DCLDE 2022 Abstracts

Authors	Affiliations	Title	Abstract
Adam Olivier (1,2); Doh Yann (3); Denis Bertrand (3);	(1) Sorbonne Université (2) Université Paris-Saclay (3) Association ABYSS	CETOSCOPE – Tracking vocal cetaceans based on visual and acoustic observations	Over the 3 last decades, by taking advantages of recent progress in term of underwater technology and power computing, marine mammals' topic has become increasingly important among the bioacoustics field. However, it is still a challenge to identify the vocalizing individuals in social cetacean groups in order to study their behaviors and interactions. To deal with this challenge, we designed an original innovative device, called CETOSCOPE, based on electronic devices that are low-cost and easy to buy. CETOSCOPE includes a 360° video camera and a passive acoustic array based on 4 synchronized hydrophones. We tested different 3D configurations to select the best solid structure in order to minimize the errors of the localizations of the vocal sources. The video camera allows to giving information from the whole 3D scene around the device. The array of hydrophones has 2 roles: 1) acoustic data is collected in order to analyze the vocal repertoire of the cetaceans, and 2) the acoustic recordings is used to estimate the positions of the vocal emitters and track them. Comparing to other devices (for example, Glotin et al., 2018 ; Hoffman-Kuhnt et al., 2018), we were able to build the 3D movements of each vocal individuals. At the end, our device was tested in swimming pool and then used in the wild. Results showed the 4 possibilities: the dolphins emitted or not clicks and were present or not on the screen. It was possible to study their behaviors in approach, during and after the interactions.
Allen, Ann N. (1), McCullough, Jennifer (1), Szesciorka, Angela (2), Harvey, Matt (3), Wood, Megan (2), Oleson, Erin M. (1)	(1) NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, United States. (2) Ocean Associates Inc. Under Contract to NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, United States (3) Google, Inc., Mountain View, CA, United States	Et twang, Bryde's? Biotwang occurrence in the Mariana Archipelago	A complex biological sound dubbed a 'biotwang' was identified in the Mariana Islands in 2014 and was attributed to baleen whales, but without a specific species ID. During a 2018 survey, using a combination of visual sightings and sonobuoy data, we positively identified Bryde's whales as producing the biotwang call. We explored the geographic and temporal patterns of occurrence of the biotwang in the western Pacific using a variety of datasets, including towed array and drifting recorder (DASBR) data from two surveys in 2018 and 2021, as well as long-term records from bottom-mounted recorders (HARPs) from sites off Tinian (2011 to 2019), Saipan (2010 to 2021), and Pagan Islands (2015-2021). We used machine learning techniques and PAMGuard detectors to identify the biotwang calls in the various acoustic data. The DASBR and towed array data provided good spatial coverage of the waters surrounding the Mariana Islands, allowing us to discern patterns of spatial occurrence of the calls. Biotwang detections from the HARP data allowed us to examine their seasonal patterns, as well as their variability over a several year period. The combination of these types of acoustic data provide a comprehensive picture, both spatially and temporally, of Bryde's whale biotwang occurrence in the Mariana Archipelago.
Barkley, Yvonne (1);, Karlina Merkens (2), Megan Wood (2), Erin Oleson (3), Tiago Marques (4)	(1) Cooperative Institute for Marine and Atmospheric Research; (2) Saltwater, Inc.; (3) NOAA Pacific Islands Fisheries Science Center; (4) University of Saint Andrews	How many clicks does it take? Investigating click rate variability for sperm whales in Hawaiian waters	Density estimates of marine mammals are essential for addressing management and conservation-related questions. Cue-based density estimation methods are becoming more widely used for cetacean populations as they rely on counting acoustic cues instead of individual animals. To convert cue density to animal density, an estimate of the population's average cue production rate is required. However, cue rates can differ depending on context and few studies have assessed this variability to date. Sperm whales are an excellent species to measure and assess cue rate variability due to their distinct echolocation clicks, which vary based on group demographics and behavior. In the absence of acoustic tag data from the Pacific Ocean, we analyzed four years of towed hydrophone array data from visual and acoustic line-transect surveys to conduct the first click rate analysis for sperm whales in Hawaiian waters. Using automatic click detection with manual validation of over 60 acoustic encounters, we annotated regular and slow clicks, creaks, and codas totaling over 119,000 clicks. We then examined click rates as they related to visual group size estimates, group demographics, behavior, and group distance from the array to better understand click rate variability within different contexts. Results will contribute to a growing knowledge base for marine mammal cue rates for density estimation applications as part of the Acoustic Cue Rates for Passive Acoustic Density Information (ACCURATE) Project.

Barlow, Jay (1)	(1) NOAA Southwest Fisheries Science Center	Variation in source levels affects density estimation in strange ways: why mean values aren't good enough.	A key parameter in acoustic density estimation is the area effectively surveyed. One way to estimate this parameter is to model sound propagation to predict at what range a given source level can be detected. In doing so, one simple approach would be to use a mean value of empirically estimated source levels. However, a 20 dB natural variation in source levels can lead to a 100-fold variation in detection area. Because detection area is not linearly related to source level, an unbiased mean estimate of source level will lead to a biased estimate of density. In this presentation, I use simulation modeling to illustrate the magnitude of this bias and how it varies with different propagation conditions and source frequencies. I also explore methods to reduce or eliminate this bias by 1) using alternative weightings for estimating mean source level (instead of using the log-weighting implied by averaging dB levels) and 2) using the distribution of natural variation in source levels in estimating the effective area surveyed for abundance estimation. Results show that ignoring the natural variation in source levels can lead to substantial biases in abundance estimates. There is a need for additional research in quantifying the distribution of source levels whenever they can be measured.
