFS framework is a non-traditional approach to multi-target tracking, which treats the collections of targets and observations as finite sets. Within the RFS framework, several filters exist and among these is the Probability Hypothesis Density (PHD) filter[1]. The PHD filter propagates the first-order moment of the multi-target posterior and allows for simultaneous tracking of a time varying number of targets, in the presence of missed detections and clutter (false alarms).

In this work, two approximations of the PHD filter; the Gaussian Mixture PHD filter [2,3] and the Sequential Monte Carlo PHD filter[4], are adapted for the task of dolphin whistle tracking. The challenges associated with each proposed filter will be discussed. Further, the performances of the proposed filters are studied on a large dataset comprising of over 9000 whistles form six dolphin species.

Both proposed filters appear to be efficient and precise tools for the automated extraction of the whistles, suitable for real-time implementation, and widely applicable to different dolphin species.

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Joint detection-classification of baleen whale sounds using sparse representations

Thomas Guilment[1], Dominique Pastor[1], François-Xavier Socheleau[1], and Simon Vallez[2]

[1] IMT Atlantique, Lab-STICC, Bretagne Loire University, Technopole, Brest-Iroise CS83818, Brest 29238, France
[2] Sercel, 12 Rue de la Villeneuve, 29200 Brest, France

Passive acoustic monitoring is very useful to help scientists study baleen whales, detect their presence during seismic surveys and as a consequence, mitigate the impact of man-made acoustic activities. As a result, the development of efficient and robust automatic detection and classification methods is needed to analyze the growing amount of acoustic data generated by these recording systems. Moreover, these methods should be suitable to real-time applications. Here, we propose a general method capable of jointly detecting and classifying multiple baleen whale calls. The main idea is to use multiclass classification with a rejection option, i.e. an option to handle "unwanted signals", to design a "multiclass detector" (MD). The MD has been designed to meet the following requirements: (i) it is modular in that, call classes can be appended or removed to/from the MD without requiring "retraining" and (ii) it is tuned by a very few (easy-to-set) parameters. The proposed approach relies on the sparse framework recently developed in signal processing and machine learning. Sparse representations express a given signal as a linear combination of base elements in which many of the coefficients are zero. Such representations can capture the possible variability observed for some vocalizations and can automatically be learned from the time series of the digitized acoustic signals, without requiring prior transforms such as spectrograms, wavelets or cepstrums. This framework is general and applicable to any mysticete call lying in a linear subspace described by a dictionary-based representation. The proposed method has been applied on marine data recorded in the southern Indian Ocean (DEFLOHYDRO 2007) and in the California Bay (DCLDE 2015). To test the rejection option, noises and seismic environment recorded by Sercel has been added to this dataset. In total, more than 50 hours of acoustic data have been analyzed, including more than 3000 calls.

Estimating cetacean detection probabilities using slow-moving autonomous ocean vehicles: an example with Blainville's beaked whales

Danielle Harris[1], Selene Fregosi[2], Holger Klinck[3], David K. Mellinger[2], David Moretti[4], and Len Thomas[1]

[1]Centre for Research into Ecological and Environmental Modelling, University of St Andrews
[2]Cooperative Institute for Marine Resources Studies, Oregon State University
[3]Bioacoustics Research Program, Cornell Laboratory of Ornithology, Cornell University
[4]Naval Undersea Warfare Center, Newport, Rhode Island

Autonomous underwater vehicles such as ocean gliders and vertical profiling floats have the potential to play a key role in future marine mammal monitoring efforts. When equipped with hydrophones, these vehicles can collect passive acoustic data and provide both broad spatial and temporal coverage of a survey area due to their slow movement. While a variety of methods have been developed to estimate animal density from acoustic data collected by fixed or moving platforms, estimating cetacean density from autonomous ocean vehicles requires investigation.

Here we present results from a project with the primary goal of estimating cetacean density from data collected by ocean gliders and profiling floats, taking into account species' acoustic and behavioral differences. There are four broad objectives: (1) evaluate whether glider data can be analysed using design-based density estimation methods; (2) quantify glider/profiling float survey effort and evaluate encounter rates of example cetacean species; (3) estimate the probability of detecting cetacean vocalizations on gliders/profiling floats; (4) estimate animal densities of example species using glider data.

Results are presented from the third objective using Blainville's beaked whale (Mesoplodon densirostris) as the primary study species. A field trial was conducted at a US Navy testing range equipped with bottom-mounted hydrophones, where it was possible to localise Blainville's beaked whales. Localised whales were used as detection trials for a concurrently deployed glider. Detection probability as a function of perpendicular range from the glider was modelled using logistic regression with a Generalised Additive Model. Depth of the glider was included as covariate, which was retained in the model through AIC-based model selection. Results suggest that detection probability at zero horizontal distance from the glider is not certain and detection probability increased with glider depth. Both of these results correspond to the acoustic behaviour and foraging ecology of Blainville's beaked whales.

Validation of a near-field beamforming acoustic localization algorithm for large baseline marine arrays using in-situ playbacks

Dean L. Hawthorne[1*], Kristin B. Hodge[1], Helen Bailey[2], Aaron N. Rice[1], and Holger Klinck[1]

[1]Bioacoustics Research Program, Cornell Lab of Ornithology, Cornell University, Ithaca, NY 14850, USA
[2]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD 20688, USA

Acoustic source localization on large baseline marine arrays is often limited by low signal-to-noise ratios (SNRs) of a target signal at the receivers. To improve the precision of the estimated source locations, we developed an algorithm based on near-field beamforming which is more robust than time difference of arrival (TDOA) techniques.

The algorithm works by searching over a two dimensional space for the global maximum in the power output of a delay-and-sum beamformer. The spatially varying part of the power can be written as the sum of the cross-power spectra of the sensor pairs. To improve the output SNR, we used generalized cross-correlation with a mask in the time-frequency plane. For the mask, we binarized the spectrogram of the target signal with a threshold equal to the 70th percentile of the signal's power spectrum.

We validated the performance of the algorithm by conducting playback experiments off the coast of Maryland, USA. The array under test consisted of nine single hydrophone Marine Autonomous Recording Units (MARUs), deployed in an approximately body-centered hexagonal geometry in a water depth between 20 to 40 meters. The distance between nearest-neighbor MARUs was 7.1 kilometers. Playbacks were performed at locations spanning the entire array aperture with the transducer operated at 3 m depth. The playback signals consisted of frequency modulated linear chirps in the 300 Hz to 600 Hz frequency range, approximately one second in duration. The source level of the playbacks was 166 dB re 1 µPascal at 1 meter.

Preliminary results indicate that the RMS error (n = 8) is19.2 meters near the array centroid and rises to 196 meters on the array perimeter. The complete data set consists of 17 source locations with ranges up to 25 kilometers from the array centroid. A comparison to a TDOA Maximum Likelihood algorithm is presented.

Improving marine mammal classification using context from multiple hydrophones

Helble Tyler A., Regina A. Guazzo, Stephen W. Martin, E. E. Henderson, Gabriela C. Alongi, Glenn Ierley, and Cameron R. Martin

SPAWAR Systems Center San Diego, Scripps Institution of Oceanography, National Marine Mammal Foundation

Detection, Classification, Localization, and tracking (DCLT) of marine mammals is oftentimes performed in that order. However, in the sonar-signal processing communities and elsewhere, classification is usually the final step. More appropriately, the working order should be "DLTC". If classification is performed at the final step, the results can be greatly improved by using the context of the calls. By grouping likely calls into tracks, a collective of calls can provide much more information for classification than single calls alone. Additionally, when multiple species are calling at the same time, the location of the calls can be used to distinguish confusing signals. The time-series and spectral information of a call can also be enhanced by localizing first, and choosing the nearest hydrophone to the calling animal for signal analysis. If localization is not possible, classification can still be enhanced if two or more hydrophones are available with overlapping coverage. Multiple sensors also provide the ability to reduce sensor self-noise, and noise from fish and snapping shrimp. Collectively, these techniques were applied to vocalizing baleen whales on the Navy's Pacific Missile Range Facility, and proved to greatly enhance the ability to classify Bryde's, humpback, fin, and minke whales. Similar techniques and results will also be discussed using time-synchronized HARPs.

A method for annotation of odontocete echolocation clicks

John Hildebrand, Alba Solsona Berga, and Kait Frasier

Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0205

The 8th DCLDE challenge dataset includes about 4 TB of acoustic data that has been annotated for odontocete echolocation clicks. This paper presents the MATLAB based software tool – DetEdit - used for manual annotation of these data using a graphical user interface. This approach examines bouts of echolocation clicks, contiguous periods with sustained clicking. For each bout a set of displays are presented with different click parameters including time series of click amplitude, spectrogram, and inter-click-interval. Additional displays show either individual or average click properties such as the waveform, spectra, RMS amplitude and peak-to-peak amplitude. Using a brushing tool, clicks are selected by species or as false, with subsequent separation by annotation color (e.g. red denotes false detections) in the various display windows. With this procedure it is possible to rapidly and accurately annotate large numbers (~1M) of clicks.

Characterizing Blue and Fin Whale Populations Using a Large Ocean-Bottom Seismometer Array

Rose S. Hilmo and William S. D. Wilcock

University of Washington, School of Oceanography, Seattle, WA 98195

Passive acoustic techniques are a valuable complement to visual surveys and tagging of marine mammals, but data sets covering large areas are expensive to acquire. Large ocean-bottom seismometer (OBS) networks are being increasingly deployed for a year or more for geophysical studies and these provide opportunistic data sets that can support low-cost studies of the low frequency calls of baleen whales. One example of such a data set is the Cascadia Initiative, a 4-year deployment of 70 OBSs off the coast of the Pacific Northwest over an area extending ~1000 km along the coast and a ~300 km offshore. Most of the Cascadia Initiative OBSs sample at 50 Hz and with the exception of a few regions of densification, the instrument spacing varies from 35 km near the coast to 70 km in deep water. We will present tools that we have been developing to obtain ranges to vocalizing blue and fin whales to support density estimation.

The first harmonic of the 16 Hz NE Pacific blue whale B call is detected by Cascadia Initiative OBSs at ranges >100 km, so we have implemented tracking by applying a Bayesian inversion location method to arrival times detected at multiple OBSs. For 20 Hz fin whale calls, the network is too sparse for multi-station tracking, so we have developed a ranging method that uses the times and amplitudes of multipath arrivals at a single OBS. To date, these methods have been tested on small subsets of OBS data. Our ultimate goals are (1) to expand this analysis to support density estimation and ecological interpretations of the full Cascadia Initiative dataset and (2) to work with colleagues to create a user-friendly tool set that can be applied widely to OBS data sets to support density estimation.

Whistling By – Issues with Identifying Moving Vocalising Dolphins

Matthias Hoffmann-Kuhnt[1], Abel Ho[1], Denise L. Herzing[2], and Mandar A. Chitre[1]

[1] Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore

[2] Wild Dolphin Project & Florida Atlantic University

One of the biggest challenges in analyzing cetacean vocalizations and behavior is to determine, in a group of animals, which animal has been vocalizing and then to match that to the observed behavior recorded on underwater video. To address this problem, we have developed a portable underwater recording system that synchronized video and high-frequency audio obtained from a 3-hydrophone array (Hoffmann-Kuhnt et al 2016). In post-processing, the acoustic information was then converted into azimuthal and elevation direction-of-arrival angles and the resulting sound source location then overlaid on the corresponding video frame. While this procedure provided very good results in identifying echolocating dolphins- the performance on whistles was problematic for several reasons: Whistles most often have a duration of around a second or more – and thus continuing across several frames of video. This makes the use of time-of-arrival beamforming (TOA) possible only for the frame in which the vocalization starts – but difficult for later frames, particularly if the frequency of the whistle does not change. Secondly, over the duration of the whistle, the dolphin might be moving across the field of view of the video, and the initial location of the sound source would then not be accurate anymore. Thirdly, because of the movement of the animals relatively to the hydrophone positions, the recordings might have a different duration of the same vocalization on the different hydrophones (Doppler shift). Recordings of dolphin vocalizations obtained with the device in the Bahamas in 2016 and 2017 were used to test several methods of solving this problem. We applied different whistle detection and beamforming methods and compared the results of these algorithms and their performance on the obtained data.

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The Spatio-Temporal Distribution of Cuvier's Beaked Whale Buzz Detections off San Clemente Island, California

Susan Jarvis, Nancy DiMarzio, David Moretti, Ronald Morrissey

Naval Undersea Warfare Center Division, Newport, RI USA

Beaked whales, such as Blainville's and Cuvier's beaked whales, produce bouts of very rapid clicking that serve as a homing signal just prior to a prey capture attempt. These homing sequences have been dubbed "buzzes". Buzz clicks have a structure that is markedly different from and a source level that is significantly lower than the foraging clicks produced by these animals [1]. To date most of the studies of beaked whale echolocation behavior, especially buzz production, has relied on analysis of data from recording acoustic tags, e.g. DTAGs, placed on vocal animals. While the data from DTAGs has proved invaluable it is also limited. Tagging beaked whales is quite difficult thus the spatial and temporal coverage of tagged animals remains sparse.

A recently developed classification algorithm, the Class-specific Support Vector Machine (CS-SVM)[2], is capable of robust real-time detection and classification of both foraging clicks and buzz clicks from Blainville's and Curvier's beaked whales as they are received on bottom mounted hydrophones. The CS-SVM has been integrated into the Marine Mammal Monitoring on Navy Ranges (M3R) system and is currently deployed at all of the US Navy's major undersea ranges, including the Southern California Offshore Range (SCORE) located off San Clemente Island, California [3]. We believe the CS-SVM buzz classifier is the first algorithm developed to detect beaked whale buzzes on remote hydrophones. Its incorporation into M3R provides a new and unique ability to study buzz production over the geographically large (1000+ sq. km) areas represented by the hydrophone arrays resident on Navy ranges. This paper presents results from analysis of approximately 3.5 years of buzz detections from 89 broadband, bottom-mounted hydrophones at the SCORE range including the spatio-temporal distribution of buzz detections across the range area.

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Probability of passive acoustic detection of right whales from autonomous platforms equipped with a real-time monitoring system

Hansen Johnson[1,2], Mark Baumgartner[2], Ying-Tsong Lin[3], Arthur Newhall[3], and Christopher Taggart[1]

[1] Oceanography Department, Dalhousie University, Halifax NS, Canada
[2] Biology Department, Woods Hole Oceanographic Institution, Woods Hole MA, USA
[3] Applied Ocean Physics & Engineering Department, Woods Hole Oceanographic Institution, Woods Hole MA, USA

Mitigation of anthropogenic impacts on North Atlantic right whales and other at-risk species is critical, but challenging given the cryptic nature of whale behaviour and the limitations of conventional visual surveys. Using passive acoustic monitoring (PAM) to alert ocean users to whale presence in near real-time can provide an effective mitigation option. The Woods Hole Oceanographic Institution (WHOI) has developed the digital acoustic monitoring (DMON) instrument and low-frequency detection and classification system (LFDCS) to detect and classify baleen whales in near real-time from autonomous platforms (e.g., buoys and gliders). A limitation of many PAM systems, including the DMON/LFDCS, is the uncertainty in acoustic detection range from the PAM platform. Our goal was to determine the range-dependent probability of detection of the DMON/LFDCS on mobile and fixed platforms. Over a 4-week period in spring of 2017, we concurrently deployed a 4-element vertical line array (VLA), an 8-element horizontal line array (HLA), a DMON/LFDCS-equipped Slocum glider, and a DMON/LFDCS buoy at a shallow (~30m) site ~15 km southwest of Martha's Vineyard, Massachusetts, USA. We used a normal mode back-propagation technique with the HLA/VLA data to localize right whale upcalls, and then conducted a call-by-call comparison among calls detected on the HLA/VLA and those detected by the glider and/or buoy to determine the range-dependent detection probability among platforms. The results help us to better quantify and improve the performance of the DMON/LFDCS on different platforms, which in turn allows us to disseminate more accurate information about whale distribution and near real-time locations to research, government, and industry stakeholders.

An acoustic survey of beaked whale and Kogia in the main Hawaiian Islands using drifting recorders

Jennifer L. Keating[1,2], Erin M. Oleson[2], Jay Barlow[3], and Karlina Merkens[2,4]

[1] Joint Institute for Marine and Atmospheric Research, U. of Hawai‘i at Manoa, Honolulu, HI 96822, USA
[2] Protected Species Division, Pacific Islands Fisheries Science Center, NOAA Fisheries, Honolulu, HI 96818, USA
[3] Marine Mammal and Turtle Division, Southwest Fisheries Science Center, NOAA Fisheries, La Jolla, CA, USA
[4] Lynker Technologies, Boulder, CO, USA

During the 2017 Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) a network of 13 drifting hydrophone recorders was deployed around the main Hawaiian Islands with the goal of improving detection of beaked whales and Kogia. These Drifting Acoustic Spar Buoy Recorders (DASBRs) contained a two-element vertical hydrophone array at 150 m depth, sampling at 288kHz for 2 min of every 10 min. Deployment locations were planned to cover a 50 nmi minimum convex polygon around the main Hawaiian Islands (MHI Stratum). In actuality, DASBRs drifted significantly within the MHI Stratum and up to 200 nmi beyond. Overall the DASBRs collected data on 251 days and over 6,354 km of drifting track. Using the Click Detector Module within PAMGuard (version 2.00.11), 2-min periods of clicking were classified based on peak frequency. We found frequency modulated (FM) pulses characteristic of Longman’s, Cuvier’s, Blainville’s, and Cross Seamount beaked whales (BWC) in over 900 2-min files, spread along the drift track of each DASBR. Additionally, two types of Kogia echolocation clicks were detected with peak frequencies of 116 kHz and 123 kHz. To further improve detections of Kogia echolocation clicks, custom MATLAB subroutines were used to re-analyze the recordings in greater detail resulting in 60 2-min detections. Acoustic detections of beaked whales and Kogia were much more numerous than those from the towed array efforts during HICEAS and will enhance understanding of the distribution of these species in the main Hawaiian Islands.

Toothed whale classification- incorporating echolocation click properties and global distribution

Jens C. Koblitz [1, 2], Anne K. Scharf[3], Kaitlin E. Frasier[4], Melissa Soldevilla[5], Simone Baumann-Pickering[4], and Marie A. Roch[6]

[1] Department of Collective Behaviour, Max Planck Institute for Ornithology, Radolfzell, Germany
[2] Department of Biology, University of Constance, Konstanz, Germany
[3] Deptartment of Migration and Immuno-Ecology, Max Planck Institute for Ornithology, Radolfzell, Germany
[4] Scripps Institution of Oceanography, UC San Diego, La Jolla, CA, USA
[5] NOAA Southeast Fisheries Science Center, Miami FL
[6] San Diego State University, San Diego, CA, USA

About 75 toothed whale species are known to inhabit the oceans and rivers of the world. The echolocation signal produced by each species for spatial orientation, communication, and foraging falls into one of four known phonic groups: the low-frequency sperm whale clicks, broad-band dolphin clicks, narrow-band-high-frequency clicks (NBHF) and beaked whale frequency modulated sweeps. Given 75 species, one produces sperm whale clicks, 38 dolphin clicks, 15 NBHF clicks and 21 beaked whale sweeps. Click variability and structure differs among species and groups. Some species within these groups can be uniquely identified based on spectral or temporal features of their clicks, while others may only be identifiable to the more general phonic group.