Baumann-Pickering, Simone (1); Solsona Berga, Alba(1); Trickey, Jennifer S. (1); Wiggins, Sean M. (1); Aguilar, Catalina(1); Hildebrand, John A. (1)	Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0205	Passive acoustic density estimation of Cuvier's beaked whales in Southern California waters	Cuvier's beaked whales are top predators foraging on patchy prey resources in the deep sea. Their habitat is undergoing unprecedented alterations due to climate change and other anthropogenic pressures; however, long-term consequences of disturbance are poorly documented. Sustained deep-sea observations are rare, difficult to obtain and can generate big, challenging datasets. Long-term passive acoustic recordings were collected in the Southern California Bight at 21 sites since 2006. At 11 of these sites, Cuvier's beaked whales were regularly observed over a cumulative ~40 years of acoustic effort. An important aspect for this time series was adapting for variations in instrumental response over more than 140 instrument deployment periods. Using click-count and group-count methodology for passive acoustic density estimation, we provide long-term insight into the variability in densities of Cuvier's beaked whales across the region. We have immense gaps in our understanding of these top predator life histories, their function in deep sea ecosystems, as well as impacts of sustained anthropogenic threats. Long-term population trend estimates will become feasible with reliable density estimates generated from passive acoustics and can guide management and mitigation strategies.
Baumgartner, Mark (1); Bonnel, Julien (1)	(1) Woods Hole Oceanographic Institution	Real-time detection and classification of marine mammals from expendable profiling floats	Marine mammal occurrence and distribution in the world's ocean basins are difficult to observe because these areas are remote and rarely visited by visual survey vessels. Sustained passive acoustic monitoring is also difficult because archival recorders must be recovered and re-deployed from ships whose high costs are difficult to justify for long voyages. Long-endurance expendable profiling floats have been used by the physical oceanography community for the past two decades to measure ocean heat content throughout most of the global ocean (Argo program). These profiling floats operate at sea for years at a time, making them ideal platforms for access to remote ocean basins. To provide these expendable platforms with a passive acoustic monitoring capability, we integrated the low-power digital acoustic monitoring (DMON2) instrument in a commercially available profiling float (MRV ALTO). Every half hour, the DMON2 transmitted to the profiling float controller both ambient noise spectra (up to 30 kHz) and summary baleen whale detection information from the low-frequency detection and classification system (LFDCS). Upon surfacing, the float relayed these data to shore via Iridium short-burst data messages where they were displayed on a publicly accessible website in near real time. Because the float is not intended to be recovered, the on-board detection and classification of marine mammal sounds is critical to its use for long-endurance passive acoustic monitoring missions. We will present preliminary results from an 8-week at-sea trial conducted during summer 2021, and our plans for upcoming expendable missions in the North Atlantic Ocean.

Bazúa-Durán, Carmen (1), Montejano-Zea, Elena (1)	(1) Facultad de Ciencias, UNAM. Circuito Exterior s/n, Ciudad Universitaria, 04510 Ciudad de México, México	Dolphin whistle stereotypy for a measure of dolphin abundance	Whistles have been studied extensively for both wild and captive dolphins. They are used in the communication between individuals, to maintain contact within a herd, and to coordinate herd movements, having some whistle types that are an individual distinction or signature. However, little is known on how whistles can be used to ascribe individuals. Therefore, our current work is focused on determining the stereotypy of the most frequently emitted whistles by four captive bottlenose dolphins, Tursiops truncatus, housed in two different marine parks in Mexico City. Stereotypy was computed by changing the similarity index while classifying whistles into whistle types using Matlab BELUGA and ArtWARP. The whistling dolphin identity was determined using the López & Bazúa (2010) method. Results indicate that signature whistles are highly stereotyped, having a similarity index greater than 94-95%, while other whistle types are also highly stereotyped but cannot be considered signature whistles. Therefore, computing whistle stereotypy is helpful in assessing the minimum number of whistling dolphins in a pod. This is especially important in the wild, where in some occassions it is very difficult to assess how many individuals are present. This very simple method promises to be useful to quantify the number of dolphins whistling using solely underwater recordings. Further work will include testing this method with wild bottlenose dolphin recordings. It is necessary to implement such methods to better understand how dolphins are using whistles, since acoustic communication is the most important sense in dolphin species. [Work supported by PAPIIT & PASPA-UNAM]
Best Paul (1), Paris Sébastien (1), Marxer Ricard (1), Glotin Hervé (1)	(1) Université de Toulon, Aix Marseille Univ, CNRS, LIS, DYNI, Marseille, France	Deep learning for Antarctic Blue and Fin whale vocalization detection	We report results of an automatic detection system for Antartic baleen whale sounds .We experiment on the dataset from Miller et al. [1], containing 7 types of vocalizations from fin whales (Balaenoptera Physalus) and blue whales (Balaenoptera Musculus). We trained a deep learning model with an architecture inspired from Grill and Schlüter [2], on a task of multi-label classification. The model takes Mel-spectrograms of 10 second audio excerpts, and outputs a vector of 7 confidence values (one for each vocalization type). Excerpts are extracted from all available recordings, with labels denoting the presence of an annotation within the 10 seconds (for each type). Binary cross entropy loss between labels and confidence values is used to optimize the model's parameters. We rely on the area under the receiving operating characteristics curve (AUC-ROC) to measure model performances (averaged from the scores of each of the 7 classes). Our experiments show that the addition of brown noise during training, a large receptive field, and per-channel energy normalization [3] (PCEN) improve performances (0.04 gain in AUC-ROC). However, the use of spectral data augmentation for regularization (inspired from SpecAugment [4]) appeared to be counter productive (0.05 drop in AUC-ROC). In order to assess its generalization capabilities, we test our model on the Kerguelen 2005 subdataset (while training is done over the remaining data). We chose this train/test split so the recording system and location of the test set is not found in training. Our best performance was 0.89 of average AUC-ROC (Bm-A : 0.80, Bm-B : 0.77, Bm-Z : 0.82, Bm-D : 0.92, Bp-20Hz : 0.97, Bp-20Plus : 0.98, Bp-Downseep : 0.94) [1] Miller, Brian S., et al. "An open access dataset for developing automated detectors of Antarctic baleen whale sounds and performance evaluation of two commonly used detectors." Scientific Reports 11.1 (2021): 1-18. [2] Grill, Thomas, and Jan Schlüter. "Two convolutional neural networks for bird detection in audio signals." 2017 25th European Signal Processing Conference (EUSIPCO). IEEE, 2017. [3] Wang, Yuxuan, et al. "Trainable frontend for robust and far-field keyword spotting." 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2017.
Bouffaut, Léa (1,2); Taweesintananon, Kittinat (2); Kriesell, Hannah J. (2); Rørstadbotnen, Robin A. (2); Potter, John R. (2); Klinck, Holger (1); Johansen, Ståle E. (3); Landrø, Martin (2)	(1) K. Lisa Yang Center for Conservation Bioacoustics, Cornell Lab of Ornithology (2) Acoustics Group, Department of Electronic Systems, NTNU (3) Department of Geoscience and Petroleum, NTNU	Listening at the speed of light: baleen whale monitoring using distributed acoustic sensing	What if you had a hydrophone every few meters, over tens of kilometers, and accessible in real-time? This is the new perspective brought by Distributed Acoustic Sensing (DAS). It repurposes Fiber Optic (FO) telecommunication cables lying at the bottom of the world's oceans to record acoustic data at these unprecedented scales, while recent improvements in sampling frequency and data quality have opened the door to monitoring water-born acoustic sources. This work demonstrates the potential of DAS for the monitoring of low-frequency baleen whales (<300Hz), using a 120 km FO cable with 4-m spatial resolution from a shore station in Longyearbyen out to the open ocean, through Isfjorden, in Svalbard archipelago, Norway. The data recorded over 42 days revealed the presence of North Atlantic blue whales producing stereotyped calls and a variety of down-sweeps that could be attributed to blue (D-calls), fin (D-calls or pulses), or sei whales. Further analysis showed (1) the possibility of simultaneous detection, localization, and tracking of multiple whales at different locations along the FO cable, (2) variations in acoustic use inside and outside the fjord, and (3) that the combination of DAS and whale signals can be used for subsurface exploration. Overall, DAS's additional dimension and coverage, not limited to low frequencies, can reduce the monitoring gaps. Still, real-time artificial intelligence and advanced data management schemes are necessary to handle such big datasets.

Bremnes, Kenneth (1); Hobrak, Lucas (1); Moen, Rebecca (1); Reichmuth, Colleen (2); Sills, Jillian (2); Rasmussen, Jeppe (3)	(1) Center for Artificial Intelligence Research, University of Agder; (2) Institute of Marine Sciences, Long Marine Laboratory, University of California Santa Cruz; (3) Center for Coastal Research, University of Agder.	Hawaiian monk seal vocalization detection and classification using Deep Learning	The Hawaiian monk seal, Neomonachus schauinslandi, is a highly endangered species with an urgent conservation priority. Applying passive acoustic methods to detect and monitor this species would inform research and management efforts. However, manually processing large acoustic datasets is slow, labour intensive and prone to human errors. Therefore, machine learning models were developed to automate the process and increase accuracy. This approach is divided into two classification problems with two Convolutional Neural Networks. The first model, based on ResNet, detects and isolates data where vocalizations are present. The second model, based on VGG net, classifies calls into 6 previously defined perceptual types. Both approaches convert acoustic data into spectrograms and utilize image classification. Approximately 100 hours of recordings from a captive, adult male Hawaiian monk seal were manually annotated, creating a dataset of 1200 labelled vocalizations used for model training and testing. After implementing data augmentation to balance the dataset and prevent overfitting, our models achieved an accuracy of 92% detection and 84% classification of different call types. Future work includes expanding the dataset by increasing the number of calls and including more individuals and environmental settings.
Cohen, Rebecca E.; Wiggins, Sean M.; Baumann-Pickering, Simone; Hildebrand, John A.; Frasier, Kaitlin E.	Scripps Institution of Oceanography, UCSD	Atlantic Echolocation Click Types Labeled to Odontocete Species Identity Using Machine Learning and Spatiotemporal Correlates	To fully utilize large marine passive acoustic data sets we must be able to reliably discriminate between species' vocalizations. Delphinid species are particularly challenging due to high levels of intra-specific variability and inter-specific overlap in vocalization characteristics. To improve delphinid species acoustic discrimination, we focused on echolocation, an acoustic behavior conserved across all odontocete species which demonstrates less behavioral plasticity than tonal calls. We combined ~33 years of passive acoustic data from 11 autonomous monitoring sites spanning the US eastern seaboard with historical sighting data to identify recurring odontocete click types and match them with their putative generating species. Supervised and unsupervised machine learning algorithms were used for acoustic signal discovery and classification. This yielded a set of distinct click types, some attributable to known species based on previous work, and labeled time series of click type presence at each monitoring site. For the click types of unidentified origin, we compared the seasonal presence and geographic distribution of each click type to the distribution of historical sightings of each odontocete species known to inhabit the region to identify potential spatiotemporal matches. Species identity of sightings colocated and contemporaneous with autonomous acoustic encounters and previously published click spectra were also considered to build evidence for attribution of previously unidentified click types to short-beaked common dolphins, short-finned pilot whales, and Risso's dolphins. These characteristic click types can be used to gain new insights from existing and forthcoming marine passive acoustic data sets, with particular utility in population assessment and management applications.
Conant, Peter (1); Li, Pu (1); Liu, Xiaobai (1); Klinck, Holger (2); Fleishman, Erica (3); Cholewiak, Danielle (4); Gillespie, Douglas (5); Helble, Tyler (6); Nosal, Eva-Marie (7); Roch, Marie A. (1)	(1) San Diego State University; (2) Cornell University; (3) Oregon State University; (4) NOAA Northeast Fisheries Science Center; (5) St. Andrews University; (6) US Navy, Naval Information Warfare Center Pacific; (7) University of Hawai'i;	Deep Silbido – Whistle extraction with deep neural networks	We present a tool for the extraction of toothed-whale whistle contours. This work extends our previously published research on the use of deep neural networks (Li et al. 2020 IJCNN). Here, we identify time-frequency peaks in spectrograms on the basis of contextual information provided by a deep convolutional residual network. Contextual peak prediction is more reliable than traditional energy peak detectors and learns to ignore strong energy associated with echolocation clicks and other types of clutter. The predicted peaks can be assembled into whistles by tracking algorithms, such as our 2011 graph search algorithm for whistle extraction. We applied the algorithm to 8,399 annotated delphinid whistles from the DCLDE 2013 conference data and to the entire DCLDE 2022 data. Precision on the DCLDE 2013 data was 90.3% and recall was 74.9%. Preliminary analysis of performance tests on the DCLDE 2022 data suggest strong concordance with analyst annotations and we will present results of ongoing performance analysis on these data. The work is open source and freely available at https://github.com/MarineBioAcousticsRC/silbido.