Within these phonic groups, toothed whale species often have differences in their global distribution. In regions where diversity is low, quantifying within-signal variability for acoustic classification may become more tractable. Combining known species-specific distributions and acoustic properties of echolocation signals greatly reduces classification complexity. This synthesis evaluates these spatial and acoustic differences and presents species and geographic regions where classification to species level is feasible and where it is challenging. Based on these results, taxonomic units are identified where targeted future research on click characteristics might advance species specific acoustic classification.

Comparison of Error Sources in TDOA Algorithms.

David Lechner, Shane Guan, Joseph Vignola, Diego Turo, and Chanseok Jeong

The Catholic University of America, Department of Mechanical Engineering, Centre for Acoustics and Vibration Engineering.

This talk will present preliminary results and status in development of an automated tracking algorithm for whale signals using the Comprehensive Test Ban Treaty (CTBT) sensor network. The data from the CTBT stations is being made available for academic work, and the stations are also detecting bioacoustics sounds as well as seismic activity. We present an approach used to process several channels of the acoustic data collected off Cape Leeuwin, Australia, and automatically search for biologic activity using cross-correlation and Time-Difference-of-Arrival methods. Potential error sources include differences in acoustic propagation paths, sound speed used, potential of hearing multiple Whales, and multipath smearing of signal data. Accuracy of various localization algorithms will be compared and error sources will be discussed using simulated data, then applied to CTBT data sets.

Sparse hypothesis for time-frequency representation: application to the detection of the vocalization of marine mammals

Florent Le Courtois[1], Angélique Drémeau[2], and G. Bazile Kinda[1]

[1]Shom, Brest, France
[2]ENSTA Bretagne, Brest, France

Time-frequency representation is widely used to investigate the acoustic soundscape contributors. In particular, it is a relevant framework for the detection of tonal components that could be emitted by biological activities such as baleen calls and dolphin whistles. The detection of these sounds are commonly performed using image processing tools directly applied on spectrograms; while simple and intuitive, such methodologies strongly depend on the parameters of the short-time Fourier transform (STFT) leading to possible detection differences according to the setups of the transform. Moreover, Fourier-based estimators are known to lack of robustness in case of high signal-to-noise ratios (SNR), and trade-offs on time and frequency resolutions have to be made in order to overcome this limitation.

To tackle the intrinsic weakness and the drawbacks of the STFT, we introduce a new super-resolution methodology, based on a sparse assumption in the frequency domain. This formalism is suitable for the frequency estimation of the different signals of interest, even under low SNRs The method is shown to improve the detection performance. A validation is proposed using simulated and in-situ measured data. A particular attention is dawn on the accuracy of the frequency estimation.

Fine scale harbour porpoise distribution and density in a tidal rapid habit using PAM

Jamie Macaulay[1], Jonathan Gordon[1], Doug Gillespie[1], Alex Coram[1], Chloe Malinka[2], Peter Madsen[2], and Simon Northridge[1]

[1] Sea Mammal Research Unit, University of St Andrews, Scotland
[2] Aarhus University, Aarhus, Denmark.

Tidal rapids are unique habitats which attract some species of top predators to forage, including cetaceans. The proposed deployment of tidal turbines in these habits brings with it concerns about habitat exclusion and possible collision risk. Initial assessment of these concerns requires detailed information on the fine scale three-dimensional distribution and baseline behaviours of cetaceans in these habitats prior to turbine deployment. To study tidal rapid habitats, we developed a passive acoustic monitoring (PAM) approach which uses drifting vertical hydrophone arrays to localise the 3D positions of vocalising cetaceans (focusing primarily on harbour porpoises) combined with much simpler (and less expensive) drifting single autonomous PAM recorders. Tidal rapid habitats are highly energetic, heterogeneous environments where variability in noise levels, bathymetry, and animal acoustic behaviours mean that the probability of detecting vocalising cetaceans varies substantially over small spatial and temporal scales. Therefore, relative or absolute density estimation is challenging. To overcome these problems, we used a Monte Carlo simulation-based approach. First, the probability of localisation was simulated. This required knowledge of the source levels, noise, vertical angle distribution and harbour porpoise beam profile. All these parameters could be calculated from data collected on the vertical arrays, except for the full 4π beam profile. This was acquired experimentally from captive harbour porpoises in Denmark. The probability of localisation was then combined with localisation data collected on the vertical arrays to calculate the depth distribution of animals in various parts of the tidal stream. A second Monte Carlo simulation was then used to calculate a time and space varying probability of detection for all PAM drifters. Results show that harbour porpoise density is highest in the tidal rapid jet steam but low in the very highest current areas.

Joint analysis of pulsation and peak frequency: a model for examining frequency decrease in pulsed blue whale song

Franck Malige[1,7,8,9], Julie Patris[1,7,8,9], Susannah Buchan[2,3,7,9], Kathleen Stafford[4], Rodrigo Hucke-Gaete[5], Luke Rendell[6], Sergio Neira[2], and Hervé Glotin[1,7,8,9]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] COPAS Sur-Austral, University of Concepción, Chile; [3] Centro de Estudios Avanzados en Zonas Áridas, Chile ; [4] University of Washington, USA; [5] Universidad Austral, Chile ;
[6] University of St. Andrews, UK; [7] BRILAM, STIC AmSud ; [8] EADM GDRS CNRS MADICS, France ; [9] SABIOD.org

The peak frequencies (frequency band of most energy) in blue whale songs are known to be decreasing with time, worldwide and for all studied song types [1]. The cause of this pattern remains unknown. We analysed temporal trends in the frequency of the South East Pacific 2 (SEP2) blue whale song type using two decades of non-continuous recordings from four different locations in the tropical and south east Pacific.

Since this type of song has several amplitude-modulated parts, we analysed not only the peak frequency but also the frequency of the repetition of the pulses. Thanks to the high sample rate of some of our recordings, we performed autocorrelation on the signal, thus obtaining a very high accuracy on the pulse frequency. Our analysis shows a decrease in both peak frequency and pulsation frequency of this type of song, that is compared to other studies [4].

Along with this analysis, we present a new mathematical model of the song that questions the type of link between pulsation and peak frequency for this blue whale song type [2,3]. This model may be used to classify any song type which contains amplitude modulation and we discuss other blue whale songs in the context of these results.

Wav samples are available at : http://sabiod.org/workspace/BombyxUTLN_ChanaralChili/

We thank BRILAM STIC AmSud 17-STIC-01, reserva Chañaral, Explorasub, Agrupación turistica Chañaral de Aceituno.

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Estimating density of fin whales and beaked whales outside Navy Ranges

Tiago A. Marques[1,2], Len Thomas[1], and Dave Moretti[3]

[1] Centre for Research into Ecological and Environmental Modelling, The Observatory, University of St Andrews, St Andrews, KY16 9LZ, Scotland
[2] Centro de Estatística e Aplicações da Universidade de Lisboa, Faculdade de Ciências da Universidade de Lisboa, Bloco C6 - Piso 4, Campo Grande, 1749-016 Lisboa – Portugal
[3] Naval Undersea Warfare Center (NUWC), Newport, RI

Due to some species cryptic behaviour with respect to visual surveys, but frequent acoustic emission, passive acoustic density estimation is becoming increasingly used for cetaceans. However, unfortunately, dedicated studies with reliable survey designs for estimating density from such data are still rare, with most applications to date having been associated with Navy ranges built for other purposes.

In this talk we will present the DECAF-TEA (Density Estimation for Cetaceans from Acoustic Fixed Sensors in Testing and Evaluation Areas) project, which aims to estimate the density of beaked and fin whales on the SCORE US Navy range. While the work will be conducted on the SCORE range to help validation, the goal is to do the estimation independently of SCORE's hydrophones, hence demonstrating that the methods might be used outside a Navy range.

For estimating whale density, a mixed design that deals with short propagation distance species (e.g. beaked whales) and long propagation distance species (e.g. fin whales) will be considered. From this mixed design, both distance sampling (DS) and spatially explicit capture recapture (SECR) approaches will be considered. For beaked whales, we consider pairs of 3D bearing sensors to provide estimates of 3D localizations of detected whales, and from such data estimate detectability via distance sampling. At the same time, single units might provide a way to estimate density of fin whales via SECR. In either case, cue rates will be obtained from independent sources.

In the context of DS we explore the impact of measurement error on the 3D bearing estimates and how this error propagate via errors in localization all the way through to potential bias in density estimation.

Acoustic discrimination of fish versus mammal-eating killer whales by long-finned pilot whales: evidence with playback experiments

Massenet M.[1], Isojunno S. [2], Vester H.[3], Visser F. [4,5], Kvadsheim P. H.[6], Lam F-P.[7], Miller P.J.O.[2], and Curé C.[1]

[1] Cerema, Ifsttar, UMRAE, F-67035 Strasbourg, France; [2] Sea Mammal Research Unit, University of St. Andrews, St. Andrews, Fife KY16 8LB, UK; [3] Ocean Sounds, Hjellskjaeret, 8312 Henningsvaer, Norway; [4] Kelp Marine Research, Loniusstraat 9, Hoorn, the Netherlands; [5] Behavioural Biology Group, Leiden University, PO Box 9505, Leiden, 2300 RA, the Netherlands; [6] Norwegian Defence Research Establishment FFI, Maritime Systems Division, NO-3191, Horten, Norway; [7] Acoustics and Sonar, TNO, The Hague, 2509 JG, the Netherlands

Killer whales (KW) may be potential competitors and/or predators of other cetacean species. When encountering killer whales, the other cetaceans can exhibit various types of behavioural responses ranging from avoidance to approaches, defence behaviours, feeding associations or neutral interacting events (Jefferson et al., 1991; Jourdain and Vongraven, 2017). Since KW sounds vary among populations (Filatova et al., 2015), we hypothesized that other cetacean species can acoustically discriminate among KW populations and adjust their behaviour accordingly to the perceived risk. We tested this hypothesis on free-ranging long-finned pilot whales (Globicephala melas, PW) in the Norwegian sea where they compete with fish-eating KW for the same exploited food resource territories. To do so, we conducted sound playback experiments and exposed PW to i) familiar fish-eating KW sounds (fKW, n=7) simulating a known competitor, ii) unfamiliar mammal-eating KW sounds (mKW, n=6) representing a potential predation risk, and iii) two control sounds, a broadband noise (CTRL-, n=7) and a repeated upsweep 1-2kHz signal (CTRL+, n=5). We quantified the PW behavioural responses by using acoustic-and-motion tags (Dtag, Johnson and Tyack, 2003) and visual observations of the surface tagged whale behaviour and its group. We showed that PW barely changed their behaviour in response to CTRL- whereas they horizontally turned toward the sound source and exhibited spyhops in response to both KW sounds and CTRL+, probably to investigate the source. Moreover, parts of the behavioural responses were specific to both KW sounds and CTRL+, showing PW's ability to discriminate across these stimuli. PW aggregated with other subgroups and increased their surface synchrony and calling rate only in response to fKW, whereas they tightened individual spacing within their group and stopped feeding in response to mKW. We conclude that when detecting the sounds of KW, PW are able to discriminate between competition-risk and potential predation-risk contexts, enabling them to adjust their behavioural response strategy according to the perceived threat.

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Enhancements to Software for Detection, Classification, and Localization

David K. Mellinger, Curtis Lending, Sharon L. Nieukirk, Sara L. Heimlich

Cooperative Institute for Marine Resources Studies, Oregon State University
Pacific Marine Environmental Laboratory
National Oceanic and Atmospheric Administration

Ishmael is a software system in use since 2001 for viewing, analyzing, and annotating bioacoustic signals. A number of enhancements have recently been made: (1) Ishmael stores configurations for specific detection types and parameter settings. Configurations for detectors specific to various geographic locations in the Atlantic and Pacific are now available for download and installation in Ishmael. Each configuration also has associated detection performance data in the form of Receiver Operating Characteristic (ROC) and Detection Error Tradeoff (DET) curves. (2) Ishmael now interfaces to the Real-time Odontocete Call Classification Algorithm (ROCCA), such that when Ishmael detects a click or whistle, it can send detection information to ROCCA for automatic classification using one of ROCCA's geographically specific configurations. Results are sent back to Ishmael for logging. (3) Ishmael can now send sound or spectrogram data to MATLAB™ for detection and classification, with results sent back to Ishmael for further processing. This enables users to write relatively simple code in MATLAB for using their own detection/classification algorithms via Ishmael. (4) Ishmael now interfaces to the Marine Mammal Monitoring on Navy Ranges (M3R) acoustic system, allowing Ishmael's detection/classification abilities to be used on instrumented US Navy ranges, both in real time and for recorded data. (5) Ishmael's written documentation now includes a User Guide and a Tutorial. Video documentation covers activities commonly performed in Ishmael. Workshops have been presented on detection, classification, and localization using Ishmael as a key part of the bioacoustic analysis process. [Funding from LMR.]

Spectral spacing by singing humpback whales

Eduardo Mercado III[1], Yann Doh[2], Gilles Nolibé[3], and Olivier Adam[4,5]

[1] Dept. of Psychology, University at Buffalo, SUNY, New York, USA
[2] Gualiba, Guadeloupe, France
[3] CeSigma - Signals & Systems, La Garde, France
[4] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France
[5] Institute des Neurosciences Paris Saclay, CNRS UMR 9197, Université Paris Sud, Orsay, France

Humpback whales singing in isolation often produce unit sequences that are spectrally interleaved (e.g., the acoustic power of a unit is focused in frequency bands that do not overlap with those of a preceding unit). Spectral interleaving across consecutive units could help singers avoid self-interference from reverberation. However, in areas where multiple singing whales are audible, there is the potential not only for self-interference, but also for inter-singer interference. If songs serve as a beacon for other whales, then spectral convergence across singers could effectively extend the range of song detectability. Alternatively, if individual singers benefit from spectrally interleaving consecutive units, then they should also benefit from avoiding using the same frequency bands that other audible singers are using. Knowing whether singers within hearing range of one another converge or diverge in their frequency usage can clarify singers' goals.
Preliminary analyses of recordings made with an array moored in Saint-Marie channel, Madagascar, were conducted to evaluate the frequency bands used by multiple humpbacks producing overlapping songs. Analyses focused on recordings containing small numbers of distant singers to facilitate the identification of frequencies within songs that propagated long distances in the shallow waters (< 80 m depth) within this channel. Singers consistently focused spectral energy within a relatively narrow band (250-350 Hz), and intermittently focused energy in surrounding bands (100-150 Hz, and 500-1000 Hz). High-resolution spectra of 30 s sections of recordings were analyzed to determine the spacing of spectral peaks between 100-1000 Hz. Spacing of spectral peaks was well fit by a two-term Gaussian model (r-square =.96), with a modal inter-peak spacing of ~20 Hz within focal bands. This spacing is similar to the sequential spectral spacing measured in recordings of single singers, suggesting that singers in choruses may produce units focused in separate frequency bands, thereby reducing inter-singer interference.

Kogia click characteristics: new recordings, new locations, new instruments, new detectors

Karlina Merkens[1], Jennifer Keating[1], David Mann[2], Vincent Janik[3], Tess Gridley[4], Curt Jenner[5], and Erin Oleson[5]

[1] Contractor to NOAA/NMFS/Pacific Islands Fisheries Science Center
[2] Loggerhead Instruments
[3] Sea Mammal Research Unit
[4] Namibian Dolphin Project
[5] NOAA/NMFS/Pacific Islands Fisheries Science Center

Recordings of acoustic signals made by dwarf sperm whales (*Kogia sima*) and pygmy sperm whales (*K. breviceps*) are notoriously difficult to collect because of the boat-shy, cryptic behavior of both species plus their preference for staying in small groups in deep-water, offshore habitats. Additionally, the high frequency sounds generated by both species have historically been beyond the recording capabilities of many field research instruments. Opportunistic recordings collected over the past two decades, particularly those from the last few years, have greatly expanded scientific understanding of the types of signals made by these two species, which increases the likelihood of further Kogia-focused research. Here we present a summary of the characteristics of the signals from recent recordings of Kogia collected from new locations, particularly the Indian, North Pacific, and South Atlantic Oceans, to highlight consistencies and inconsistencies between regions and individual animals. We also present recordings from multiple instruments in different configurations and depths, to demonstrate how some of the variability in the recorded signals may be due to differences in the recording platform. Additionally we consider a comparison between the current PAMGuard detector and a MATLAB-based detector. In a difficult noise environment the PAMGuard detector identified 12 of the 60 encounters found by the MATLAB-based detector. In summary, these new data sets and analysis methods emphasize high variability in Kogia recordings, indicating that researchers should be cautious to classify unknown signals, but should also be encouraged that low similarity to known signals does not necessarily indicate mis-classification.

Sequential pattern mining of Pacific walrus sounds

Xavier Mouy[1,2], Francis Juanes[3], and Stan Dosso[1]

[1] University of Victoria, School of Earth and Ocean Sciences, Victoria, BC, Canada.
[2] JASCO Applied Sciences Ltd, Victoria, BC, Canada.
[3] University of Victoria, Biology Department, Victoria, BC, Canada.

Walruses produce a variety of underwater sounds including bells, grunts, and low frequency pulses called knocks. In the high Canadian Arctic, knock sequences by mature male Atlantic walruses serving as mating displays have been shown to be highly stereotyped and repeated over long periods of time. Stirling et al. (1987) observed that individual male Atlantic walruses produced specific knock sequences, and that these individual knock sequence patterns persisted over several years. Pacific walruses summering in the eastern Chukchi Sea also produce knock sequences; however, these sequences have not been well studied and their function is still unclear. The objective of this study is to apply data mining techniques to detect, classify, and identify frequent patterns of knocks produced by Pacific walrus. The data set considered was collected by 30 autonomous acoustic recorders deployed in the northeastern Chukchi Sea from 2007 to 2011. Walrus knocks were detected using a combination of a kurtosis-based detector and a random forest classifier. Detected knocks were grouped into knock-trains, labelled by type, and presented to the PrefixSpan algorithm to find the most frequent knock-train sequences in the data. One of the most frequent knock sequences was detected over several years and at different locations. It is unlikely that all repetitions of this sequence were produced by the same animal, suggesting that some knock sequences in the eastern Chukchi Sea may be shared at the population level. The approach developed in this paper can be applied to sounds from other soniferous animals such as sperm whales, humpbacks or fish to efficiently uncover patterns in their vocalizations.

Abundance Estimation for Passive Acoustic Monitoring of Cetaceans using Click-based Correspondence Analysis

Carlos de Obaldía, and Udo Zölzer

Department of Signal Processing and Communications, Helmut Schmidt University, Hamburg

The analysis of the underwater soundscape is of great interest for engaging in the conservation and behaviourial research of marine mammals. In this sense, the assesment of the number of active individuals in a particular region is of importance where visual surveys become impractical. To count particular species in a region, several algorithms can be employed in order to detect, segment and classify echolocation clicks. In this work, a Passive Acoustic Monitoring System (PAM) for the online identification, segmentation, and classification of cetacean echolocation clicks is presented. The algorithm analyzes an incomming waveform by discarding harmonic information based on a source separation algorithm. Click signals are detected by analyzing different frequency bands with an energy operator. Detected clicks are then segmented and selected for further classification by discarding false encounters based on a simple decision tree built on spectral features. Several cross-dependent features are further extracted from each segment and between consecutive segments in order to estimate the number of active individuals on a particular region using a rule-based correspondence analysis algorithm. For finding correspondences, correlation and spectral distance strategies are used to differentiate on the similarity of consecutive clicks in a particular time frame. The system is thus capable of estimating the number of active individuals and is intended towards applications where multiple species are present. The method is evaluated using real world recordings and synthesized tracks of different species.