Constaratas, Alexandra Nathalie (1); Holcer, Draško (1); Širović, Ana (2)	(1) Blue World Institute of Marine Research and Conservation; (2) Norwegian University of Science and Technology	Automated detection and classification of Cuvier's beaked whale, sperm whale, and delphinid clicks from the Adriatic and comparison of algorithm performance on DCLDE Oahu dataset	No consistent acoustic surveying effort has been conducted previously in the deep, southern waters of the Adriatic Sea and thus little is known on the year-round occurrence of cetaceans in this area. To improve that knowledge, passive acoustic data were collected approximately 25 mi offshore Dubrovnik, Croatia, from October 2018 to December 2019 using a High-frequency Acoustic Recording Package (HARP) deployed at 1,000 m depth. The occurrence and characteristics of Cuvier's beaked whale (Ziphius cavirostris), sperm whale (Physeter macrocephalus) and delphinid echolocation clicks were assessed in the southern Adriatic Sea using an automated click detector and classifier. The clicks were detected using a customized version of the Kaiser-Teager energy detector and classified based on their values of peak frequency, duration and inter-click interval (ICI). The clicks of all three groups occurred during all analysed months without a clear seasonal pattern. Delphinid clicks and Cuvier's beaked whale clicks exhibited a strong diel pattern with most clicks detected in the evening, whereas sperm whale acoustic presence was sporadic. We used the same two-step process of click detection and classification on the DCLDE Oahu dataset on the same species, including delphinids likely to be present in the Adriatic Sea, to compare the performance of the detector between the Adriatic and DCLDE Oahu datasets.

Cook, Ashley(1); Debich, Amanda(1)(2); Frasier, Kaitlin(3); Garrison, Lance(2); Hildebrand, John(3); Rasmussen, Jeppe(4); Soldevilla, Melissa (2)	(1) Cooperative Institute for Marine and Atmospheric Studies, University of Miami; (2)National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center; (3)Scripps Institution of Oceanography, University of California, San Diego; (4)Center for Coastal Research (CCR), Center for Artificial Intelligence Research (CAIR), University of Agder.	Detection of Rice's whale calls in the Gulf of Mexico using passive acoustic data and deep learning	Rice's whales (Balaenoptera ricei) are an endangered species with a limited distribution in the Gulf of Mexico. Data from long-term PAM studies aimed at understanding this species' distribution, seasonal occurrence, and movement patterns require robust and reliable automated methods to detect Rice's whale calls to accurately describe their presence. Deep learning methods can facilitate call detection and classification by increasing the accuracy and speed of the identification process while generating fewer false positives than commonly used automated detection and classification algorithms. This study uses a two-step approach composed of a faster region-based convolutional neural network (rCNN) followed by a ResNet CNN to detect Rice's whale calls. Calls were manually detected in 209 hours of randomly subsampled HARP recordings deployed in the Rice's whale core habitat from August 2015 through May 2016 to train and test call detection algorithms. Annotated images of spectrograms were created for 1,564 labeled long-moan calls and 1610 labeled noise periods and used to create and train the networks using a ResNet-18 architecture for the faster-rCNN and a custom-built architecture for the CNN. Both classifiers were trained using 70% of the spectrograms in the dataset and tested on the remaining 30%. Using a 0.5 threshold, the CNN achieves 96.2% precision and 98.7% recall on testing dataset. Performance of the two-step detector is compared with an existing spectrogram correlation detector using precision and recall metrics to determine the best detector for evaluating Rice's whales seasonal and interannual occurrence patterns in their core habitat.
Coppolaro, Veronica (1,2); Marcoux, Marianne (1,2) and Mundy, C.J. (1)	(1) Centre for Earth Observation Science, University of Manitoba (2) Fisheries and Oceans Canada	Acoustic survey of marine mammals and anthropogenic underwater noise off the Southern coast of Southampton Island, Hudson Bay	Decreasing sea ice is affecting ship traffic in the Arctic. The number of marine vessels is consistently increasing in the Canadian Arctic, including around Southampton Island in Hudson Bay. This area was recognized as an important migration route for the Eastern Canada-West Greenland bowhead whale (Balaena mysticetus) and the Western Hudson Bay beluga whale (Delphinapterus leucas), and as year-long grounds for the Central-Low Arctic walrus (Odobenus rosmarus). These species are all listed as "Special Concern" by the Committee on the Status of Endangered Wildlife in Canada. Moreover, these waters are important subsistence harvesting grounds for local communities and were included in the Southampton Island Area of Interest in 2019. Given the significance and the increasing pressure on this marine ecosystem, it is important to understand how climate change and the related increase in human activities might influence the marine mammal community. To date there is a paucity of information in this area regarding marine mammal seasonal presence and acoustic behavior, and underwater acoustic pollution caused by anthropogenic noise. In this work, passive acoustic monitoring was used to compensate for this deficiency and to study how different species react to underwater noise from vessel traffic. Preliminary analyses of acoustic data collected in 2018 are presented. In early summer, recordings mainly include beluga, bearded seal, and walrus vocalizations, along with recurring vessel traffic noise. Based on initial findings, pinnipeds seem less disturbed by vessel underwater noise than cetaceans. Suggestions on future passive acoustic monitoring survey strategies for this area are also presented.