Progress in phases: using passive acoustics to estimate false killer whale abundance in Hawaiian waters

Erin M. Oleson[1], Jennifer L. Keating[2], and Amanda L. Bradford[1]

[1] NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu HI
[2] Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, Honolulu, HI

Standard line-transect surveys for cetaceans operate under the assumption that groups are tight clusters of individuals, and estimates of group size, together with the perpendicular distance from the group's center to the trackline, provide the encounter data needed to estimate density and abundance. Research in Hawaii has revealed the tendency of false killer whale groups to associate in small, coordinated subgroups that can span tens of kilometers, violating this line-transect assumption. Ship-based, cetacean line-transect surveys conducted by the Pacific Islands Fisheries Science Center use a two-phased data collection protocol for false killer whales, where subgroups (not groups) are the detection unit. In phase 1, the visual and acoustic data collection teams independently record subgroup detections while surveying the trackline in passing mode (the ship does not stop or leave the trackline when detections are made). Phase 2 begins once all subgroups are past the ship's beam. In this phase, the acoustics team directs the ship toward the highest concentration of subgroups, where visual observers record size estimates for as many subgroups as possible. The Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS), conducted from July to December 2017, was the first large-scale survey of the U.S. Exclusive Economic Zone around the Hawaiian Islands to use this systematic data collection protocol. During HICEAS, 22 groups of false killer whales were visually and acoustically detected using the two-phased protocol, collectively representing several dozen subgroups. Five of these groups were only acoustically detected during phase 1 (visual detection occurred during phase 2). Acoustic subgroup detection rates were higher than the visual rate in both phases, indicating that acoustic detections would provide a more precise estimate of abundance upon overcoming challenges associated with acoustic-only subgroup identification, localization, and enumeration. This presentation details these challenges and progress made to-date.

Monohydrophone 3D localization of Baleen whales

Julie Patris[1,6,7,8], Dimitri Komatitsc[2,8], Mark Asch[3,7,8], Susannah Buchan[4,5,6,8], Franck Malige[1,6,7,8], and Hervé Glotin[1,6,7,8]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LSIS, DYNI team, Marseille, France
[2] AMU, CNRS, LMA, Marseille, France ; [3] Université de Picardie, CNRS, LAMFA, Amiens, France; [4] COPAS Sur-Austral, Universidad de Concepción ; [5] Centro de Estudios Avanzados en Zonas Aridas ; [6] BRILAM, STIC AmSud ; (7) EADM GDRS CNRS MADICS, France ; (8) SABIOD.org

One key-parameter for whale density estimation through passive acoustics is recovery of animal position (Marques et al. 2013). Most commonly, the localization process requires an array of 4 synchronized hydrophones (Kuperman et al. 2004), which is a more technically complex and expensive option than installing one single sensor. Several attempts have been made towards recovering the position of the singer with only one hydrophone (McDonald et al. 1999, Kuperman et al. 2001, Bonnel et al. 2014), however, these methods usually permit only range (and sometimes depth) estimation.
Here, we use seismic modelling methods (SPECFEM, Tromp et al. 2008) to understand the propagation of whale vocalizations in a specific context. Thanks to this precise time-domain modelling, we explore all the information inside the signal, including modifications produced by environmental complexity (bathymetry, speed variation, etc.). Subsequently we applied a low-cost inversion method based on Green's functions reciprocity principle to reconstruct the whale's position.
First tests on simulated data confirm that the technique is well suited to biological signals of very low frequency, such as the Southeast Pacific two Blue whale song type (described in Buchan et al. 2014). We also show the possibilities of this method for determining the range of an animal in shallow coastal waters. The results of two simulations in a 3D 10 km-wide box lead to the recovery of the range (with a precision greater than 100 m) in 98 % of cases, of the depth in 100 % of cases and of full position (that is range, depth and azimuth, thanks to our 3D modelling, with a resolution greater than 500 m) in 43% of cases.
Although these first tests ignore much of the real-word problems (fine modelling and source signal estimation) that we are currently addressing in a study in northern Chile, we think that they are encouraging and open the way for time-domain spectral-element methods in bioacoustics and shallow-water propagation modelling.

We thank the Chañaral reserve, Explorasub, agrupación turistica Chañaral de Aceituno, BRILAM STIC AmSud 17-STIC-01.

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Estimating the density of blue whales in the Southern California Bight: reducing uncertainty in cue rate and detection probability

Goldie Phillips[1], Leah Lewis[1], Ally Rice[1], Tyler Helble[2], Dennis Rimington[1], Gerald D'Spain[1], John Calambokidis[3], Ana Širović[1]

[1] Scripps Institution of Oceanography
[2] SPAWAR Systems Center Pacific
[3] Cascadia Research Collective

When using passive acoustics for density estimation, the cue rate and average probability of detection are often major contributors of variance. To reduce the uncertainty of the cue rate estimate used to assess blue whale density in the Southern California Bight, we employed recordings collected by acoustic tags (44 Bioacoustic probes, 15 Acousondes, and 61 Dtags) deployed on blue whales during a variety of studies occurring between 2002 and 2016. Generalized linear mixed models were used to examine the effects of a number of environmental and behavioral variables on the production rate of manually detected blue whale D calls attributed to the tagged animal. Overall, we found that time of day, dive behavior, and the proximity of call time to the tag deployment time were all statistically significant predictors of blue whale call rates. To reduce uncertainty in the estimate of average detection probability, we used data collected by bottom-mounted High-frequency Acoustic Recording Packages (HARPs) to incorporate frequently ignored background noise variability into the estimation process. First, the Peregrine parabolic equation acoustic propagation model was used to model complex pressure around a recorder deployment site. Using this output in a Monte Carlo simulation process, detection probability was estimated at multiple points within a 3D grid extending outward from the deployment site by automatically detecting representative D calls to which randomly selected background noise samples had been added. Automatic detection was performed using a version of the general power-law detector specifically adapted for blue whale D calls. We describe insights gained from both approaches, and, with the integration of their collective output into the density estimation process, present the first preliminary estimates of southern California blue whale density, obtained exclusively from long-term passive acoustic data collected using HARPs.

Beaker BANTER: Application of Compound Classification to Beaked Whales

Shannon Rankin, Eric Archer, Jay Barlow, Taiki Sakai, and Emily Griffiths

Southwest Fisheries Science Center, NMFS/NOAA, La Jolla, USA

BANTER is a newly developed acoustic event classification scheme that utilizes information from multiple rather than single call types (e.g. dolphin whistles, clicks and burst pulses). BANTER performs stably and yields a high rate of correct classification when applied to dolphins (Rankin et al. 2017). Its conceptual framework easily lends itself to other species, study areas, and taxa. As part of an effort to expand the application of BANTER, we tested alternative approaches to apply this compound classification scheme to events consisting solely of click detections. Specifically, we developed a series of alternative detectors, measurements and call classifiers for beaked whale echolocation clicks. Multiple click detectors were developed within Pamguard and applied to beaked whales detected on DASBRs (drifting acoustic spar buoy recorders) deployed off the U.S.West coast in 2016. Stable first stage classifiers with good discrimination results will be identified for implementation in BANTER. Event-level (second stage) classification results from BANTER will be compared with manual classification by a team of expert acousticians. These results will be used to inform development BANTER in open-source R software language.

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DyniClick: open-source toolbox for stereo click detection, analysis & tracking

Julien Ricard and Hervé Glotin

Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
EADM GDR CNRS MADICS, France
SABIOD.org
BRILAM STIC AmSud

Many marine mammals produce audio impulses, called clicks, to scan their environment through echolocation but also probably to communicate. Automatically detecting those clicks allows to monitor the presence of species of interest to study the dynamics of their populations on large temporal and spatial scales. Further analysis can help gain insights into the physical or physiological information they contain about their sources and their environment and into some possible messages aimed at social interaction.

In order to facilitate the extraction and the exploitation of this data, we have initiated the development of an open-source toolbox, DyniClick, implemented in Python and dedicated to click detection, analysis and tracking. The click detector is based on the derivative of the log-amplitude envelope. This detection is performed across different frequency bands, and only click candidates detected in all the bands are kept, which allows to configure the detection to target specific species or to filter out some noise. A second module provides tools to analyse the detected clicks and extract information about their acoustic characteristics and, when several channels are recorded, their localisation (azimuth), which is not common in other state of the art system [2].

Because our first species of interest has been the sperm whale, the toolbox also includes specific algorithms to detect the so-called pulses contained in their vocalisations and to estimate the Inter Pulse Interval (IPI) related to the size of the individuals [1]. Finally, in order to track an individual and to characterize its clicks, we implemented in a third module a click clustering algorithm based on the proximity in the temporal and spatial dimensions. The resulting click sequences, each assumed to belong to a single individual, can then be further explored to detect patterns or any information they could contain. DyniClick is available at https://github.com/dynilib/dyniclick, with some applications presented in DCLDE2018 and [3].

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Acoustic detections of minke whales in north-east Scotland

Denise Risch[1], Samuel Wilson[1], Mathilde Hoogerwerf[1], Nienke van Geel[1], Ewan Edwards[2], and Kate Brookes[2]

[1] Scottish Association for Marine Science (SAMS)
[2] Marine Scotland Science (MSS)

Despite frequent records from other parts of the North Atlantic (e.g., Mellinger et al. 2000, Risch et al. 2013), minke whales (Balaenoptera acutorostrata) have never been recorded acoustically in known summer feeding areas in the North Sea. Long-term passive acoustic recordings were used to investigate the acoustic detectability, seasonal occupancy and diel vocal behaviour of minke whales in the Moray Firth and off the north-east coast of Scotland. An automated minke whale pulse train detector, developed using verified minke whale vocalizations from the western North Atlantic, was applied to multi-year acoustic data from ten recording sites. When tested against manually verifed data from across the whole array, the pulse train detector used in this study successfully detected 58.4% of individual pulse trains and 94.3% of 10min bins with detections. However, precision values were low, with only 5% of individual pulse trains and 7% of 10min bins with detections being valid, necessitating post-hoc data validation. A substantial proportion of false detections originated from noise related to shipping and seismic survey activity. Minke whales were detected acoustically from May to November, with most detections occurring in June and July. Detections decreased in August and increased again in September, showing a second peak in October. No detections were made from December to April. Spatially, most detections occurred at deeper recording sites and in the northern part of the Moray Firth. Minke whale detections showed a statistically significant diel pattern, with a detection peak during night-time. This study confirms the acoustic detectability of minke whales in a known summer feeding ground in the North Sea. Results highlight the potential of using passive acoustic monitoring to study the seasonal occupancy and spatial distribution of minke whales in UK coastal waters, the wider North Sea and the eastern North Atlantic.

Humpback whale calves' vocal repertoire in the Sainte Marie channel breeding ground

Anjara Saloma[1,3], Mathilde Martin[1], Chloé Huetz[1], Aristide Andrianarimisa[3], Olivier Adam[1,2] and Isabelle Charrier[1]

[1] Université Paris-Saclay, Université Paris-Sud, CNRS, UMR 9197, Institut des Neurosciences Paris-Saclay, 91405 Orsay, France.
[2] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France
[3] Zoology and Animal Biodiversity, University of Antananarivo, 101 Antananarivo, Madagascar

Humpback whales use vocalizations during diverse social interactions or to organise activity such as foraging or mating. Unlike songs, which are confined to males, social calls are involved in social interactions, and have been reported to be produced by all types of individuals, adult males and females, juveniles and calves alike (Dunlop et al. 2007, Zoidis et al. 2008). Recent studies have described these social calls in different geographic areas (Dunlop et al. 2007, Stimpert et al. 2011, Rekhdal et al. 2013, Fournet et al. 2015); however, the context and biological functions of these social calls remains unknown. This study, aims to investigate the vocal repertoire of humpback whale calves during interactions with their mothers. We recorded mother-calf vocal activity during the breeding season in Madagascar by using Acousonde tags attached to mother-calf pairs (either mother or calf or both). Based on a previous description of the vocal repertoire of social sounds in the study area, we were able to identify 9 types of calls by calves, varying from low to mid-frequency, including one call presenting amplitude modulation. Two of the calves' vocalizations reported in this study were similar to calves' vocalizations described in the literature of other geographic area (Zoidis et al. 2008), and four call types appeared to be group-specific. Though humpback whale calves' vocalizations are in general relatively simple in structure, we found that calves are also able to produce combined calls, composite calls and sequenced calls. Such diversity in call production may be part of the vocal ontogeny of humpback whales, and could lead to a more stable and complex vocal repertoire at adulthood.

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WhaLeNet: Using a standard neural network to improve the generalisability of a right whale upcall detector

Y. Shiu[1], K. Palmer[2], D. Cholewiak[3], E. Fleishman[4], D. Gillespie[5], T. Helble[6], K. LeCam[2], X. Lieu[2], E.M. Nosal[7], M. Roch[2], and H. Klinck[1]

[1] Cornell University, 159 Sapsucker Woods Rd, Ithaca, NY 14850 USA
[2] San Diego State University, 5500 Campanile Dr., San Diego, CA 92182-7720
[3] NOAA Northeast Fisheries Science Ctr, 166 Water Street, Woods Hole, MA 02543 USA
[4] Center for Environmental Management Military Lands, Colorado State University,
[5] University of St. Andrews, St. Andrews, KY16 8LB, Scotland
[6] SPAWAR Systems Center Pacific, 53560 Hull Street, San Diego, CA 92152 USA
[7] University of Hawaii, 2540 Dole ST, Holmes Hall 405, Honolulu, HI 96822

A common pitfall of supervised machine learning systems for bioacoustic analysis is the lack of ability to generalize to data that differ significantly from the training set. Many models are transferable to data collected in similar sound environments, times of year, geographic areas, or with similar instrumentation. For example, top systems developed during the 2013 North Atlantic Right Whale Kaggle competition achieved 93% performance as measured by area under the receiver operating curve. However, the most accurate models from the competition exhibited poor performance when presented with novel data containing conditional mismatches. In this work we report on our efforts to improve the robustness of the canonical right whale up call detector by using deep neural networks. We present several neural network models constructed based on the 'LeNet' architecture. Unlike work for previous classification challenges, we trained our classifier on the basis of multiple data sources, including MARUs and Autobuoys. For the evaluation phase, we applied our models to the 2013 DCLDE workshop dataset and compared our results to the submitted classifiers presented at the workshop. We then applied our model to a variety of other validated datasets, including recordings collected from Virginia, Maryland, and New York, to test generalisability. This work was funded by the Office of Naval Research

Unsupervised clustering approach to classify beaked whale's clicks

Natalia Sidorovskaia and Kun Li

Department of Physics, University of Louisiana at Lafayette, Lafayette, LA 70504-3680, USA

Passive acoustic data are broadly used to study cetacean's populations and habitat use. This study focuses on the classification of beaked whale calls. As for beaked whales, one of the challenging automatic processing goals is the identification of different species of beaked whales (Gervais's, Cuvier's, etc.). At present, traditional detection and classification methods employ the band-energy-based approach to search for acoustic events above baseline level in long-term spectrograms and further rely on manual inspection by an experienced operator to provide species' relevant information. However, such detectors initially have a large percentage of false positives and require extensive manual work to obtain final results. Current data collection systems in passive monitoring lead to the large volumes (hundreds of Tb) of acoustic data, which are post-processed to detect the acoustic events of interest. Thereby, the operator inspection approach becomes impractical as volumes of collected data increase. This paper focuses on developing a multi-stage fully automatic detector for beaked whale's species. The proposed method utilizes unsupervised machine clustering of spectral features extracted from potential detection events. The algorithm was applied to the workshop dataset and successfully classified beaked whale species' encounters in fully automatic mode with low percentage of false classifications when compared to the annotated challenge dataset. The proposed method may provide a tool for analysing and processing large volumes of acoustic data with minimal operator involvement.

Detection of blue whale D calls from long-term recordings in Southern California

Ana Širović[1], Ally Rice[1], Lynnette Reed[1], Mukta Kelkar[1], Goldie Phillips[1], and Tyler Helble[2]

[1] Scripps Institution of Oceanography, University of California San Diego
[2] SPAWAR Systems Center Pacific

Blue whales produce several distinct signals including songs and downswept calls. Automated detection of regionally distinct song units has been successfully demonstrated in the past, but development of a detector for the downswept D calls has been more challenging. A version of the general power-law detector was adapted for blue whale D calls based on the recordings from the Southern California Bight (SCB). This detector was then used to automatically extract start times of D calls occurring over a decade (2008-2017) across six sites in the SCB. After the detector was run across the data, all detections were manually verified and false detections were excluded from further analysis. This extra step was required because we opted to keep a generalized detector rather than tuning a more call-specific classifier due to a large variability in this call type, and unknown level of change in the call over longer time. The seasonal presence of D calls was evident across sites, with peak calling usually occurring during the summer months (June-July) and at times a secondary peak in the fall (October-November). But comparison of sites also revealed finer scale interannual variability of habitat use by these animals across southern California. For example, during 2014 and 2015, when few blue whales were detected in their prime detection areas in the north, the detections remained common in southern parts of the SCB. The SCB is also an area with variable ambient noise levels. We will discuss how natural variability in noise across these sites affects the detection range at each site, as well as the comparison of call densities across sites.

Gaussian Mixture Models for Automatic Classification of Cuvier's Beaked Whale echolocation clicks

Alba Solsona Berga[1,2], Marie Roch[3], Mike van der Schaar[2], Michel André[2], and Simone Baumann-Pickering[1]

[1]Scripps Institution of Oceanography, University of California San Diego, USA
[2] Laboratori d'Aplicacions Bioacústiques, Universitat Politècnica de Catalunya, Barcelona Tech, Vilanova i la Geltrú, Spain
[3] San Diego State University, San Diego, USA

Anthropogenic underwater noise is now recognized as a global threat to marine fauna, and beaked whales appear especially vulnerable to high-intensity noise with numerous cases of mass-stranding followed by naval exercises in different locations (Cox et al., 2006; Filadelfo et al., 2009). These elusive species are potential indicators for the effects of underwater noise, which increases the need for information about their spatio-temporal presence and abundance. Passive acoustic monitoring has shown to have a great potential to document their distribution (Baumann-Pickering et al. 2014). However, the challenge that comes along with such monitoring is the processing and logging of the deluge of data coming from these acoustic recorders. Several approaches have been presented previously that involved manual or semi-automated methods to classify to species level (BaumannPickering et al. 2013).

Here we present a fully automated classification approach based on Gaussian Mixture models, with an emphasis on Cuvier's beaked whales. Using the previous DCLDE 2015 challenge dataset, we extracted descriptive temporal and spectral features grouped in four feature combinations. The combination that resulted in the best classification consisted of 14 different features. A portion of the data was used to train one hundred Monte-Carlo three-fold experiments, and the remaining data to test the performance of the models. The system performed remarkably well with an error rate of 8% over training and test sets. More so, we present its application on the DCLDE2018 development data that resulted in different performance between sites with error rates ranging from 0.4% to 44%.