DeAngelis, Annamaria (1), Ackerknecht, Taylor (2), Baumann-Pickering, Simone (2), Bell, Joel (3), Cholewiak, Danielle (1), Cohen, Rebecca (2), Field, Chelsea (2), Frasier, Kait (2), Hildebrand, John (2), Mueller Brennan, Liam (4,5,10), Sakai, Taiki (6,7), Soldevilla, Melissa (8), Solsona-Berga, Alba (2), Trickey, Jennifer (2), Valtierra, Robert (9), Westell, Annabel (4), Van Parijs, Sofie (1)	(1) Northeast Fisheries Science Center, National Marine Fisheries Service, Street, NOAA; (2) Scripps Institution of Oceanography, UCSD (3) Naval Facilities Engineering Systems Command Atlantic; (4) Integrated Statistics Inc; (5) under contract to the Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA; (6) Environmental Assessment Services, LLC; (7) under contract to the Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA; (8) Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA; (9) Marine Acoustics Inc.; (10) Oregon State University	Combining spatial and temporal acoustic datasets to examine the summer presence of beaked whales off the east coast of the US	Beaked whales (family Ziphiidae) are cryptic, deep diving cetaceans that prefer offshore habitats. Since the early 2000s, much effort has been placed in defining the acoustic characteristics of the species within this family, as they emit unique echolocation click types while foraging. Thus, passive acoustic monitoring (PAM) of this family has helped to expand the current knowledge of their behavior, distribution, and habitat use through combinations of various acoustic recording devices. However, very few studies have utilized these different devices simultaneously. From 28 June – 25 August 2016, two broadscale shipboard cetacean abundance surveys were conducted by the National Oceanic and Atmospheric Administration's Northeast and Southeast Fisheries Science Centers along the entire US eastern seaboard with towed hydrophone arrays deployed. In addition, bottom mounted recorders that are well-designed for capturing the temporal distributions of this family at fixed sites over time (HARPs), were also collecting continuous passive acoustic data at 11 sites along the shelf break. Here, we combine the results of examining both the spatial and temporal distributions of these species using both types of platforms (mobile and fixed) during the time of the shipboard surveys (28 June – 25 August 2016). We also examine the depths of foraging beaked whales using surface reflections collected on the towed hydrophone arrays to look at their vertical water column distribution cross-species. This is the first study of its kind that provides a comprehensive look at how this family is utilizing a large area in three-dimensional space and time.
Dombroski, Julia R. G. (1); Gillespie, Douglas (2); Parks, Susan E. (1); Carbaugh-Rutland, Alexander W. (3); Širović, Ana (4)	(1) Bioacoustics and Behavioral Ecology Lab, Biology Department, Syracuse University, USA; (2) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, Scotland, UK; (3) Department of Biology, Norwegian University of Science and Technology, Norway; (4) University of Miami, USA	Can we rely on accelerometer data to assign calls to tagged baleen whales?	Knowledge of individual cue rate is key parameter for acoustic density estimation. One approach to estimating these cue rates is to deploy sound and motion tags which allow synchronous tracking of an individual`s behavioral context and vocal behavior. However, determining whether a call was produced by the tagged (focal) whale or by a nearby individual (non-focal) is challenging. Some evidence has been put forth that accelerometer signals could solve this problem. This method presumes that only body vibrations from the tagged calling whale produce detectable accelerometer signals. However, given body density and wave properties of low-frequency calls, nearby non-focal calling whales might also produce detectable accelerometer signals. We used data from three different tag types (B-probes, Dtags and Acousondes) deployed on blue and right whales to explore when accelerometer signals are detected on the tags and what causes the variability in received signals. Preliminary results revealed that: amplitude and relative phase of accelerometer signals might indicate distance from the sound source; the sampling frequency of accelerometer and source levels of calls limit detection of accelerometer signals for right whale calls and some blue whale call types; tag type, call types and received levels of calls affect signal quality across accelerometer axis. Therefore, using accelerometer data is not a universal solution to assign calls to tagged baleen whales. The reliability of this method depends on target species, tag type, call characteristics, and above all, on the frequency sampling of accelerometer data.
Ferguson, Elizabeth L.	Ocean Science Analytics	Evaluation of a Deep Learning Neural Network for Use in Real-Time Passive Acoustic Monitoring	Deep learning methods of detecting and classifying marine mammal sounds are rising in popularity due to their high accuracy of identifying signals in dynamic acoustic environments. However, most deep learning models are built using expensive software or are limited to use with archival passive acoustic data. Application of these methods to towed hydrophone array data has the potential to improve monitoring capabilities through reduction of false positive detections from noise and classification of signals in real-time independent of operator experience. PAMGuard, an industry standard software for real-time passive acoustic monitoring, recently added a deep learning module that allows users to import models developed with accessible software. In this effort we build a multi-species deep neural network using Ketos, a Python based tool that can be imported into PAMGuard. We utilize a subset of the recordings from the DCLDE 2022 towed array dataset for the training and testing of the deep neural network. The performance of the recall and precision of the model, in addition to recommendations and limitations associated with real-time monitoring will be presented.

Frankel, Adam S.; Gagnon, Chuck; Stevenson, Dorene; Edell, Michael; Clark, Christopher W.; Dugan, Peer.	Marine Acoustics, Inc.	Remote measurement of cue rates from free-ranging whales across ocean basin scales	Accurately measured cue rates remain one of the most difficult parameters to measure. These rates are often obtained from tags placed on individuals. Acoustic recording tags have limitations that include cost and short duration. A large-scale hydrophone array operated by the U.S. Navy offers the ability to track individual animals for days or weeks at a time. This allows the measurement of a cue rate over a long duration that includes pauses between vocalization bouts. This continuity is made possible through connecting the geographic tracks of individual animals. The large geographic range over which animals can be tracked allows for cue rate measurements that are not only species specific but can be seasonally, geographically, and even behavioral state specific as well. The duty cycle, or percentage of time the defendant whale is vocalizing, has been reported previously and has been shown to vary as a function of swimming speed. Humpback whale singers (N=355) had a mean duty cycle of 53% with a standard deviation of 22%. Monthly duty cycles between November and April varied between 25 and 61% with no strong seasonal pattern seen in these months. Future observations will attempt to track animals earlier and later in the year. Cue rates for fin, blue and sei whales will be presented. Potential limitations of this system include restrictions on geographic specificity of data points.
Frazao, Fabio (1), Kirsebom, Oliver S. (1); Nguyen Hong Duc, Paul (2); Joy, Ruth (3); Matwin, Stan (1)	(1) MERIDIAN, Institute for Big Data Analytics, Dalhousie University; (2) School of Mathematics and Statistics, Carleton University; (3) School of Environmental Science, Simon Fraser University;	Comparing sequence and snapshot artificial neural networks. A study case for the acoustic detection of blue whales.	In recent years, deep artificial neural networks have been applied to acoustically monitor marine mammals with significant success. The most commonly used approaches use network architectures developed for image classification tasks in computer vision. Audio clips, usually represented in the time-frequency domain, are treated as isolated snapshots. Sequence architectures, on the other hand, take a sequence of events into consideration and are often employed in natural language processing tasks, such as translation. In this contribution, we use the DCLDE 2015 dataset to build blue whale (Balaenoptera musculus) detectors using both approaches and compare their performances. The snapshot detector was based on a residual network architecture and used magnitude spectrograms representing 5 seconds of audio. The output is a score (a single number between 0 and 1) indicating whether the clip contained a blue whale call or not. The sequence detector was based on temporal convolutional layers and gated recurrent units. It used spectrograms with the same parameters but with a length of 180 seconds. The output is a vector of scores, indicating when a blue whale call was detected within the 3 minutes clip. Using the same amount of training data and same score threshold (0.5), the sequence detector showed superior precision (0.90 vs 0.47) but inferior recall (0.68 vs 0.95) when detecting individual calls. Sequence architectures might provide a better alternative to the more widely-used snapshot architectures for detectors. We also suggest that detection systems can take advantage of both approaches.
Frouin-Mouy, Héloïse (1,2); Frasier, Kaitlin E. (3); Hildebrand, John A. (3); Rafter, Macey (3); Garrison, Lance P. (2); Soldevilla, Melissa S. (2)	(1) Cooperative Programs for the Advancement of Earth System Science (CPAESS) | University Corporation for Atmospheric Research (UCAR); (2) NOAA Southeast Fisheries Science Center; (3) Scripps Institution of Oceanography, University of California San Diego	Density estimation of beaked whales in the northern Gulf of Mexico from a decade of acoustic monitoring	Passive acoustic density estimation methods have focused on beaked whales since these long-diving, cryptic species are challenging to survey visually but are readily detected using passive acoustic methods. From 2010-2020, the Scripps-led GOM HARP passive acoustic monitoring project collected nearly-continuous acoustic data at five sites using fixed seafloor sensors. This study expands on weekly density estimates developed for Cuvier's and Gervais' beaked whales over the 2010-2013 period using both cue-counting and group-counting methods (e.g. Hildebrand et al. 2015). This starts with improvements in click detection and classification using a recently developed machine learning pipeline (Frasier 2022) combining unsupervised and supervised learning phases and producing two levels of classification. The bin-level classification has high accuracy, while the click-level classification has the advantage of providing a label for every signal and might reveal smaller detection events but generates many false positives. We examined the trade-off between this new algorithm and a prior expert (manual) approach. Density estimates of beaked whales in the northern Gulf of Mexico are calculated using results from the new classifier and compared to previously published results. Finally, by using data from a multi-channel HARP, an alternative approach will be tested to estimate the detection function. Using an approach similar to Barlow et al. (2021), detection angles will be estimated from the time-difference-of-arrival of signals on the hydrophones. Applying a maximum simulated likelihood approach, these detection angles and the depth distribution of animals (estimated from other studies) will be used to estimate range-dependent detection probability for beaked whales.

Garrobé Fonollosa, Laia (1); Gillespie, Douglas (1); Pirotta, Enrico (2)(3); Brotons, José María (4); Cerdà, Margalida (4); Rendell, Luke (1)	(1) Scottish Oceans Institute, University of St Andrews, St Andrews, Sctoland; (2) Department of Mathematics and Statistics, Washington State University, Vancouver, WA, USA; (3) School of Biological, Earth and Environmental Sciences, University College Cork, Cork, Ireland; (4) Asociación Tursiops, Palma de Mallorca, Balearic Islands, Spain	A deep learning acoustic framework to detect sperm whale echolocation clicks: A case study investigating occurrence in the Balearic Sea	Passive Acoustic Monitoring (PAM) is an increasingly popular tool to study the occurrence of sperm whales (Physeter macrocephalus), which emit frequent and easily detectable echolocation clicks. The amount of data generated by PAM studies calls for robust automatic classifiers. Deep Learning (DL) techniques have been proven effective in identifying acoustic signals in challenging datasets, but due to their black-box nature, their underlying biases are hard to quantify. For this work, a multi-step DL algorithm was developed to classify acoustic files according to the presence/absence of sperm whale vocalizations. At the core of the proposed DL classifier there was a Convolutional Neural Network (CNN) trained to detect sperm whale echolocation clicks from spectrogram representations of 5-second audio segments. Temporal context was incorporated via a Linear Neural Network which operated on sequences of outputs from the CNN click detector. After having been trained on recordings from three different sampling locations in the Balearic Sea, the classifier generalised well on new data from those sites, yielding areas under the ROC curve between 0.895 and 0.933 when tested against manual classifications. Seasonal and diel variations in sperm whale detections in the area were modelled for both the proposed classifier and a traditional Multi-Hypothesis Tracking click train detector refined for the used dataset. Results showed agreement between both classifiers, exhibiting increases in both occurrence and diurnal activity in Summer and Autumn months. The findings of this project highlight the potential of DL algorithms to extract biologically useful information from large acoustic datasets.
Gkikopoulou, K.C. (1) , Gillespie D.M. (1), Harris, D. (2), Johnson, M.P. (3), Tyack P.L. (1), Aguilar de Soto, N. (4) , Hickmott, L. (1,5) and Marques T. A. (2)	(1) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews; (2) Centre for Research into Ecological and Environmental Modelling, Buchanan Gardens, University of St. Andrews; (3) Aarhus Institute of Advanced Studies, Aarhus University; (4) BIOECOMAC, Department of Animal Biology, Edaphology and Geology, University of La Laguna; (5) Open Ocean Consulting	Stability of acoustic cues for density estimation.	The spatial density of echolocating species can be estimated by passive acoustic detection of their sounds. It is important to use sound cues that are both produced in a consistent way by the animal, and that can be detected in a consistent way by human operators and/or PAM software. Possible acoustic cues from echolocating toothed whales are individual clicks, sequences of clicks (click trains) and the presence of these cues in a pre-specified time interval. Here we explore different ways of counting acoustic signals and their variance, taking into account both the sound production mechanism (e.g. click directionality, and production rate (regular clicks versus rapid buzzes)) as well as the detection system (e.g. click trains may have a lower false positive rate than individual clicks). We use a simulation-based approach to investigate count stability for two deep-diving species with different sound production characteristics: Blainville's beaked whales (Mesoplodon densirostris) and sperm whales (Physeter macrocephalus). We use DTAG data collected at two different locations for each species: El Hierro (Canary Islands, n=14) and the Bahamas (n=5) for Blainville's beaked whales and the Mediterranean (n=7) and New Zealand (n=6) for sperm whales, to inform diving and acoustic production behavior. We perform sensitivity analyses on the choice of acoustic cue on species acoustic detectability, taking in to account the detection system. We explore the differences and the implications of using either moving or stationary passive acoustic platforms, on the performance of the procedures considered.