Application of machine learning techniques to identify foraging calls of baleen whales

Michelle K. Tanalega, Tetyana Margolina, John Joseph

Naval Postgraduate School, Department of Oceanography

An unsupervised machine learning algorithm has been applied to passive acoustic monitoring data sets to detect and classify foraging calls of blue whales, *Balaenoptera musculus*, and fin whales, *Balaenoptera physalus*. This approach involves using a k-means clustering algorithm to cluster data based on common features, which produces a number of specified centroids. The centroids are then compared to machine-selected candidates for classification. Once divided into initial clusters, further clustering is done to fine tune results. Preliminary testing of the algorithm yielded promising results. The cross-validation method and the DCLDE 2015 scoring tool were used to estimate out-of-sample performance of the detection algorithm. The automated detector/identifier has been applied to data collected during different seasons, and its performance was analyzed for various types of noise present in data, signal-to-noise ratios, and acoustic environment. The advantages of this approach over traditional manual scanning are increased reliable performance and time and cost efficiency. This approach could potentially be a faster method of sorting and classifying large acoustic data sets.

A double-difference method for high-resolution acoustic tracking using a deep-water vertical array

Ludovic Tenorio-Hallé, Aaron M. Thode, Jit Sarkar, Christopher Verlinden, Jeffrey Tippmann, William S. Hodgkiss, and William A. Kuperman

Marine Physical Laboratory, Scripps Institution of Oceanography, La Jolla, USA

Ray tracing can estimate an acoustic source's depth and range over long ranges in a waveguide by exploiting multipath arrival information on a vertical array. However, systemic errors resulting from environmental mismatch in the model or array tilt often yield imprecise localizations and highly scattered trajectories when ray tracing multiple events from a moving source.

"Double-difference" methods have been applied to earthquake (Waldhauser and Ellsworth, 2000) and fin whale (Wilcock, 2013) localizations using widley spaced seismic stations, by precisely determining the relative locations of multiple events, rather than their absolute positions. This approach, which exploits changes in relative travel-times between events, has recently been reformulated to recover the depth and range trajectories of a source using a single multi-hydrophone vertical array (Tenorio-Halle et al., 2017).

The method measures changes in relative arrival times between multipath arrivals for several events, as well as changes in ray arrival angles between events, to determine the relative ranges and depths between events. This technique has been tested on data recorded on a short aperture vertical array off the coast of Southern California in 4 km deep water. Results from applying this double-difference method to a controlled acoustic source, being towed at 50 km range from the array, are first presented to show that its trajectory can be accurately recovered. A sperm whale trajectory is then computed using this approach.

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Correlogram processing for Odontocete click tracking using multiple independent autonomous acoustic sensors

James A. Theriault[1], Craig Sheppard[2], Joey Hood[2], and Matthew Coffin[2]

[1] Ocean Environmental Consulting, Halifax, NS
[2] GeoSpectrum Technologies Inc., Dartmouth, NS

Observing odontocete behaviour during dives is difficult without instrumenting (tagging) individual animals. However, one method of studying submerged behaviour is to acoustically track clicking animals using Time Difference of Arrival (TDOA) techniques. In principle, multiple animals can be studied while clicking by cross-correlating the acoustic detections from multiple seabed sensors. However, for odontocetes, discrete clicks are almost indistinguishable between individuals, yielding ambiguous click associates. However, a method of using multiple clicks within a train while managing multipath arrivals which allows this ambiguity to be resolved has been developed. Using recordings from multiple closely spaced (≈200 m) GuardBuoy sensors deployed on the Canadian Scotian Shelf, cross-sensor correlograms are produced to estimate the TDOA tracks of individual sperm whales, and, as a more challenging case, of individual delphinids. The raw time series are reduced to a synthetic time series of binary (1-bit) click detections. The synthesized click-detection time series are used in calculating cross-sensor correlograms to generate improved TDOA tracks from a number of vocalizing animals as compared with using the raw time series.

Using ‘azigrams’ to display directional information from DIFAR sonobuoys

Aaron Thode[1], Katherine Kim[2], Shannon Rankin[3], and Melissa Soldevilla[4]

[1] Scripps Institution of Oceanography, UCSD, La Jolla, CA USA
[2] Greeneridge Sciences, Inc., Santa Barbara, CA, USA
[3] Southwest Fisheries Science Center, NMFS/NOAA, La Jolla, CA, USA
[4] Southeast Fisheries Science Center, NMFS/NOAA, Miami, FL, USA

The AN/SSQ-53D/E Directional Frequency Analysis and Recording (DIFAR) sonobuoy is an expendable device that has the ability to measure acoustic particle velocity along two orthogonal horizontal axes, along with acoustic pressure. This information allows the bearing of low-frequency acoustic sources to be measured from a single compact sensor. Surplus sonobuoys (and related custom sensors) are being used by several research and commercial groups worldwide to locate low-frequency baleen whales. Conventional beamforming (adding weighted time series together) is the standard way of estimating bearing, but suffers several disadvantages: the ‘cardioid’ beampattern is imprecise, expensive to compute, and vulnerable to directional noise contamination. Here we demonstrate an alternative (multiplicative) processing scheme that computes the “active intensity” (D’Spain, 1991) of an acoustic signal, whcih can then be used to estimate the dominant directionality of a noise field as a function of time and frequency. This information can be conveniently displayed as an ‘azigram’, which is analogous to a spectrogram, but uses color to indicate compass direction, and not sound pressure level. Data from the Beaufort Sea, Pacific Ocean, and Gulf of Mexico are used to demonstrate the approach, which can be computed without demultiplexing the raw signal. Azigrams have been used to help diagnose sonobuoy issues and improve detectability and bearing estimates of low signal-to-noise ratio signals. The ability to construct azigrams without demultiplexing the signal makes real-time processing and “scrolling” of DIFAR directional information feasible.

Evaluation of methods for estimating call density from static acoustic sensors: bowheads in the Beaufort

Cornelia S. Oedekoven[1], Len Thomas[1], Tiago A. Marques[1], Danielle Harris[1], Aaron M. Thode[2], Susanna B. Blackwell[3], Alexander S. Conrad[3], Katherine H. Kim[3], and Gisela Cheoo[4]

[1] Centre for Research into Ecological and Environmental Modelling, University of St Andrews
[2] Scripps Institution of Oceanography, University of California San Diego
[3] Greeneridge Sciences Inc.
[4] University of Lisbon

We used 8 years of data from 5 static passive acoustic arrays in the Beaufort Sea to compare and evaluate multiple methods for estimating call density of migrating bowhead whales. Each array comprised between 3 and 13 direction-sensing recorders (Directional Autonomous Seafloor Acoustic Recorders – DASARs), typically separated by 7km and located in shallow water (20-55m) off the north coast of Alaska. Bowhead calls were detected and classified by two methods: manually by observers screening the spectrograms of the recordings and using an automated algorithm; calls on two or more DASARs could be localized (in 2D). We compared three methods of density estimation separately on manual and automated data: (1) direct census (where calls within a fixed radius of each sensor are assumed to be detected with certainty, and those outside that radius are discarded); (2) distance sampling (where range-specific detection probability of calls is estimated from the distribution of detection distances); and (3) spatially-explicit capture recapture (SECR, where range-specific detection probability is estimated from the pattern of detections across sensors). Direct census and distance sampling methods produced similar results; SECR was problematic for automated data due to a large number of detections on single sensors (probably mostly false positives) and for manual data due to non-independence between sensors. We discuss the pros and cons of each method.

Marine mammal species classification using Convolutional Neural Networks

Mark Thomas[1,2], Bruce Martin[1,3], and Stan Matwin[2]

[1] JASCO Applied Sciences, 32 Troop Avenue, Dartmouth NS, B3B 1Z1
[2] Department of Computer Science, Dalhousie University
[3] Department of Oceanography, Dalhousie University

In recent years, deep neural network architectures have become the state-of-the-art approach to tackling many complex pattern recognition problems, such as voice and image recognition. One particularly effective neural network architecture is the Convolutional Neural Network (CNN). In this work, we propose using a deep CNN to identify marine mammal species using a large dataset of annotated spectrograms of their vocalizations. First, the spectrograms are padded to be a standard image size. The images are the input to a five-layer CNN that is trained from a database of over 450,000 vocalizations from 11 distinct marine mammal species as well as false alarm sources. The database is divided into 90% training, 5% validation, and 5% test using stratified sampling. One of the CNN classes groups summer downsweeps from blue, fin, and sei whales. The outputs of this group is passed to a secondary classifier to distinguish between these species. The current accuracy of the secondary classifier is roughly 0.8.

Automated detection of non-stereotyped whale calls using dictionary-based representations: application to blue whale D-calls

Maëlle Torterotot[1], François-Xavier Socheleau[2], Flore Samaran[3], and Jean-Yves Royer[1]

[1] Laboratoire Géosciences Océan, IUEM, University of Brest & CNRS, 28280 Plouzané, France
[2] IMT Atlantique, Lab-STICC, UBL, 28280 Plouzané, France
[3] ENSTA Bretagne, Lab-STICC, UBL, 29806 Brest, France

Blue whales are known to produce stereotyped calls or songs, as well as variable calls commonly called arch-sounds or D-calls (Thompson 1996, McDonald et al. 2001). The latter sounds are often difficult to detect with common automated detection methods, such as spectrogram correlation or matched filters, due to their highly variable shapes in a time-frequency representation (Oleson et al. 2007b). Here, we test a new detection algorithm relying on a dictionary-based representation with a sparsity constraint. This detector first captures and learns the variability of D-calls from a series of randomly selected acoustic signals in a set of identified calls; then, the detector can be applied to the complete database. The main advantage of this dictionary-based approach is that it is applicable to any mysticete call that lie in a linear sub-space and particularly to non-stereotyped calls, such as D-calls.
To test the performance of this detector, we manually selected about 800 blue-whale D-calls from 90 hours of the OHA-SIS-BIO database (7 years, 6-7 sites). This database is made of yearly continuous records, sampled at 240 Hz, from the southern Indian Ocean and comprises various types of calls from Antarctic blue whales, three populations of pygmy blue whales and fin whales (Leroy 2017). We built different dictionaries to cross-validate our results. Each of them is made of 85 D-calls (~10% of the identified D-calls) randomly picked among the positive SNR vocalisations. For a false-alarm rate of 5 false detections per hour, our detector, with either dictionary, detects 85 % of the calls in the test database whereas the XBAT software (Figueroa, 2006) only detects 70% of them. However, the detector also captures fin-whale 40 Hz pulses, which have a time-frequency shape similar to D-call ends and need to be sorted out.
This detector will then be applied to the whole OHA-SIS-BIO database. The objective is to analyze the seasonal and geographical occurrence of D-calls with respect to that of blue whale species detected in the southern Indian Ocean.

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Towed array shape estimation for passive acoustic monitoring from a wave-propelled USV

Alfie Anthony Treloar[1], Alan Hunter[1], Jan Bujalka[2], and Roy Wyatt[2]

[1] University of Bath, Claverton Down, Bath, UK, BA2 7AY
[2] Seiche Ltd., Bradworthy, Devon, UK, EX22 7SF

The use of towed hydrophone arrays deployed from wave-propelled autonomous surface vehicles presents a unique opportunity for long-duration, wide-area passive acoustic monitoring of marine mammals. Example applications include population surveys for environmental conservation and mitigation zone enforcement for offshore anthropogenic activities. These vessels present certain challenges for robust direction-of-arrival estimation using beamforming. The limited propulsion power compared to traditional tow-vessels imposes the constraint of a short array and a shallow tow depth. Moreover, the intermittent nature of propulsion inherent to these platforms exacerbates the problem of uncertainty in the array profile. Uncompensated array curvature causes beamforming errors, which can lead to inaccurate bearing estimates, misdetections, and false alarms.

Data from the Unmanned Warrior ’16 trial has been used to investigate these challenges and explore potential techniques for improvement. During the trial, multiple tonal signals were emitted from a SAAB autonomous underwater vehicle at frequencies comparable to those of certain whales. At the same time, an Autonaut unmanned surface vehicle (USV) towing a Seiche Digital Thin Line Array was used to measure the acoustic emissions from this source. We will present results from several beamforming techniques applied to these acoustic data, including conventional, MVDR (minimum variance distortionless response) and MUSIC (multiple signal classification). Various methods for estimating the array profile and compensating for these uncertainties will be explored, and their applicability and effectiveness assessed using simulation and application on the experimental data.

Heuristic Classification of Hydrophone Recordings

Daniel M. Wolff[1], Patricia Gray[2], and Rafael de la Parra Venegas[3]

[1] University of North Carolina Greensboro, Greensboro, NC 27412 USA
[2] University of North Carolina Greensboro, Greensboro, NC 27412 USA and BioMusic International Research and Education Project
[3] Ch'ooj Ajauil AC, Quintana Roo, Mexico, and Mexican Caribbean Marine Mammal Stranding Network

An unsupervised machine listening system is constructed and applied to a dataset of 17,195 30-second marine hydrophone recordings. The system is then heuristically supplemented with anecdotal listening, contextual recording information, and supervised learning techniques to reduce the number of false positives. Features for classification are assembled by extracting the following data from each of the audio files: the spectral centroid, root-mean-squared values for each frequency band of a 10-octave filter bank, and mel-frequency cepstral coefficients in 5-second frames. In this way both time- and frequency-domain information are contained in the features to be passed to a clustering algorithm.

Classification is performed using the k-means algorithm and then a k-nearest neighbors search. Different values of k are experimented with, in addition to different combinations of the available feature sets. Hypothesized class labels are "primarily anthrophony" and "primarily biophony", where the best class result conforming to the former label has 104 members after heuristic pruning. This demonstrates how a large audio data set has been made more tractable with machine learning techniques, forming the foundation of a framework designed to acoustically monitor and gauge biological and anthropogenic activity in a marine environment.

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Inter and Intra Specific Variation in Echolocation Signals Among Odontocete Species in Hawaii, the Northwest Atlantic and the Temperate Pacific

Tina M. Yack[1,2], Julie Oswald[2,3], Kerry Dunleavy[2], and Danielle Cholewiak[3]

[1] EcoSound Bioacoustics, 9423 Saint Andrews Dr. Santee, CA 92071, USA
[2] Bio-Waves, Inc., 364 2nd St #3, Encinitas, CA 92024, USA
[2] University of St. Andrews, East Sands, St. Andrews, Fife, Scotland, UK
[3] Passive Acoustic Research Group / Protected Species Branch, NOAA Northeast Fisheries Science Center, 166 Water Street,Woods Hole, MA 02543, USA

Odontocete species use echolocation signals (clicks) to forage and navigate. The aim of this study is to explore inter- and intra-specific variation in clicks among odontocete species in the Northwest Atlantic, Temperate Pacific, and Hawaii. Clicks were examined for seven species of odontocetes; bottlenose dolphins, common dolphins, striped dolphins, rough-toothed dolphins, pilot whales, Risso's dolphins and Cuvier's beaked whales. Newly developed PAMGuard tools were used to automatically measure a suite of click parameters. Seven parameters were compared within and between species; duration, 10dB bandwidth, 3dB bandwidth, center frequency, peak frequency, sweep rate, and number of zero crossings. Significant differences in duration, center and peak frequency were evident between species within study areas (Dunn's test with Benjamini-Hochberg adjustment $p<0.05$). Geographic variation in click parameters between the three study regions was also examined. Results showed statistically significant pair-wise differences between geographic regions for all echolocation click parameters, with the exception of sweep rate of Risso's dolphin (Hawaii vs. Atlantic), and pilot whale (Temperate Pacific vs. Atlantic) echolocation clicks, the number of zero crossings (Hawaii vs. Atlantic) and 10dB bandwidth (Temperate Pacific vs. Hawaii) of striped dolphin echolocation clicks, and duration, 3dB bandwidth and 10 dB bandwidth of Cuvier's beaked whale echolocation clicks (Hawaii vs. Atlantic) (Dunn's test with Benjamini-Hochberg adjustment $p<0.05$). Results of this study suggest that there are species-specific differences in clicks among odontocetes and that geographic variation exists for multiple species. The ecological significance of these findings will be discussed along with implications for classifier development.

The Effects of Ambient Noise and Propagation Loss on the Acoustic Detection of Killer Whales in Inshore Waters in British Columbia, Canada

Yurk, H.[1], Austin, M. [2], Mouy, X.[2] and O'Neill, C[3]

[1] Aquatic Ecosystems Marine Mammal Science, Fisheries and Oceans Canada, Pacific Science Centre, 4160 Marine Drive, West Vancouver, BC, Canada V7V 1N6
[2] JASCO Applied Sciences, 4464 Markham Street, Victoria, BC, Canada V8Z 7X8
[3] Institute of Ocean Sciences, Fisheries and Oceans Canada, 9860 West Saanich Road, Saanich, BC, Canada V8L 4B2

Detection range of cetacean signals is constrained by the received signal loudness, its energy composition across the signal frequency range, and the signal to noise ratio. These parameters are influenced by the sound propagation and ambient noise conditions along the path between signaller and receiver. Detection ranges of calls from a local group of killer whales were modelled along radials around passive acoustic monitoring stations in the Salish Sea. The model implemented separate sound speed profiles and ambient noise levels for summer and winter as well as site specific propagation. A field study measured received levels of transmitted signals that matched frequency contours and source levels of killer whale call elements, as well as from a transmitted recording of a local killer whale call. These acoustic signals were broadcast from different angles to a calibrated hydrophone. The model results suggest that sounds between 2 and 3 kHz yield the greatest detection ranges due to their higher source levels. Also, modelled detection ranges were found to be greater in the winter, due to a surface sound channel. Significant variability in modeled propagation losses resulted in substantial detection range differences among sites. Initial results from the field study suggest that the model, which considered call frequencies between 1-8 kHz, may overestimate detection ranges in winter, possibly due to effects from the seasonal surface sound channel. Acoustic signals from sources near the surface, such as vessels, propagate further within the surface channel, resulting in total masking of signals below 5 kHz at the same depth and partial masking of signals up to 10 kHz. The results of this study suggest that a sound surface channel in a high vessel traffic area can significantly affect signal detection ranges, and therefore depth-dependent ambient noise is an important parameter for detection range estimates because lower signal frequencies can be masked by noise.

Underwater source localization using unsynchronized passive acoustic arrays

Daniel P. Zitterbart and Ying-Tsong Lin

Woods Hole Oceanographic Institution

Localizing sources of underwater sound is a well studied field that is utilized by several scientific and naval communities. The scope of localization might differ dramatically, from the necessity to localize targets with a sub-meter accuracy to estimation of the position of an object on a kilometer scale.

Advances in data storing capabilities during the last decade now allow multi-year deployments of autonomous passive acoustic monitoring arrays for which past-recovery time synchronization cannot be guaranteed. For localization of transient signals, like marine mammal vocalization, arrival time based localization schemes are currently the prevalent method. Appling arrival time based methods to non-synchronized multi station arrays eventually leads to large localization uncertainties.