Grebner, Dawn (1); Renken, Martin (1)	(1) Naval Undersea Warfare Center Division, Keyport	Algorithms for detecting highly directional and very high frequency sounds from harbor porpoises	Detection of marine mammal sounds is important for species presence awareness and habitat usage (on Navy ranges). While it is common knowledge that finding an ideal detector suited for a diverse array of species is unlikely, maximizing detections of individual broadband sounds from a single species with low false alarms can also be problematic when future research goals extend beyond presence awareness. Two types of detector algorithms previously used or discussed in marine mammal detection literature were developed to find a reliable detector for highly directional and very high frequency echolocation clicks produced by harbor porpoises (Phocoena phocoena); they include a spectral energy-based threshold and harbor porpoise click matched filter. A single hydrophone system captured acoustic data with harbor porpoise sounds. Data sampling was opportunistic and collected over a period of one and a half years. Visual analysis using spectrograms for a subset of the data aided in identifying and locating harbor porpoise clicks. A comparison of both detector performances to visual click counts will be discussed along with potential paths forward to maximize the probability of detections while keeping the false alarm rate low enough to be usable.

Gruden, Pina (1); Nosal, Eva-Marie (2); Oleson, Erin (3)	(1) Cooperative Institute for Marine and Atmospheric Research (CIMAR), Research Corporation of the University of Hawaiʻi; (2) Ocean and Resources Engineering, University of Hawaiʻi at Manoa; (3) Pacific Islands Fisheries Science Center, NOAA	Towards a unified multi-target tracking framework for marine mammals	Underwater acoustic recordings of marine mammal vocalizations are typically noisy and often contain multiple animals vocalizing simultaneously. In addition, measurement availability can change significantly during a single recording, as animal call rates vary with different behavioral states and as propagation conditions fluctuate. Tracking signals produced by individuals or a closely spaced group of animals can be difficult in such cases and often involves substantial manual effort. We discuss and build on a general framework, formulated on multi-target Bayesian and finite set statistics [Gruden, P. et al., J. Acoust. Soc. Am. 150(5), 2021], that allows automatic tracking of multiple targets in the presence of false alarms and missed detections. This framework addresses a variety of passive acoustic tracking applications, including tracking bearing and/or location estimates, or other features of interest. To demonstrate the use of this framework on the DCLDE Oahu dataset, we examine joint multi-target tracking of broadband clicks and narrowband whistles for different species to improve on time-difference-of-arrival tracking compared to either signal type alone. We also demonstrate how surface reflections can be tracked with this framework to improve localization estimates and briefly discuss applications to other array types beyond the DCLDE Oahu dataset.
Hanson, Paige (1); Margolina, Tetyana (2); Joseph, John (2)	(1) Eckerd College 1; (2) Naval Postgraduate School 2	Acoustic Identification of Feeding Aggregations in the Monterey Bay National Marine Sanctuary	Sound plays many important roles in the lives of cetaceans including foraging, navigation, social interaction, mating, and detecting predators. To investigate the role of sound within the ocean, passive acoustic monitoring has often been implemented. One leading example of passive acoustic monitoring is SanctSound, which monitors the soundscapes of national marine sanctuaries, including Monterey Bay National Marine Sanctuary (MBNMS). Within MBNMS, concentrations of food drive feeding aggregations, which are defined as multi-species gatherings feeding upon a schooling group of prey. I hypothesize that feeding aggregations produce unique acoustic signatures that can be identified from acoustic data. I will use data from SanctSound to identify the acoustic signatures produced by feeding aggregations occurring in September 2019 within MBNMS by visually scanning the data. To provide additional support that the acoustic identification is a true feeding aggregation, chlorophyll A, upwelling indices, and whale watching visual data will be utilized, and the power spectral density will be analyzed. Preliminary acoustical analysis identified a hypothesized feeding aggregation on September 3rd, 2019, from 6-8 GMT. The outcome of this research will explore acoustic ecology since feeding aggregation acoustic signatures likely advertise food availability to pelagic predators, including cetaceans. The identification of feeding aggregation acoustic signatures is also a tool for the conservation of cetaceans and for future research, which is important for the marine ecosystem and a large proportion of the human population.
Harris, Danielle (1); Pereira, Andreia (2); Hilmo, Rose (3); Matias, Luis (2); Mellinger, David K. (4); Wilcock, William (3); Heaney, Kevin D., (5); Marques, Tiago (1); Miksis-Olds, Jennifer L. (6); Seger, Kerri D. (5); Thomas, Len (1); Tyack, Peter (1)	(1) University of St Andrews, UK; (2) University of Lisbon, Portugal; (3) University of Washington, WA, USA; (4) Oregon State University, OR, USA; (5) Applied Ocean Sciences, LLC, VA, USA; (6) University of New Hampshire, NH, USA	Using ocean bottom seismometers (OBSs) for blue and fin whale density estimation: a review	Monitoring programs to determine marine mammal densities are costly, so it is beneficial to investigate alternative surveying and analytical methods that allow monitoring programs to be cost efficient yet robust. One approach is to use data from instrumentation deployed for other purposes. Ocean bottom seismometers (OBSs) and the Comprehensive Nuclear Test Ban Treaty Organization International Monitoring System (CTBTO IMS) are prime examples of such "platforms of opportunity". Many hundreds of OBSs are used by the global academic community and they are being deployed increasingly often in large arrays for periods of a year or more. The experiment sites often fall in areas of research interest for baleen whales, particularly blue and fin whales, which call below the 25 - 100 Hz upper frequency limit of OBSs. Here we review the current status of OBS datasets with a view to using these data for global blue and fin whale density estimation. The review focuses on (1) an overview of previous OBS studies relating to cetacean monitoring and (2) the variability in OBS datasets and how we anticipate this variability will affect future density estimation analyses. This review is part of a recently initiated larger project "CORTADO: Combining global OBS and CTBTO recordings to estimate abundance and density of fin and blue whales", which will (1) demonstrate density estimation methods across a selection of OBS and CTBTO IMS deployments, including a variety of instrument configurations and acoustic propagation conditions and (2) provide an accompanying set of software tools and training materials.