Advances in data storing capabilities during the last decade now allow multi-year deployments of autonomous passive acoustic monitoring arrays for which past-recovery time synchronization cannot be guaranteed, especially if moorings have to be deployed completely subsurface, e.g. due to sea ice formation.

Here we present a backpropagation based localization scheme that overcomes the necessity to synchronize between array stations for localization purposes and therefore can be used on fully submerged, low-cost PAM arrays. It utilizes waveguide dispersion measured within distributed arrays for simultaneous source localization and time synchronization. We present numerical and experimental results to demonstrate that localization uncertainty significantly improves compared to arrival time based methods. This localization scheme allows for low uncertainty out-of-array localization, thus a large ratio between localization distance and array aperture can be achieved.

Poster sessions

Credit photo: Joël Detcheverry – association SPM Terre Vivante

Abstracts

(*alphabetic order*)

Optimization of a general power law algorithm for detection of humpback whale calls in heterogeneous acoustic datasets

Ann Allen[1], Tyler Helble[2], and Erin Oleson[1]

[1] NOAA NMFS Pacific Islands,
[2] SPAWAR Systems Center Pacific

The Pacific Islands Passive Acoustic Network is a network of bottom mounted High-frequency Acoustic Recording Packages (HARPs) spread over a variety locations in the North Pacific, including Hawaii, Wake, Palmyra, and the Commonwealth of the Northern Mariana Islands. The HARPs are deployed for a period of several months to a year, often with duty cycled recording periods. Several sites have had recorders deployed almost continuously for the last six to ten years. These data represent a unique, in both scale and longevity, marine mammal acoustic monitoring effort. The data were collected to aid in evaluating the occurrence, distribution, seasonality, and characteristics of cetacean sounds throughout the Pacific Islands, an area otherwise particularly difficult to monitor. However, the extremely large volume of acoustic data makes hand-marking periods of calling for each whale species an insurmountably time consuming task. Additionally, the variations in site conditions and noise conditions make using most automated methods of detection exceedingly difficult to implement and produce inconsistent results. Here we implemented a generalized power-law (GPL) detection algorithm to automatically detect periods of humpback whale vocalizations in the HARP recordings. Short periods of data from each recording site were hand audited for humpback vocalizations. The GPL algorithm was run on the same periods of recording as the hand marked data using a standard set of parameters for humpback calls. The GPL parameters were then optimized based on an extended period of manually audited data from one site. The GPL algorithm was then re-run on the manually audited data sections using the optimized parameters. The detection results of non-optimized and optimized GPL parameters were compared for sensitivity, specificity, and overall efficacy of humpback call detection across the varied sites and conditions. Here we summarize the advantages and disadvantages of the detection methods, the unique problems encountered, and solutions applied.

Assessing the effect of shipping noise on St. Lawrence Estuary beluga

Line Bourdages, Yvan Simard, Nathalie Roy, and Florian Aulanier

Fisheries and Oceans Canada, Maurice Lamontagne Institute, Mont-Joli, Québec, Canada

Within the framework of Canada's Ocean Protection Program (OPP), a 5-year research program was recently launched to assess the effect of shipping noise on the endangered St. Lawrence estuary beluga (SLEB). This program aims at increasing knowledge on three levels: the spatial and temporal distributions of shipping noise (1) and SLEB (2), as well as the overlap (3) of these two levels, i.e. the exposure and effects of noise on the SLEB.

To increase knowledge on these three levels of inquiry, several observational activities have been realized and others will be conducted in coming years. During the Summer of 2018, a network of 10 PAM moorings will be deployed within the St. Lawrence estuary, in an attempt to optimize year-round coverage of shipping noise and beluga uses within the SLEB habitat. The two-hydrophone arrays will be moored either using bottom-mounted landers or "I"-type moorings, one of which equipped with three hydrophones and configured following ANSI 512-64-2009 standards to measure ship source levels.
Drifting vertical arrays will also be used in combination with acoustic tags on belugas to evaluate behavioural effects and the exposure of the tagged animals to shipping noise. Finally, aerial surveys will be conducted to complement data on beluga seasonal distribution and movements in SLE and exposure to noise.

In addition to measurements, important modelling efforts are being conducted, such as probabilistic acoustic simulations of shipping noise from year-round traffic data for present conditions and various future scenarios. These modelling efforts will be validated with the above year-round measurements from the 10-station PAM network.

In this presentation, we introduce this intensive large-scale project along with the planned observational and modelling activities. We highlight the several opportunities allowed by the new observational network and give an overview of accomplishments to date, preliminary results and expected outcomes.

Introducing DeteClic: a user-friendly and comprehensive automated click detector to monitor odontocetes

Fabio Cassiano[1], Juliette Biquet[1,2], Angélique Drémeau[1], Christophe Guinet[2], Gaëtan Richard[1,2], and Flore Samaran[1]

[1] Laboratoire Lab-STICC (UMR 6285, ENSTA Bretagne)
[2] Laboratoire UMR CEBC (Chizé)

Passive acoustic monitoring is now intensively used to study cetaceans. Given the growing amount of collected data, it is of interest to implement automatic methods to monitor cetaceans' sounds. In that aim, we developed DeteClic, a transparent and user-friendly odontocetes click detector on Matlab. This detector takes the form of an intuitive interface to analyze pulsed and loud acoustic signals. DeteClic can be used along the entire bioacoustics analyzing process, from the display of graphic representations to the click detection and their understanding. Our detector allows for (i) manual labeling, based on both listening and visualization, and (ii) automatic detection. DeteClic includes 4 different automatic click detection approaches: (i) a Teager-Kaiser energy operator [1], (ii) an intercorrelation computation with a given reference signal, (iii) a spectrogram analysis [2], and (iv) a kurtosis-based statistical detection [3]. Combining the results of these 4 methods enhances the automatic detection robustness. To assess its performances, we equipped DeteClic with an evaluation tool, relying on automatic comparison of manually- and automatically-detected clicks. DeteClic can therefore be used to compare the results of the methods (i.e. recall and precision rates [4]) depending on acoustic environments and recordings. In addition to the clicks detection and based on how the user defines a train of clicks (using criteria in time between clicks and train duration [5]), DeteClic enables a presence event analysis. Finally, we provide a series of outputs easily reusable for any further statistical or visual analysis. We first tested DeteClic on sperm whale clicks, recorded during longline fishing campaigns around the Kerguelen Islands (southern Indian Ocean). Considering clicks detected by at least three methods was the most efficient approach (average recall of 71±5% and precision of 54±5%). Discriminating click trains allowed for a greater precision in detecting echolocation events and an accurate presence event analysis.

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Monitoring of the distribution of sperm whales using PAM gliders

Pierre Cauchy[1], Karen Heywood[1], Denise Risch[2], Nathan Merchant[3], and Bastien Queste[1]

[1] University of East Anglia
[2] Scottish Association for Marine Science
[3] Center for Environment, Fisheries and Aquaculture Science

Passive acoustic measurements from gliders are in their infancy but highly promising. New methods developed for moorings or drifting platforms can be adapted for gliders. The long range, low cost, high-resolution and multidisciplinary capabilities of a glider, together with processing and transmitting of Passive Acoustic Monitoring (PAM) sensor data in real time, will revolutionise the way acoustic data are applied both scientifically and commercially. Demonstrating the ability to use glider for joint marine biology and physical oceanography purposes will increase experiments opportunities, and allow to map cetacean behaviour to oceanographic features of interest (blooms, krill swarms).
We have been deploying PAM gliders for 5 years, recording underwater ambient noise in the Mediterranean Sea, the North Atlantic Ocean and the Southern Ocean. The analysis of the recorded ambient noise led to the detection of whistles and echolocation clicks, from various species (sperm whales, long-finned pilot whales, dolphins). Our Mediterranean dataset consists of 5 glider deployments, from December 2012 to April 2013 and in June 2014, in the Gulf of Lion, the Ligurian Sea, and the Algerian basin. We focused on detecting sperm whale regular clicks, using PAMGuard and Matlab for manual processing.
We discuss automatic data processing, sampling strategies (duty cycle, glider deployment and ploting), and assess the ability to successfully monitor the distribution of sperm whales in the NW Mediterranean Sea using PAM sensors mounted on the existing glider observing transects (moose-network.fr)

Bi-class classification of humpback whale sound units against complex background noise with Deep Convolution Neural Network

Dorian Cazau[1], Riwal Lefort[1], Julien Bonnel[1], Julien Krywyk[2], Paul Nguyen Hong Duc[3] and Olivier Adam[3,4]

[1] ENSTA Bretagne, Lab-STICC UMR CNRS 6285, Brest, France
[2] logiCells, Paris, France
[3] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France
[4] Institute of Neurosciences Paris-Saclay, Bioacoustics Team, CNRS UMR 9197, Université Paris Sud, Orsay, France

Automatically detecting sound units of humpback whales in complex time-varying background noises is a current challenge for scientists. In this paper, we explore the applicability of Convolution Neural Network (CNN) method for this task. In the evaluation stage, we present 6 bi-class classification experimentations of whale sound detection against different synthetic underwater soundscapes. These soundscapes have been built additively using real-world background noises of different natures, including rain, wind and passing boats. In comparison to classical FFT-based representation like spectrograms, we showed that the use of image-based pre-trained CNN features brought higher performance to classify whale sounds and background noise.

An automatic method for a detection of blue whale calls

Alejandro Cuevas, Alejandro Veragua, Sonia Español-Jiménez, Angelo Falchetti, Gustavo Chiang, Felipe Tobar

Dpt. Of Electrical Engineering, Universidad de Chile
MERI Foundation
Center for Mathematical Modeling, Universidad de Chile

Marine mammals produce distinctive sounds, either as part of social display or as an aid in navigation and foraging. In the case of blue whales (Balaeonoptera musculus), these acoustic signals are detectable at longer distances. Similarities and dissimilarities in blue whale songs can answer questions regarding stock provenance, population structure, seasonal distribution, patterns migration or behaviour. Blue whale songs detected in Chile have a pattern sequence that repeat themselves in large time periods. These songs were represented by 20-dimensional features corresponding to their mel frequency ceptrum coefficients, with the aim to develop an automatic method for isolating the blue whale calls. These features were then grouped via a Gaussian mixture model with a Dirichlet prior over the number of clusters. The segmentation proposed was then validated by a bio-acoustic expert. The proposed method was able to discriminate between different types of submarine recordings and that, critically, one of them is a blue-whale call. We obtained a performance of at least 85%, and we are focused on improving the performance of the proposed methodology in order to better understand blue whale behavioral patterns.

Humpback whale song theme recognition tool

Divna Djokic[2], Julie Patris[1,4,5,6], Franck Malige[1,4,5,6], Renata Sousa Lima[2], and Hervé Glotin[1,4,5,6]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] Laboratory of Bioacoustics,Physiology & Behavior, U. Fed. Rio Grande Norte, Natal, Brazil
[3] Graduate Program of Psychobiology, Biosciences Center, UFRN, Natal, Brazil
[4] BRILAM, STIC AmSud ; 5 : EADM GDRS CNRS MADICS, France ; 6 : SABIOD.org

Humpback whale sounds are highly structured [1]. The patterns are usually characterized as units, phrases, themes and songs. In order to verify if any hierarchical pattern within the song structure is visualized using a semi-automated tool, a human expert translated the recordings into a series of units coded by letters without any other input.

Based on these strings of letters, we present the Levenshtein-distance [2] matrix as a tool to visualise the biggest structures (songs and themes) in a given recording avoiding an additional bias on the boundaries of the hierarchical levels within a single continuous recording.

This tool has proved possible to automatically extract both songs and themes from a recording. This unsupervised classification is a complement to previous Hierarchical Dirichlet Process Hidden Markov Model [3], and will be used to compare themes and their evolution within and between localities.

Wav samples are available at : http://sabiod.org/workspace/BombyxUTLN_ChanaralChili/

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Cachalot ultra high frequency near field multichannel analysis

M. Ferrari[1,2,4,5], R. Marxer[1,4,5], V. Roger[1,4,5], V. Gies[8,4,5], F. Sarano[3,5], M. Asch[2,4,5], H. Vitry[6], A. Preud'homme[6], R. Heuzey[7], V. Sarano[3,5], and H. Glotin [1,4,5]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France ;
[2] Université de Picardie, CNRS, LAMFA, Amiens, France ; [3] Longitude 181, ONG, France
[4] EADM GDR CNRS MADICS, France ; [5] SABIOD.org ; [6] Marine Megafauna Conservation Organisation, Mauritius ; [7] Un océan de vie, ONG, France

Due to their large size and long dives sperm whales are difficult to study in controlled conditions. The production of their vocalisations remains less understood than that of other smaller cetaceans such as dolphins. While anatomic descriptions have been performed via dissections, functional aspects and mechanisms involved are still unclear. We study their acoustic production through data-driven techniques on multichannel near-field audio-visual recordings. Under the authority of Marine Megafauna Conservation Organisation and, as part of the global program Maubydick, a team led by François Sarano has been conducting a longitudinal study on the same group of 27 sperm whales since 2013. The main goal is to understand the relationship between individuals inside the family group and the dynamic of the mauritian population. The main originality is that the data (behavioural, acoustic, genetic) are collected underwater by scientists and cameran who are fully accepted by sperm whales and could record and film their most intimate behaviour (as suckling, sleeping, playing) without disturbing them. In 2017 and 2018 the team has collected a set of audio-visual recordings using the custom antenna of Univ Toulon [3] to record the animals in near field. Audio was captured at 600kHz SR with 2 or 3 hydrophones of 100kHz to 300kHz bandwidth [3,4], 65cm apart, while video was recorded by a GoPro. The procedure has resulted in several hours of data containing clicks, codas and creaks. Two main studies are in progress: i) characterisation of the vocalisation directionality by multi-modal analysis; and ii) an exploration of meaningful information contained in clicks. The Direction of Arrival (DOA) is characterised using Generalized Cross-Correlation (GCC) beamforming with adaptive time-frequency weighting and pooling [1]. DOAs are crossed with the animal positions obtained from the video by a simple tracking algorithm. In the second study clicks are extracted and their DOA estimated. Deep learning is employed to analyse fundamental aspects of the clicks, such as the individual producing it or the vocalisation type. Two paradigms are used: autoencoders (AEs) and siamese-nets [2]. AEs work by reducing the signals to a few characteristics while allowing their reconstruction. Siamese-nets are trained to maintain small distances between representations of clicks belonging to a given group, and large distances with others.We group together clicks coming from the same direction at similar times. The obtained representations are visualised in search of interesting invariants like individual signatures.

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Acoustic Presence of True's Beaked Whale in Eastern Atlantic Ocean, Southwest of Portugal?

Odile Gerard

DGA Naval Systems, Toulon, France

Beaked whale are the most sensible species to noise. Strandings have been reported to occur in conjunction with sonar exercises, although the exact mechanism is unclear. For this reason, automatic detection and classification of these species is very important.

Despite an important research effort, the signals of some beaked whale species remain unknown. Until now, most known beaked whale produce upsweep frequency modulated clicks which seem species specific. The inter-click interval seems to be regular and is a characteristic that helps classification.

In October 2017, at the Society of Marine Mammalogy Conference, AnnaMaria Izzi presented the first description of True's beaked whale clicks recorded in the Western North Atlantic. This species was the last known beaked whale species in the North Atlantic Ocean for which there were no published acoustic records. True's clicks are similar to Gervais', but with some higher frequency characteristics.

The Centre for Maritime research and experimentation (CMRE) conducted a sea trial in Eastern Atlantic Ocean, Southwest of Portugal. Analysis on this dataset has been presented at the 5th edition of DCLDE. Given Anamaria Izzi's new findings, further analysis of this dataset confirms the presence of True's beaked whales in this area. Additional characteristics of these clicks are presented, based on frequency and ICI.

Qualilife-JASON 1 MHz SR Multichannel Recorder, Luxmeter and Low Power Wake-up Detector

V. Gies[1,3,4,5,6], V. Barchasz[1,3,4,5,6], M. Fourniol[1,3,4,5,6], and H. Glotin[2,3,4,5,6]

[1] Université de Toulon, Aix Marseille Univ, ISEN, CNRS, IM2NP - UMR 7334, 83000 Toulon, France
[2] Université de Toulon, Aix Marseille Univ, CNRS, LIS, Dyni team, Marseille, France
[3] Université de Toulon, Plateforme technologique SMIoT, smiot.univ-tln.fr, 83000 Toulon, France
[4] BRILAM STICAmSud ; [5] EADM MADICS CNRS, France ; [6] SABIOD.org

Advanced environmental monitoring requires to record efficiently high frequency acoustic signals occurring at a random time. If used for localization, it requires to couple several microphones together with a high precision. In this paper, we introduce a new recorder named JASON-QUALILIFE, with advanced specifications.
This recorder can manage 5 data channels, each one having a maximum sampling rate of 800 kHz to 2 MHz depending on the number of channels used. Its 16 bits channels feature each one a seventh order anti-aliasing filter, and an adjustable analog gain for a large range of use. Furthermore, analog filtering can be also set-up on each channel of this recorder depending on user specifications. In order to reduce power consumption and achieve long term advanced recording, we also introduce Qualilife Wake-Up Detector [1], an extension board used for detecting instants when signal having a specific frequency is present on the environment, and triggering the recorder. This allows to reduce power consumption, data storage saturation, and useless post-processing work to rise alarms or to find out interesting target events.
Following the emerging idea of using edge computing techniques, this wake-up detector performs locally an early pre-filtering stage, allowing to use a very high sampling rate multichannel recording system, usually consuming an important amount of energy for long term recording. Moreover, we developed and integrated a high dynamic luxmeter (working from sun zenith to lunar eclipse), synchronized with the sound recorder. It has been efficiently used in Amazon, Med. sea and Indian Ocean over last years [2,3].
These coupled systems open avenues for advanced recording and analysis of environmental submarine acoustic signal.

We thank UTN, INPS UTLN Pôle for its support, http//smiot.univ-tln.fr, http://sabiod.org/smiot

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Acoustic signalling predicts surface behaviour in common bottlenose dolphins (*Tursiops truncatus*)

Gridley, T.[1,2], Badenas Krakauer, A.[2, 3], James, B.S.[2], and Elwen S.H.[2]

[1] Centre for Statistics in Ecology, Environment and Conservation, Department of Statistical Sciences, University of Cape Town, South Africa. C/O Sea Search Research and Conservation NPC, 4 Bath Road, Muizenberg, Cape Town, 7945, South Africa.
[2] Sea Search Research and Conservation NPC, 4 Bath Road, Muizenberg, Cape Town, 7945, South Africa.
[3] Ghent University, Marine Biology Section, Ghent Belgium
[4] Mammal Research Institute, Department of Zoology and Entomology, University of Pretoria, Private Bag X20, Hatfield 0028, Gauteng, South Africa. C/O Sea Search Research and Conservation NPC, 4 Bath Road, Muizenberg, Cape Town, 7945, South Africa.

The repertoire of sounds used by highly social animals can be diverse. Although sounds can be adventitious, many serve a distinct function such as the acoustic signals utilized in communication or prey manipulation. Understanding the link between acoustic signaling and animal behaviour may provide useful information on habitat utilization within a population's range. Our overall aim is to develop models which can reliably predict group behaviour of bottlenose dolphins from acoustic data collected from static passive acoustic devices which monitor acoustic activity 24 hrs per day. Ideally models would operate on acoustic data only, without auxiliary group information. Here we used a supervised learning approach, i.e. Random Forrest Classification, to predict bottlenose dolphin behaviour from ground-truthed data collected when both group surface behaviour and acoustic behaviour were documented. Acoustic data were collected at 3 minute samples from freely interacting groups of common bottlenose dolphin (Tursiops truncatus) inhabiting Walvis Bay, Namibia. Dolphins were recorded during focal group follows under different behavioural contexts and social grouping dynamics (n = 373 samples from n = 63 encounters). Classification was conducted using the presence or absence of 7 acoustic signals which represent the vocal repertoire of this population and the overall repertoire richness during the sample as predictor variables. An overall out-of-sample correct classification rate of 59% was achieved, a 44% improvement over a random classification. Correct classification rates varied by behaviour, performing well for predicting socialising behaviour but poorly for travelling. The addition of group size information slightly improved classification success (overall classification success 65%, 52 % better than random). Further development of this method would enable predictions of group behaviour in the absence of visual data, allowing inference of habitat use from static passive acoustic devices. Such information can assist in decision making within a marine spatial planning process.

Sound Source Separation of Overlapping Signals through High-resolution Beamforming

Abel Ho[1], Matthias Hoffmann-Kuhnt[1], Mandar A. Chitre[1], and Denise L. Herzing[2]

[1] Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore.
[2] Wild Dolphin Project & Florida Atlantic University

Underwater acoustic recording with large pods of wild dolphins often produces recordings with multiple vocalizations from different dolphins. This presents the challenge to isolate the signal from each sound source and analyse them independently when the vocalizations are happening at the same time. Echolocation clicks are generally easier to separate as they have a very short duration and therefore overlap less frequently. One of the major issues was to separate a much quieter long duration tonal whistle that was overlapped by multiple high amplitude broadband clicks. This caused an overlap in both time and frequency during the duration of each click. When multiple dolphins are whistling at the same time, it is also hard to distinguish which whistle is coming from which animal because of overlapping in time and occasionally overlapping in frequency as well. A portable integrated video and 3-hydrophone array large bandwidth(0.1kHz~160kHz) acoustic recording has been developed to acquire synchronized video and acoustic recording in field. Recordings with this device in Bahamas waters were analysed to identify the vocalizing animal. Using the 3-hydrophone array, high resolution frequency domain beamforming using a ray model approach was used to solve for the sound source coming from each direction. Simulations and actual field recording results will be presented. The final isolated sound signals could then be used for further processing including detection and classification with much higher performance.

Who is vocalizing? an innovative detection-localization system to study dolphins communications and social behaviors

Juliana Lopez Marulanda[1], Yann Doh[1,4], Fabienne Delfour[2,3], Torea Blanchard[1,2], Bertrand Denis[4], Isabelle Klein[4], and Olivier Adam[1,5]

[1] Institut des Neurosciences Paris Saclay, CNRS UMR 9197, Université Paris Sud, Orsay, France
[2] Laboratoire d'Ethologie Expérimentale et Comparée E.A. 4443 (LEEC), Université Paris 13, Sorbonne Paris Cité, F-93430 Villetaneuse, France
[3] Parc Asterix, France
[4] Association Abyss, 1 rue du quai Berthier 97420 La Réunion, France
[5] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France

Bottlenose dolphins are highly social cetaceans that strongly rely on acoustic production. The diversity of sounds has been structurally classified in whistles, clicks and burst-pulsed sounds, with some whistles called "signature whistles" that are used as cohesion calls. Dolphins' social behavior and communication studies need to link visual events and soundscape. As dolphins do not display any external cues when producing a sound, identifying who is emitting cannot be done by a human operator. Thus, our team developed a novel deployable audio-video device called "BaBeL", equipped with a 360° camera and an array of 4 synchronised hydrophones. A software has been designed to achieve 3D sound source localizations from TDOAs and replace dolphin estimated positions on the video frames. The system has been tested with dolphins in natural environment and also in captivity. The poster presents the successive versions of BaBel, the results we already obtained and also next design improvements.

Acoustical analyses of submarine explosions in northern Chile on long term continuous recordings

Franck Malige[1,5,6,7], Julie Patris[1,5,6,7], Susannah Buchan[2,3,4,5,7], and Hervé Glotin[1,5,6,7]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] COPAS Sur-Austral, University of Concepción, Chile
[3] Centro de Estudios Avanzados en Zonas Áridas, Chile
[4] Woods Hole Oceanographic Institution, USA
[5] BRILAM, STIC AmSud ; [6] EADM GDRS CNRS MADICS, France ; [7] SABIOD.org

Near Chañaral marine reserve in northern Chile, passive acoustic data were continuously collected by the installation "Bombyx II" during the austral summer of 2016/2017, during three periods of two weeks in January and February.

Recording were made using a Sony M10, with a sample rate of 48 kHz, 24 bits, and a C57 CRT hydrophone. They are deployed using a OSEAN SA submarine tube at -25m depth.

The continuity of this monitoring enabled us to record around thirty loud explosions, most of them saturating the record. We did an analysis of the type of explosions (aerial, terrestrial or submarine). Their charge weight and location was performed [1,2].

The results of this analysis point towards underwater low power explosions few kilometers away from the recording device, highly compatible with fish bombing. We think this kind of analysis could be useful for researchers and marine protected area managers throughout the world. It would be integrated into the automatic low power trigger Qualilife-JASON [3] for automatic Real Time Alert system.

Recording samples used in this communication (.wav 48 kHz SR) are available at http://sabiod.org/workspace/BombyxUTLN_ChanaralChili

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Dynimax : a browser to stretch, to scrub and to visualize bioacoustical structures

Maxence Mercier[1,5], Joseph Razik[2,3,4,5], Yann Doh[6,4,5], Sébastien Paris[2,3,4,5], Maia Hoeberechts[8,5], Vincent Roger[2,4,5,7], and Hervé Glotin[2,3,4,5]

[1] TRIPINLAB.com ; [2] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France ; [3] BRILAM, STIC AmSud ; [4] EADM GDRS CNRS MADICS, France
[5] SABIOD.org ; [6] DIRAC ONG : [7] NortekMed, France;
[8] Ocean Network Canada, Victoria Univ. Vancouver, Canada

Dynimax is an interface (Mercier 2018) for quick navigation to stretch, to scrub and to visualize the structure of bioacoustical data, e.g. the songs of humpback whale. A first tool allows the user full control over the playback head of an audio player with various real-time audio playback techniques. It also allows a time stretching to play sound at a free speed without changing the pitch. A scrubbing function based on a vocoder (Roebel 2003) allows the user to freely control a read head at a free speed without changing the step, with real-time sonogram. This is a convenient way to quickly navigate through large data set and or, high speed audio recording. It is a valuable tool for extremely slow speed reading, particularly useful for micro-sound analysis. The user can then control the playback speed and freeze the sound. If these techniques are common in music software, they are here adapted for bioacoustic, with high quality resampling and resynthesis to allow extreme stretching over time with less artifact.
A second tool, called "Circular score", proposed in Mercier 2015, aims to highlight the temporal structure of a sequence, depicting the links between similar tuples (Ngrams). In this bioacoustical version, the circular score displays consecutive Ngrams in the form of a sequence of curves linking consecutive instances of a Ngram. The demonstration is given on humpback whale song, where the matrix contains the units learned from unsupervised IHMM decomposition (Bartcus 2015). This matrix could be alternatively issued from sparse coding (Razik 2015 & 2016). We see that each curve connects two identical tuples of song units. The resulting circular score illustrates the structure of the main sequence at the chosen subsequence scale. It shows the connection between sections that are easier to organize visually compared to a linear layout, thus it is adapted to visualize long sequence. This representation is useful for quick multiscale inspection and comparison of songs. For this purpose a multistream version of Dynimax is being distributed.

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Using Deep Learning methods to classify marine mammals

Paul Nguyen Hong Duc[1], Kristelle Le Cam[2], Aurélie Pham[1], Charles Vanwynsberghe[3], Flore Samaran[3], Dorian Cazau[3], Odile Gérard[4], Paul White[5] and Olivier Adam[1,6]

[1] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France
[2] Ecole Centrale de Lyon, France
[3] ENSTA Bretagne, Labsticc, France
[4] DGA-MRIS, France
[5] Institute of Sound and Vibration Research, University of Southampton, UK
[6] Institute of Neurosciences Paris-Saclay, Bioacoustics Team, CNRS UMR 9197, Université Paris Sud, Orsay, France

The study of the underwater acoustic events is crucial to monitor the ocean. Detecting and identifying marine mammals in recordings is a challenging task as it may be long and non-reliable if made by visually and aurally inspections by an expert. With the renewed interest of Artificial Intelligence (AI), new methods can be set up to detect and identify underwater acoustic events. In this poster, we compare two different approaches to classify underwater sounds. The first one is a convolutional neural network that categorizes all the sounds at once. The second method is based on two stages and different neural models: species are first differentiated and then calls inside species are classified. Results show slight improvements with the second approach depending on classes. However, the second approach is more modular as a particular model can be used to discriminate sounds inside species.

The 3-D-V Array: A volumetric, digital towed hydrophone array system capable of bearing and location estimation in 3-D space

Tom Norris[1], Gerald D'Spain[2], Douglas Gillespie[3] Mike Oswald[1] and Elizabeth Ferguson[1]

[1] Bio-waves Inc., 1106 2nd St. #119, Encinitas, CA U.S.A.
[2] Scripps Institution of Oceanography, La Jolla, CA U.S.A.
[3] University of St Andrews, St. Andrews, Scotland, U.K.

Real-time passive acoustic monitoring of marine mammals for mitigation requirements and boat-based surveys is typically conducted using a linear towed hydrophone array system. However. most linear towed array systems have limitations which preclude them from determining the vertical component of bearings (e.g. slant angles) to marine mammal sound sources. We are developing and testing a new, 3-D towed hydrophone array system (called the 3-D-V array) that will be capable of using both time-of-arrival-differences (TOAD) and beamforming methods to estimate bearings in three dimensions, for the ultimate goal of localizing marine mammals in three dimensional space. The main objectives of this project are to design, develop and test a fully digital, volumetric, towed hydrophone array system capable of real-time monitoring of marine mammals for mitigation purposes. This system uses beamforming, TOAD, angle-of-arrival, detection and localization algorithms that are fully integrated in PAMGuard as modules, for detecting and localizing bioacoustic signals from marine mammals. We overview hardware and software developments, and present results of preliminary bench and field test of this new system. Plans will be presented for testing in fall 2018 on the seismic vessel R/V Langseth operated by Columbia University's Lamont-Doherty Earth Observatory.

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Year-round acoustic patterns of bottlenose dolphins and interaction with anthropogenic activities in the Sicily Channel, Central Mediterranean Sea

Papale, E.[1], Alonge G.[2], Grammauta R.[1], Ceraulo M.[1], Mazzola S.[1], and Buscaino G.[1]

[1] BioacousticsLab, IAMC Capo Granitola, National Research Council, Via del Mare 3, 91021 Torretta Granitola (TP), Italy
[2] SSPT-PROTER-OAC ENEA, Via Principe di Granatelli, 24, 90139 Palermo, Italy

The Sicily Channel is one of the most severely impacted areas of the Mediterranean Sea by fishing activity and shipping traffic (Lloyds 2008). As part of a long-term program for monitoring the anthropogenic effects on marine species, we acoustically evaluated the year-round presence and activity of bottlenose dolphins, and the effects of boat occurrence and noise levels. A hydrophone was deployed on an elastic beacon at three miles from the coast, in the North Western side, where the Channel creates a bottleneck. We continuously recorded for 14 months, from January 2015. Recordings were processed for analyzing daily and seasonal patterns in dolphin vocal activity. Results revealed a regular year-round acoustic presence of dolphins, with a clear diel cycle and seasonal variability for click emission rate. An increase during night time, and a peak from April to August, an abrupt decrease in September and a peak again in November were recorded. Furthermore, we estimated the anthropogenic impact by using vessel data from the Automatic Identification System and acoustic levels at one-third octave bands centered at 63, 125 and 250 Hz. Generalized Linear Mixed Models indicated that click emission rate decreased with noise levels but not in relation to boats and fishing vessels permanence frequency. Distinguishing click types in single clicks, click trains, packed clicks and burst pulses (Buscaino et al 2015), we found that dolphins change their acoustic behavioral activity by increasing feeding patterns during mid-morning, concurrently with a peak in fishing vessels permanence frequency. These results can help inform conservation efforts and the development of monitoring programs under the EU Marine Strategy Framework Directive in this key area for coastal dolphins.

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Ethoacoustics: a new model based on t-SNE & clustering - applications on Pantropical spotted dolphin during whale watching

Marion Poupard[1,2,3,4,6], Benjamin de Montgolfier[2,3,4], Vincent Roger[1,3,4,5], Devashish Lohani[1,3,4], and Hervé Glotin[1,3,4]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] Aquasearch, Sainte-Luce, Martinique, France
[3] EADM GDR CNRS MADICS, France ; [4] SABIOD.org ;
[5] NortekMed SA, France ; [6] Biosong SA, France

Marine mammals communicate among themselves through sounds, but it is complicated to study and characterise their emissions [1]. Our study focus on Pantropical Spotted dolphin (Stenella attenuata, Sa), in particular on the influence of nautical tourism in the Caribbean Sea on dolphins communication [2,3].
The objective is to identify possible correlations between the behaviors of Sa with the shape of their whistles, a framework that we named “ethoacoustics”. Therefore, we have proposed an automatic time-frequency tracking of the whistles, that has been validated manually [3]. Then, we used two different methods to reduce the dimension of the extracted acoustic patterns : ACP (linear projection) and t-SNE (non linear projection [3]). Finally, we clustered the data and measure the Normalized Mutual Information (NMI) between the behaviors or conditions, and the acoustic patterns.
This method is effective because different clusters were automatically identified with high NMI from the t-SNE representation. The main conclusion is that Sa dolphins are not communicating in the same manner when they are observed by whales-watchers or during the socialisation [3,4]. Thus, acoustic survey is a reliable non-intrusive way to characterize the form cetacean communication depending on anthropic pressure [1]. This efficient method could be used as a set up for acoustic survey in future projects.

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Supplemental material @ http://sabiod.org/workspace/dclde_ethoacoustics

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Bone conducted sound in a dolphins' mandible: Experimental investigation of elastic waves mediating information on source localization

Michael Reinwald[1], Quentin Grimal1, Jacques Marchal[2], Lapo Boschi[2]

[1] Sorbonne Université, CNRS, INSERM, Laboratoire d'Imagerie Biomédicale, LIB, F-75006, Paris, France.
[2] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, F-78210, St-Cyr, France.
[3] Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre Paris, ISTeP UMR 7193, F-75005, Paris, France.

Mammals use binaural or monaural (spectral) cues to localize acoustic sources [1]. While the sensitivity of terrestrial mammals to changes in source elevation is relatively poor, the source-localization accuracy achieved by the odontocete cetaceans' biosonar is high, independently of where the source is [2]. Binaural/spectral cues are unlikely to account for this remarkable skill. We investigate bone-conducted sound in a short-beaked common dolphin's mandible and attempt to determine whether and to what extent it could contribute to the task of localizing a sound source. Experiments are conducted in a water tank by deploying, on the horizontal and median planes of the skull, sound sources that emit synthetic clicks between 45 and 55~kHz. Elastic waves propagating through the mandible are measured at the pan bones and used to localize source positions via binaural/spectral cues, as well as a correlation-based full-waveform algorithm [3]. We find that by making use of the full waveforms, and, most importantly, of their reverberated coda, the accuracy of source localization in the vertical plane can be enhanced. While further experimental work is needed to substantiate this speculation, our results suggest that the auditory system of dolphins might be able to localize sound sources by analyzing the coda of biosonar echoes.

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Long term Cachalot & Noise monitoring on Stereo sonobuoy Bombyx

Ricard J.[1,3,6], Glotin H.[1,3,6], Ferrari M.[1,3,6], Giraudet P.[1,3,6], Roger V.[1,3,7], Pavan G.[3,4,6], Prévot J.-M.[3,5,6], Philippe O.[3,6,8], Fayet F.[3,6,8], and Marxer R.[1,3,6]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] Université de Picardie, CNRS, LAMFA, Amiens, France
[3] EADM GDR CNRS MADICS, France ; [4] CIBRA, Univ Pavia, Italy
[5] Computer Science dpt, univ Toulon, France ; [6] SABIOD.org ; [7] NortekMed, France ; [8] Osean SA, France

Monitoring the different species of marine mammals in the wild is a necessary step to study the dynamics of their populations and to better understand their behaviors and how the human activities impact them. Because the *Physeter m.* produces a large amount of characteristic and high-intensity acoustic impulses, called clicks, to scan its environment and, probably, to communicate, and because the sound propagation properties in water allow to detect these sounds from a relatively large distance, acoustic signals provide a good proxy to perform this task.
We describe here several experiments exploiting the data extracted by DyniClick [1] a toolbox we are developing for click detection, analysis and tracking, from the audio data recorded on Bombyx [2], a platform dedicated to the collection of acoustic and oceanographic underwater data and located near the Port-Cros National Parc, in the Pelagos international cetacean sanctuary.
The resulting data consists in a set of timestamped clicks along with their estimated location (azimuth), and some acoustic features, including rough Inter-Pulse Interval (IPI) and ambient noise level. In particular, the density of clicks has been used to estimate the activity of the whales at different time scales (hour, day, week…). Moreover, the estimated locations of the clicks tracked over time, has been used to estimate the number of individuals and their direction. Further analysis of this data, combined with the measured noise level, opens possibilities to gain insights on the whale behaviors and the impact of anthropic activities.

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AutoEncoder for Marine Mammal Bioacoustics

Vincent Roger[1,2,3,4], Maxence Ferrari[1,2,3] , Faicel Chamroukhi[5,2,3], Ricard Marxer[1,2,3], and Hervé Glotin[1,2,3]

[1] Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI team, Marseille, France
[2] EADM MADICS CNRS, France
[3] SABIOD.org
[4] NortekMED SA, France
[5] Université de Caen, CNRS, LMNO, Caen, France

Marine mammals are present in every sea of the world and are at the highest level of the marine food chain. But our knowledge on them is limited and we know less than the other species among the earth. To help the expert in getting more informations, we develop a model to analyze audio signals by clustering its different composants. The goal is to learn the features and the representation adapted for cetacean sound dynamics without any priors.

Our study consists of learning representation and features of sperm whale and Humpback whale, using neural network from raw audio. We are learning autoencoder to encode the signal via different type of convolutions (causal, with strides, with dilation [1]). To define the decoder we also use gradient inversion [2] to compare to classical decoders.

The resulting encodings of the representation of the transients and the stationary calls from nips4b challenge [3], are discussed and analysed using classic representation techniques like PCA or tSNE, and compared to other methods [4]. Furthermore, we detail the resulting filters. These models should help to design new topologies for the signal processing of other cetacean species. A perspective is given towards stereo autoencoders.

We acknowledge Region PACA and NortekMED for Roger's Phd, & DGA and Région Haut de France for Ferrari's Phd grant

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Automated burst pulse detection using Pamguard Whistle & Moan Detectors

Taiki Sakai[1], Shannon Rankin[2], and Douglas Gillespie[3]

[1] Lynker Technnologies
[1,2] Southwest Fisheries Science Center, NMFS/NOAA
[3] Sea Mammal Research Unit, University of St. Andrews, Scotland

Burst pulses have long been neglected in bio-acoustics research, yet have shown great potential to increase correct classification of some odontocete species. Automated detection of clicks within a burst pulse train is hampered by the short duration of clicks and the short interclick interval. Spectrograms may give a banded tonal appearance to burst pulses which can be detected using tonal spectrogram detectors. A recent study successfully applied Pamguard's automated whistle and moan (WM) detector to extract burst pulses for for dolphin species classification using the BANTER algorithm. In this study we quantify variation in detection of burst pulses with different WM settings and identify settings that maximize detection of burst pulses. Detectors are tested on synthesized burst pulses and recordings from a wide variety of odontocete species. Separate configurations to optimize detection of short, high frequency burst pulses (small odontocetes) and long duration, low-frequency burst pulses (large odontocetes, 'blackfish') are considered, as well as alternative methods based on cepstral analysis. Results will inform burst pulse detectors for an open-source version of the BANTER acoustic classifier currently under development.

Using acoustic glider to explore seamont in western Indian Ocean and looking for baleen whales

Flore Samaran, Julie Beesau, Adrien Berne, and Dorian Cazau

ENSTA Bretagne, UMR CNRS 6285 Lab-STICC, Brest, France

The project Gilder and Whales aims to demonstrate the opportunity provided by the glider technology to monitor de biodiversity and especially cetacean species in their environment. This innovative and non-invasive technology will allow to study marine mammals using the sounds they produce through 3 missions into 2 different oceans. Today, most passive acoustic monitoring observatories are moored in proximity of lands, either in permanent or temporary configuration. Very few pelagic observatories exist, because of the cost of their installation in time and money. Thus, fixed stations for passive acoustic observations do not cover all cetacean habitats in particular whale habitats due to their wide spatial distribution and mobility. Here, the use of mobile and self-logging platform as the glider is an accurate alternative. This mobile and autonomous devices can move toward places of interest in remote area to record sounds produce by cetaceans. The new french glider SEA EXPLORER (ALSEAMAR) will be used in this project. The glider is equipped with one hydrophone and different sensors for positioning, data transmission/réception and oceanographic data (pressure, temperature, light) to describe the oceanographic habitat in which the detected animals live. The autonomy of the glider is approximately 750 km for a travel period of one month. It moves at a speed of 0.5 knots, which is slow enough to ensure a good listening quality. In May 2017, the glider SEAEXPLORER has made its first mission in the south of Madagascar southeast of Walters Shoal. During 10 days, he traveled nearly 200 km and collected numerous recordings of Antarctic blue whales and Madagascar pygmy blue whales as well as fin whale calls. This is the first time that these species have been recorded in this area where access for standard monitoring methods is difficult and costly. We applied standard statistical analyses of long-term acoustic data, reporting here long-term averaged spectrogram and spectral probability density of Sound Pressure Levels. These metrics are examined along with the glider characteristic variables (e.g. depth, speed), as well as environmental variables (e.g. wind, rain, chlorophyll) matched in space and time with glider measurements. This project could attest the capability and the efficiency of the glider technology for cetacean study and conservation.

Preliminary etho-acoustic study of sperm whales' (*Physeter macrocephalus*) codas

Marie Sauvêtre[1], Justine Ngosso Macky[2], Victoire Kuhn[3], Lucie Barluet de Beauchesne[3], Fabienne Delfour[4], François Sarano[5], Véronique Sarano[5], Hugues Vitry[6], Axel Preud'homme[6], René Heuzey[7], and Olivier Adam[2,3]

[1] Gualiba, F-97190 Guadeloupe, France

[2] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, UMR 7190, F-75005 Paris, France

[3] Institut des Neurosciences Paris Saclay CNRS UMR 9197, Université Paris Sud, F-91405 Orsay, France

[4] Laboratoire d'Ethologie Expérimentale et Comparée EA 4443, Université Paris 13, Sorbonne Paris Cité, F-93430 Villetaneuse, France

[5] Longitude 181, F-26000 Valence, France

[6] Marine Megafauna Conservation Organisation, Ile Maurice

[7] Label Bleue Production Marseille

Sperm whale (Physeter macrocephalus, named here SW), the biggest marine mammal of the odontocete family, has a large geographic range and can be seen in nearly all seas around the world. Males are solitary whereas females and juveniles live in stable social units. In these groups, different interactions were reported at the sea surface or sub-surface, including social activities. Among the different types of clicks that SWs can produce, specific click series, called codas, were also recorded. Gero et al. (2016) demonstrated that several North Atlantic SWs share a same coda type, which differs from those emitted by the Caribbean Sea SWs. They hypothesized a cultural transmission through their vocal repertoire. To follow this assumption, we started a scientific project on the study of clicks emitted by SWs' off Mauritius Island (Indian Ocean). Our dataset is made by simultaneous audio and visual observations. In this work, we focused on coda sequences and associated behaviors. Firstly, our results show that codas are mainly used before and during physical contacts. Secondly, coda repertoire from Indian Ocean SWs has longer time structures made by 8 successive clicks and different inter click intervals from those emitted by the Atlantic Ocean and Caribbean Sea SWs, showing a repertoire depending on the geographical location and/or the group.

Gero, S., Whitehead, H., and Rendell, L. (2016). Individual, unit and vocal clan level identity cues in sperm whale codas, R. Soc. open sci. 3: 150372

Catching more than lobsters in traps: Can citizen science be used to protect the North Atlantic right whale?

James A. Theriault[1], Dave Flogeras[1] and Jonathan Underwood[2]

[1] Ocean Environmental Consulting, Halifax, NS;
[2] Fisheries and Oceans Canada, Yarmouth, NS

North Atlantic Right Whales (*Eubalaena glacialis*) (NARW) are one of Canada's endangered species. In 2017, an unprecedented seventeen animals died with twelve animals dying in or near the southern Gulf of St. Lawrence (GoSL). Of the approximately 450 animals that remain, one third were estimated to be in the GoSL; the location of the remaining two thirds of the population remained unknown. Citizen science may be the partial solution to observing the entire population. It can be used to help with knowledge of habitat usage when the possible range NARW is so great. Lobster fisherman (citizen scientists) venture out to tend traps when few others are on the water.

The presentation will provide the preliminary results from a project that has the goal of putting low-cost NARW acoustic detection systems in the hands of the lobster fisherman. A custom lobster trap is used to house an acoustic recorder with an acoustic processing, and telemetry unit. The recorder captures the acoustic time series while the processing subsystem extracts detection using an algorithm based on Baumgartner et al. (2011). The detection data is relayed to a deck unit as the trap is recovered every 24 to 72 hours. The presentation will focus on the architecture, system self-noise, and detector performance.

Using nonlinear time warping to estimate North Pacific Right Whale calling depths in the Bering Sea

Aaron Thode[1], Julien Bonnel[2], Margaux Thieury[2], Aileen Fagan[3], Chris Verlinden[3], Dana Wright[4,5], Catherine Berchok[4], and Jessica Crance[4]

[1] Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA
[2] ENSTA Bretagne, UMR CNRS 6285 Lab-STICC, 2 rue Francois Verny, 29806 Brest Cedex 9, France
[3] United States Coast Guard Academy, New London, CT, USA
[4] Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA, USA
[5] University of Washington, Joint Institute for the Study of Atmosphere and Ocean, Seattle, WA, 98105

Calling depth distributions are estimated for two types of calls produced by critically endangered eastern North Pacific right whales (NPRW) in the Bering Sea, using passive acoustic data collected with bottom-mounted hydrophone recorders. Nonlinear time resampling of 12 NPRW 'upcalls' and 20 'gunshots', recorded in critical NPRW habitat, isolated individual normal mode arrivals from each call. The relative modal arrival times permitted range estimates between 1 and 40 km, while the relative modal amplitudes permitted call depth estimates, provided that environmental inversions were obtained from high signal-to-noise ratio calls. Gunshot sounds were generally only produced at a few meters depth, while upcall depths clustered between 10 and 25 m, consistent with previously published bioacoustic tagging results from North Atlantic right whales. A Wilcoxon rank sum test rejected the null hypothesis that the mean calling depths of the two call types were the same (p= 2.9x10 5); the null hypothesis was still rejected if the sample set was restricted to one call per acoustic encounter (p=0.02). Propagation modeling demonstrates that deeper depths enhance acoustic propagation and that source depth estimates impact both NPRW upcall source level and detection range estimates. We speculate that the ability to infer the relative calling depths of calls (e.g. measure the relative amplitudes of first and second mode arrivals) may provide a feature for classifying species from otherwise ambiguous frequency-modulated calls, such as those produced by humpback, bowhead, and NPRW. (Work sponsored by the North Pacific Research Board)

How the spacing between distributed sensors biases source level distribution and call density estimates, and how to correct for it

Aaron M. Thode[1], Tiago A. Marques[2], Danielle Harris[2], Susanna B. Blackwell[3], Alexander S. Conrad[3], Katherine H. Kim[3], Cornelia S. Oedekoven[2], and Len Thomas[2]

[1] Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA;
[2] Centre for Research into Ecological and Environmental Modelling, University of St Andrews, UK;
[3] Greeneridge Sciences, Inc., Santa Barbara, CA, USA;

A common deployment scheme for passive acoustic localization is the distributed sensor array, where animal positions are obtained either by triangulation or by measuring the relative arrival times between sensors. From these positions one can derive source level distributions and/or call density estimates. A consequence of this technique is that the source levels of the detected calls are not an unbiased sample of the calls produced by the animals, because faint calls not detected (or detected by only one sensor) are excluded. Therefore, estimates of source level distribution are influenced by the sensor separation; the larger the sensor spacing, the more the observed source distribution will be biased toward higher source levels, potentially resulting in biased call density estimates. The choice of sensor separation effectively filters the true underlying source level distribution to produce the observed distribution, which in turn produces the apparent call density, which may not be the actual call density generated by the animals.

Seven years of bowhead whale migration data from several distributed passive acoustic arrays in the Beaufort Sea were used to study various approaches for correcting for these observational biases. All deployments used Directional Autonomous Seafloor Acoustic Recorders (DASARs) and were arranged as triangular grids. Most arrays had 7 km sensor separation, while one had only 2 km separation between DASARs.

An approach is presented for removing biases in source level distributions and call densities. The approach applies point transect theory, using source level-to-noise ratio (SLNR) as a covariate for deriving a set of parameterized detection functions for each array geometry. Applying these sets of detection functions to the observed data then provides an estimate of the true underlying source level distribution and call density (as defined over a span of source levels). The reconstructed source level distributions for both array geometries are compared.

Beaked whales use alternating echolocation regimes at the start of foraging dives

Jennifer S. Trickey, Simone Baumann-Pickering, and John A. Hildebrand

Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0205, USA

Beaked whales are deep-diving marine predators that use frequency-modulated echolocation signals to navigate and forage. The timing of their echolocation clicks while actively searching for prey at depth is generally characterized by a stable inter-click interval (ICI). However, analysis of autonomous, long-term passive acoustic data revealed a markedly different pattern during the vocal portion of their dive descents. At the start of foraging dives, beaked whales were found to alternate between two ICI regimes, in that they adjusted their click rate to simultaneously monitor two different echolocation inspection ranges as they presumably approached their intended foraging depth. One ICI regime potentially corresponds to the two-way-travel time of sound to the seafloor, and by examining the rate at which the time interval between clicks decreased in this seafloor-tracking ICI regime, we calculated estimates of dive descent rate. The second ICI regime was consistently more rapid and represents a shorter search range that is possibly used by the whale to inspect the nearby water column for the presence of prey and other features. This unique biosonar strategy was identified in acoustic encounters of four different species of beaked whales recorded at a variety of sites in the North Pacific Ocean and the Gulf of Mexico. These findings suggest that beaked whale echolocation behavior is not as stereotyped over the course of a foraging dive as previously believed. Given that a vocal cue rate multiplier is necessary for estimates of animal density based on passive acoustic data, this variability in click production rate during foraging dive descents could hold implications for cases in which a passive acoustic density estimation framework is applied to beaked whales.

Automatic Localization of Sperm Whales and Sei Whales during Marine Seismic Survey

Simon Vallez, Stéphane Coatelan, Christophe L'Her

Sercel Brest, F-29200 Brest, France

This poster shall demonstrate the performances and opportunities provided by a Passive Acoustic Monitoring (PAM) system integrated within seismic streamers.

Sercel has developed an integrated passive acoustic marine mammal monitoring system named QuietSeaTM. This system uses seismic channels to monitor the low frequency vocalizations (10Hz to 200Hz) and integrates modules inserted in streamers and below the seismic source to monitor high frequency vocalizations (200 Hz to 96 kHz).

The cetacean detection domain is broad because of the variety of the vocalizations possible and complex because the actual truth is rarely known. We focus in this poster on two case studies: the automatic localization of Sperm whales and Sei whales.

The localization of sperm whales is challenging as sperm whales vocalize while diving hundreds of meters, which makes it difficult to accurately localize in the horizontal plane. We present in this poster the method used to localize in 3D and present some results.

The poster assesses the capability of QuietSea to detect and localize Sei whales which produce downsweep calls that overlap with the seismic bandwidth. A method checking periodically that calls are not hidden by the background noise is presented.

This poster specifically provides analysis of marine mammal monitoring when the PAM system was operated as a primary system.

On the reliability of acoustic annotation and automatic detections of Antarctic blue whale calls under different acoustic conditions

Emmanuelle C. Leroy[1], Karolin Thomisch[2], Jean-Yves Royer[1], Olaf Boebel[2], and Ilse Van Opzeeland[2, 3]

[1] CNRS & University of Brest, Laboratoire Geosciences Ocean, IUEM, 29280 Plouzane, France
[2] Ocean Acoustics Lab, Alfred-Wegener-Institute, Helmholtz-Centre for Polar- und Marine Research, 27570 Bremerhaven, Germany
[3] Helmholtz-Institute for Functional Marine Biodiversity at the University of Oldenburg [HIFMB], 26129 Oldenburg, Germany

Evaluation of the performance of computer-based algorithms to automatically detect mammalian vocalizations often relies on comparisons between detector outputs and a reference data set, generally obtained by manual annotation of acoustic recordings. To explore the reproducibility of these manual annotations, we investigate inter- and intra-analyst variability in manually annotated Antarctic blue whale (ABW) Z-calls by two analysts using acoustic data from two ocean basins with different call abundance and background noise. Manual annotations exhibited strong inter- and intra-analyst variability, with less than 50% agreement between analysts. This variability is mainly caused by the difficulty of reliably and reproducibly distinguishing single calls in an ABW chorus, which consists of overlapping distant calls. Furthermore, the performance of two automated detectors, one based on spectrogram correlation and one on subspace-detection strategy, was evaluated by comparing detector output to a "conservative" manually annotated reference data set, comprising only annotations that matched between analysts. This study highlights the need for a standardized approach for human annotations and automatic detections, including a quantitative description of their performance, to improve the comparability of acoustic data, which is particularly relevant in the context of collaborative approaches collecting and analyzing large passive acoustic data sets.

Labeling method of the South Indian Ocean marine soundscape and associated database

Kristelle Le Cam, Charles Vanwynsberghe, Flore Samaran, and Riwal Lefort

Automatic detection and classification require a ground truth database in order to train supervised methods. In case of marine mammal vocalization recordings, labeling is achieved by hand via a spectrogram analysis. However, the inter and intra-analyst variability in acoustic annotations may bias both training and validation datasets by a label noise. The latter affects learning step as well as performance assessment. Therefore, well defined criteria for soundscape manual labelling are necessary to mitigate the analyst bias. In this study, we present a sound catalogue describing the biophony, anthropophony and geophony in the South Indian Ocean below 120 Hz. It uses data recorded on 2014 at South West Amsterdam (SWAMS) hydrophone station, belonging to OHASISBIO network. 19 classes are identified to discern the different soundscape components, and are organized into a tree structure. The biophonic part of this sound catalogue encompasses fin whale, Antarctic blue whale and three acoustic subspecies of pygmy blue whale vocalizations. Labels also include contextual parts: anthropogenic or natural noises, and ‘unidentified sounds’ class. Besides, annotation method identifies the different spectrogram pattern qualities that a sound component can take after propagation. To do so, we add a quality index between 1 (poor quality) and 3 (high quality) to each labeled sound, this index is mostly determined by the Signal-to-noise ratio. Thus, we can obtain detectors performance depending on the data quality index. We performed one-vs-all classifications using Convolutional Neural Networks to dissociate Australian acoustic subspecies of pygmy blue whale calls, or blue whale D-calls from the rest of the soundscape. For D-calls, the results showed an improvement of the classifier accuracy when only taking into account the high quality signals.

Active communication space for beluga whales in Cook Inlet, Alaska

Jennifer Wladichuk, and David Hannay

JASCO Applied Sciences, Victoria, Canada

Beluga whale, Delphinapterus leucas, vocalizations were captured on an array of underwater acoustic recorders near the West Foreland peninsula in Cook Inlet, Alaska. The recorders were deployed on the seafloor in water depths ranging from approximately 19 to 26 m with a minimum separation distance of 1 km and a maximum range of 10 km. The study site is approximately 90 km southwest of Anchorage near a feeding location of the Cook Inlet beluga whales. During the deployment, vocalizations were captured on all recorders simultaneously and based on the received levels a detection range of at least 9 km is observed. The highest one-third octave band level of the vocalizations were computed and compared with the audiogram as well as the ambient levels to investigate the active communication space in this environment. Results show that the whale's hearing sensitive can limit the communication space rather than the ambient noise levels. Additionally, this large detection range observed on the recorders has implications on passive acoustic monitoring (PAM) in similar environments with comparable ambient sound levels.

Ambient soundscape of grey whale feeding grounds in British Columbia, Canada

Jennifer Wladichuk[1], William Megill[2], and Philippe Blondel[3]

[1] JASCO Applied Sciences, Victoria, Canada
[2] Rhine-Waal University, Kleve, Germany
[3] University of Bath, Bath, UK

The use of vision is relatively restricted underwater, yet marine mammals are still able to navigate and find food without any noticeable difficulties. The use of sound, therefore, plays a key role in their survival. Our work has focused specifically on grey whales (*Eschrichtius robustus*) due to their close association with the shallow water environment where there is a variety of environmental acoustic cues present. One of their primary food sources along the western coast of Canada is found near kelp beds, in a highly cluttered and acoustically active environment. Because the usefulness of vision is limited by the turbidity of the coastal marine environment, it is logical to believe they rely heavily on their hearing. We propose that they are making use of the ambient noise for passive acoustic characterisation of their environment. This research investigates what sounds are available to these animals in their feeding grounds and quantifies how these acoustic cues differ between and within their feeding grounds. Ambient noise recordings were collected in three bays along the central coast of British Columbia, Canada, where grey whales are known to feed. The acoustic recordings were made using a broadband hydrophone (frequency range of 20 Hz – 20 kHz) deployed from the side of a kayak. The aim of this research is to understand how grey whales might be finding their way around, and to what impact increased levels of ambient noise might have on the whales' ability to find food and navigate within the feeding grounds.

Photo: credit Cetamada

Dataset and challenge

Dataset Documentation and Retrieval

These workshop datasets have been provided by the Scripps Institution of Oceanography for the 8th DCLDE Workshop. They consist of acoustic recordings from multiple deployments of high-frequency acoustic recording packages (Wiggins and Hildebrand, 2007) deployed in the Western North Atlantic (US EEZ) and Gulf of Mexico. Separate sets of development data are provided for mysticetes and odontocetes. The mysticete data have been decimated to 1 kHz bandwidth (2 kHz sample rate) and the odontocete data have 100 kHz of bandwidth (200 kHz sample rate). Data were selected to cover multiple seasons and locations while providing high species diversity and call counts. If you would like to learn how to access these datasets, please check out Dataset Retrieval (http://sabiod.univ-tln.fr/DCLDE/challenge.html#datasetRetrieval).
As for previous workshops, this common dataset of underwater recordings is being made available to encourage researchers to compare results. Large training and testing datasets are designed to cover the range of spatial, temporal, and recording variability that may be encountered by researchers in the field. We hope that these datasets will provide an opportunity to develop detectors and classifiers that will perform robustly across different tasks and under novel conditions. In order to emulate the research teams, an online white test system will be proposed mid february, on a small section of the test set, so that each team could during the challenge have an overview of their progress in respect to the current results of the communauty.
In order to receive updates on these task / evaluation, please register by a simple email to herve.glotin@univ-tln.fr, subject: DCLDEeval.

High-Frequency Data Content Descriptions

The high-frequency dataset consists of marked encounters with echolocation clicks of species commonly found along the US Atlantic Coast, and in the Gulf of Mexico:

- *Mesoplodon europaeus* - Gervais' beaked whale
- *Ziphius cavirostris* - Cuvier's beaked whale
- *Mesoplodon bidens* - Sowerby's beaked whale
- *Lagenorhynchus acutus* - Atlantic white-sided dolphin
- *Grampus griseus* - Risso's dolphin
- *Globicephala macrorhynchus* - Short-finned pilot whale
- *Stenella sp.* - Stenellid dolphins
- Delphinid type A
- Delphinid type B
- *Unidentified delphinid* - delphinid other than those described above

The goal for these datasets is to identify acoustic encounters by species during times when animals were echolocating. Analysts examined data for echolocation clicks and approximated the start and end times of acoustic encounters. Any period that was separated from another one by five minutes or more was marked as a separate encounter. Whistle activity was not considered. Consequently, while the use of whistle information during echolocation activity is appropriate, reporting a species based on whistles in the absence of echolocation activity will be considered a false positive for this classification task.

Low-Frequency Data Content Descriptions

The low-frequency dataset consists of annotated data for specific calls from two mysticete species found along the US Atlantic coast:

- *Balaenoptera musculus*- North Atlantic blue whale tonal calls (Mellinger and Clark, 2003)
- *Eubalaena glacialis*- North Atlantic right whale up-call (Parks Tyack, 2005)

The goal for this dataset is to identify specific blue whale tonal calls, and right whale up-calls. Analysts examined data using long-term spectral averages as well as manual scanning of the data for individual calls.

Data Format

Acoustic data are provided as wav files, with the filename encoding the site, deployment, and starting timestamp of each file.

High frequency ex: WAT_HZ_01_151014_055500.x.wav

- WAT_HZ_01 indicates the first deployment at site HZ (Heezen), within the Western Atlantic (WAT) project. Other project names are HAT (Cape Hatteras), JAX (Jacksonville), GofMX (Gulf of Mexico).
- Recording started October 14th, 2015 at 5:55:00. All times are UTC.

Low frequency files are similar but contain additional fields in the filename related to decimation from the original high-frequency dataset.
Low-frequency example: HAT_A_02_121021_000000.d100.x.wav

- HAT_A_02 indicates the second deployment at site A, within the HAT (Cape Hatteras) project.
- Recording started October 21st, 2012 at 00:00:00, and has been decimated by a factor of 100.

Recording Locations ** Updated FEB 3rd **

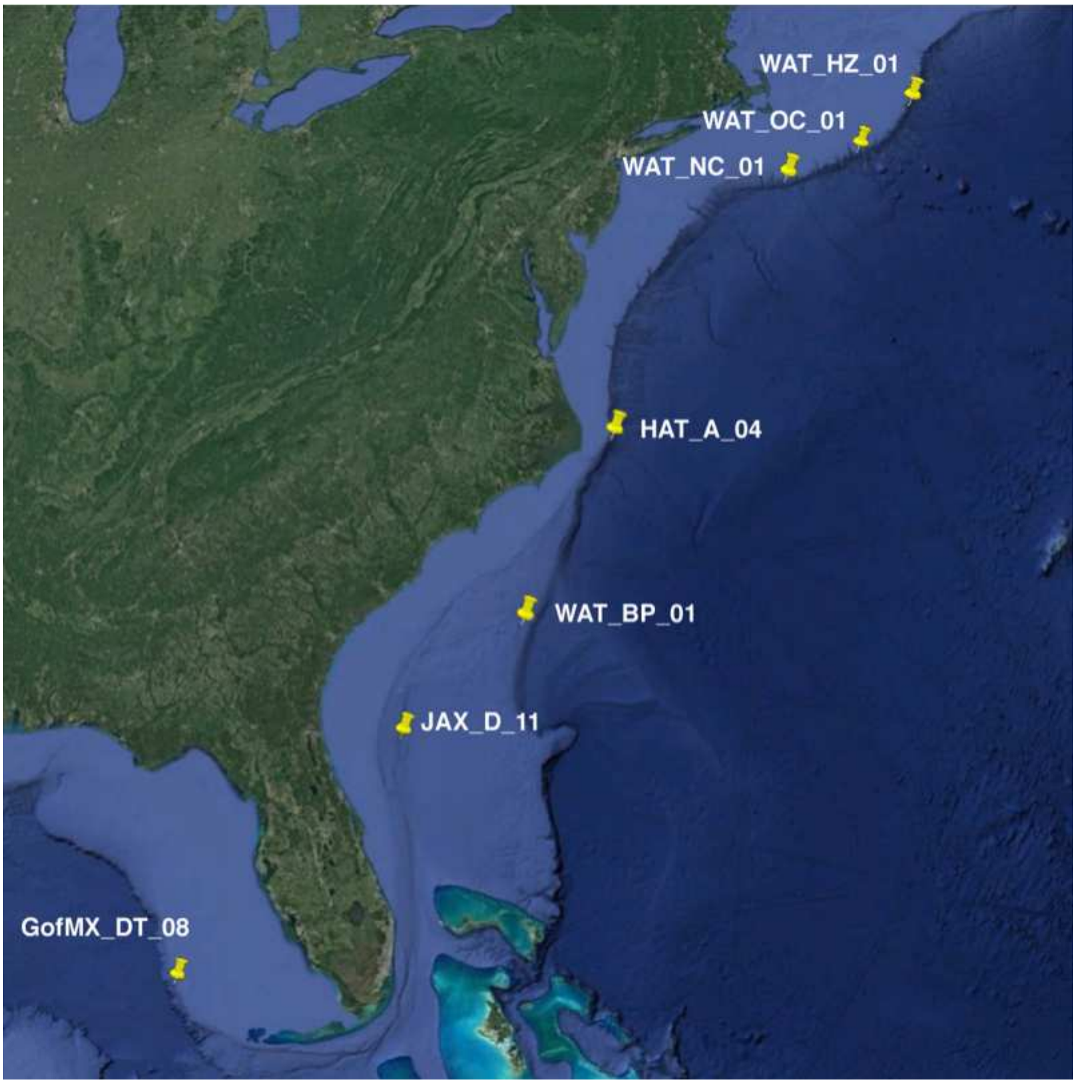
Data were recorded from different locations in the Western North Atlantic and Gulf of Mexico as shown in the figure below. The accompanying table lists the coordinates, and depth of the various sites. These data were collect between 2011 and 2015, and the time period for each recording can be inferred directly from the data.

Project	**Site**	**Deploy-ment**	**Pre-amp**	**Lat N**	**Long W**	**Depth**
WAT	HZ	1	734	41-03.7	66-21.1	850
WAT	OC	1	707	40-15.8	67-59.2	1100
WAT	NC	1	740	39-49.9	69-58.9	980
HAT	A	4	685	35-20.8	74-50.9	840
WAT	BP	1	810	32-06.4	77-05.7	945
JAX	D	11	681	30-09.0	79-46.2	800
GofMX	DT	8	638	25-32.3	84-37.9	1200

Calibration

Preamplifiers for HARPs have been calibrated and two Matlab routines are provided to show how to apply the appropriate transfer function. All necessary files will be soon available.

- gettransferfn(filename, BinsHz)- Assuming that the transfer function folder is in the same folder as this function, it will parse the filename and load the appropriate transfer function. The function will be sampled at the frequency bin center frequencies provided in BinHz and the appropriate offsets will be returned.
- tfadjustexample()- This function prompts the user for a filename, reads the first 1/10th of a second of data and produces a plot of sound pressure level after applying the transfer function.



Format of the Annotation

Comma separated value files are used as input to routines that compute the precision and recall as well as coverage and fragmentation for encounters (see Roch et al., 2011 for details). The species abbreviations in the following table should be used.

For encounter level tests, the result file should contain comma separated value (CSV) entries with each line as follows:

project, site, species-abbreviation, start-time, end-time

Time stamps are provided as follows: YYYY-MM-DDTHH:MM:SS with an optional decimal and fractional seconds following the seconds field

Example for Cuvier's beaked whale detection at HAT site A:

HAT,A,Zc,2014-05-19T07:57:30.0,2014-05-19T08:05:00.0

Call level results for blue and right whales are similar, with the addition of:

WAT, HZ, Bm, 2016-01-24T13:18:46.0, 2016-01-24T13:18:50.1

Spaces between fields may be included or omitted. A scoring script will be provided by the conference organizers in March so that participants can evaluate their algorithms performance on the development data. Ground truth data based on trained analyst annotations is provided for the development data set.

Abbreviation	Species
Me	*Mesoplodon europaeus*- Gervais beaked whale
Zc	*Ziphius cavirostris*- Cuvier's beaked whale
Mb	*Mesoplodon bidens*- Sowerby's beaked whale
La	*Lagenorhynchus acutus*- Atlantic white-sided dolphin
Gg	*Grampus griseus*- Risso's dolphin
Gma	*Globicephala macrorhynchus*- Short-finned pilot whale
Ssp	*Stenella sp.*Stenellid dolphin
UDA	Delphinid type A
UDB	Delphinid type B
UD	unidentified delphinid
Bm	*Balaenoptera musculus*- blue whale
Eg	*Eubalaena glacialis*- North Atlantic right whale

Dataset Retrieval

Analyst Annotations Retrieval (UPDATED on JAN 23rd)

The annotations of the Low-frequency and High-frequency data can be obtained from the following Google Drive links:

- LF_Annotations_Dev.zip ** UPDATED on JAN 23rd **
- HF_Annotations_Dev.zip ** version on DEC 24 rd **

Download

See information on the websiste: http://sabiod.univ-tln.fr/DCLDE/challenge.html

Evaluation Dataset (WAV files)

A separate evaluation data set will be provided ONLINE (400 Go for High-Frequency, few Go for Low-Frequency) at a later date, without labels. Participants wishing to be part of the algorithm comparison will be able to submit their detector CSV files via the web site. This (official) evaluation dataset will contain additional weeks of data from the sites that have been included in the development set and data from a deployment that was not present in the development set.

Metrics / Scoring Tools

The scoring tool is designed to compare detections with the ground truth files provided for the workshop. A link to the scoring tool will appear here in advance of the workshop. It accepts files in the workshop CSV format:

For the high-frequency task, the result file should contain comma separated value (CSV) entries with each line as follows (see the DCLDE dataset description for further details on species abbreviations, etc.):

Time stamps are provided in ISO 8601 format: YYYY-MM-DDTHH:MM:SS with an optional decimal and fractional seconds following the seconds field. Example for Cuvier's beaked whale detection at HAT site A:

HAT,A,Zc,2014-05-19T07:57:30.0,2014-05-19T08:05:00.0
Low-frequency-task results for blue and right whales are similar. Low frequency dataset groundtruth files contain an additional field describing detection quality ('good' or 'poor'). Poor quality calls will not contribute to classification scores.

WAT, HZ, Bm, 2016-01-24T13:18:46.0, 2016-01-24T13:18:50.1, good
Spaces between fields may be included or omitted.

FORMAT / SCORING = The official final scoring script is here: http://sabiod.univ-tln.fr/DCLDE/files/dclde2018-scoringtools.zip

Winner groups of DCLDE 2018 challenge

For the category High Frequency challenge, the winners are:

Kun Li, Peter Achi, Natalia Sidorovskaia
University of Louisiana at Lafayette

For the category Low Frequency challenge, the winners are:

Kerry Dunleavy, Matthew McKown
Conservationmetrics.com, California

From left to right: N. Sidorovskaia, J. Hildebrand, H. Glotin, K. Dunleavy, and P. Achi
(Photo : credit Olivier Adam)

Contacts

GLOTIN Hervé, LIS, Univ Toulon, France
HILDEBRAND John, Scripps, California, USA


Photo: credit Cetamada

Artist

The Sacrifice of Giants

Blending art with social change, The Sacrifice of Giants—is an ecologically-sensitive choreographic production of dance, video, and photography honoring the natural behavior of the inhabitants of our oceans—and, illuminating today's critical global issue: the captivity of cetaceans.

Inspired by a need to meaningfully connect to our living planet, our work attempts to sensitize society to the need for conservation of our beloved species and oceans. We believe: art and human expression cannot be separate from society. It improves society. And, inherent to modern dance is revolution. Aligning with the spirit of the field, our work is an essential component to promote public awareness for the natural world.

View excerpts: https://vimeo.com/124809692
http://www.camillehanson.com/staying-alive/

The Sacrifice of Giants is supported by The Bogliasco Foundation of NYC, U.S.A., the international marine conservation organization SOSdelfines, Sea Shepherd España, La Dolphin Connection Spain and France, Centro Cultural Conde Duque (Madrid), and Centro Danza Canal (Madrid).

Camille Hanson (Madrid, Spain)

Camille has worked extensively as a dancer, choreographer and teacher; she has produced a steady stream of work acclaimed for its ecological and social commitment. Camille has concentrated on stage productions as well as site-specific works that create evocative environments for performers and audiences to inhabit and explore. She is particularly interested in dance and image as a means of transmitting experiences and raising questions about survival in times of dramatic social and environmental change.

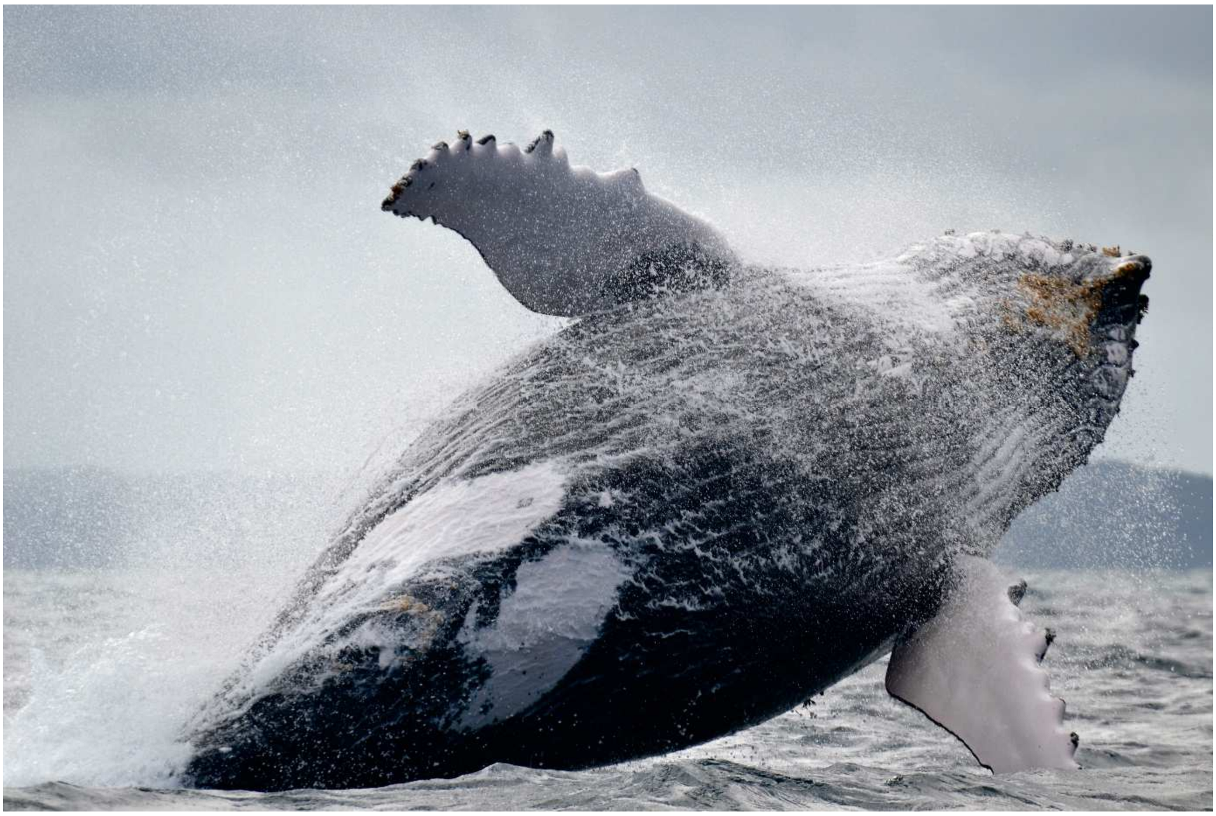
Currently, Camille works with Spanish visual artist, Juan Carlos Arévalo, fusing dance, photography and video creation into new and experimental works for festivals around Spain and Europe. Their interdisciplinary collaborations propose to break down assumptions of 'why & where' art happens in an attempt to expand our sense of empathy, responsibility and environmental awareness. Some of their stage works include: We Earth (2017), The Sacrifice of Giants (2015), Dust and Water (2012), Sensitive to Noise (2010), In Without Knocking (2009), Body Scores for Sound (2008), among others.

Hanson is a 2015 recipient of a dance fellowship from the Bogliasco Foundation, and is co- founder of Coreógrafos en Comunidad in Madrid. She teaches contemporary dance immersions throughout Spain, Europe and U.S.A.

www.camillehanson.com

Photo: credit C. Hanson


Photo: credit Cetamada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About ENSTA Bretagne, a multidisciplinary French "Grande Ecole" of Engineering & Applied Research Center, actively involved in technological innovation with maritime sector, defense, and technological industries with high added value.

ENSTA Bretagne is a famous French State Graduate, Post-Graduate and Research Institute based in Brest, port city which ranks 4th worldwide in Maritime Research. ENSTA Bretagne trains Engineers and Experts (about 1000 Students, including 600 MSc Students and 110 PhD Students) for the most innovative sectors.

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photo ENSTA Bretagne ©Simon Rohou

Websites : www.ensta-bretagne.fr/eu, www.labsticc.fr, irdl.fr, crf.cnam.fr


Joël Detcheverry – association SPM Terre Vivante

Authors

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