Helble, Tyler (1); Dugan, Peter (2); Henderson, E. Elizabeth (1)	(1) Naval Information Warfare Center, Pacific (2) Cornell University	Improving Methods for Automated Detection of Navy Sonar	An evaluation of the performance of existing sonar detectors was conducted on a variety of datasets containing Navy sonar. The evaluation datasets include hydrophone recordings from U.S. Navy training ranges and opportunistic recordings from the U.S. east coast, west coast, and Hawaiian Islands. While the existing detectors performed well under certain conditions, none of the detectors could be tuned to perform well over the evaluation datasets selected for the study. A new generalized sonar detector was therefore developed by creating a shallow learning net using the Tensor-Karas API. The net was integrated into the Cornell Raven-X software package, which is capable of processing large datasets in a variety of formats using efficient parallel processing. The detector performed well on the evaluation datasets and was further evaluated using 184 days of data recorded in the Hawaii Marine Sanctuary without any additional training. The detector performed well at identifying bouts of Navy sonar even in the presence of considerable biological activity including long periods of humpback song. The average false positive was less than 3 events/hour, which allowed a human to remove the false positives for the entire dataset in less than 2 hours.
Hendricks, Benjamin	SoundSpace Analytics	Sea-to-Screen: Building an autonomous DCL monitoring tool for coastal stewards	Detection, Classification and Localization (DCL) of marine bio-acoustic signals is a powerful tool for scientists to study marine ecosystems that can poorly be probed with electromagnetic sensors. In recent years, DCL data become increasingly thought after by marine stakeholders, who seek to manage areas under their stewardship amid challenges associated with climate change and increasing vessel traffic. Of particular interest are systems that can operate autonomously and in real-time (RT) which do not have to be controlled and interpreted by trained scientists. I present such a RT DCL monitoring system designed and developed for coastal Indigenous communities and NGOs. The system deploys a pool of species-specific detectors (currently fin, humpback, and killer whales) and an AI classification scheme based on annotated training libraries. Localization is carried out on a call-by-call basis using TDOA-generated surface probabilities. The design is tailored around performance, robustness, and simplicity to facilitate remote and autonomous operation providing reliable RT data products. To facilitate user access to key metrics, the DCL routines are integrated in a larger framework that also includes autonomous communication with the acoustic data logger, data transfer to a web-based repository, and the visual presentation of soundscape metrics via web-based interactive user dashboard. I present the integrated DCL methods, outline the sea-to-screen data flow, and discuss what is and what is not feasible within such autonomous RT applications. I also showcase results we obtained throughout the first 24 months of operation, including the first documented acoustic fin whale tracks in a Canadian coastal fjord.
Hilmo, Rose S (1).; (2) Wilcock, William S. D.	(1) University of Washington; (2) University of Washington	Ranging to fin whale calls at full ocean depths using single ocean bottom seismometers	Fin whale calls are routinely recorded on ocean bottom seismometers (OBSs), but the networks are often too sparse for multi-station call localization, in which case single station methods must be used for population density studies. Single station ranging using multipath timing and amplitude has been demonstrated in water depths of ~2500 m. In the sedimented Cascadia Basin, the analysis is complicated by subseafloor reflections and the first multipath is difficult to detect at small ranges because of the low amplitude of seafloor reflections at high incidence angles. We are conducting a study to evaluate the feasibility of multipath ranging at full ocean depths using five deep OBSs (4200-6000 m) from regions with contrasting seafloor and subseafloor properties. We detect calls using spectrogram cross-correlation to yield a time-dependent recognition score. To enhance signal to noise, we consider all the calls within a time window and pick the two strongest multipaths from 1) the autocorrelation of the recognition score and 2) the summed spectrograms for calls aligned on the peak recognition score. We use amplitudes to determine if the identified arrivals are the direct and first multipath as expected for calls at shorter ranges and estimate range by comparing the time difference between arrivals with ray tracing predictions. The method can successfully range to calls in song sequences out to >10 km at sites with highly reflective basalts or shallow lithified sediment layers. To effectively range at most sedimented sites, it is necessary to understand complex arrivals through modeling subsurface reflections.

Ho, Abel (1); Koay, Teong Beng (1); Wu, Yusong (2); Vishnu, Hari (1); Ng, Yew Choong (1); Chitre, Mandar (1); Lim, Karen (2); Tun, Karenne (2)	(1) Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore; (2) National Parks Board, Singapore	A Cloud Enabled Passive Acoustic Monitoring Array with Real-time Detection of Marine Megafauna	Various species of dolphins, porpoises and dugongs have been known to inhabit the waters in Singapore. Although there are many anecdotal sightings, quantitative analyses of their visiting patterns are not available. Due to their rare surface expression and poor visibility of local waters, it is inefficient to conduct monitoring based on boat surveys. Instead, we focus on using a 4-channel, high-frequency underwater Passive Acoustic Monitoring (PAM) array with real-time machine learning (ML) to detect and localize sparse marine mammal vocalizations. The setup includes a surface optical camera that would automatically point towards the direction of vocalization estimated by the PAM. This aims to opportunistically capture visual ground truths if the subjects surface after the acoustic detection. A variety of in-situ environmental and shipping data is also acquired to study the relationship between visits and the environment. We will present the setup of a system designed for this purpose. It consists of a solar-powered Edge Computing Unit (ECU) deployed onshore to support ML-based event detection and an Underwater Unit that hosts acoustic and environmental sensors. The ECU then uploads the detected acoustic signal, camera footage and metadata to a cloud instance created to allow remote visualization and verification. Finally, the preliminary result and operations of the integrated setup with continuous recording, real-time automated detection, localization, camera control and data snippet upload will be discussed.
Hoffmann-Kuhnt, Matthias (1); Ho, Abel Zong Hao (1), Vishnu, Hari (1)	(1) Acoustic Research Laboratory, National University of Singapore	Sing Me a Song! - Trials and tribulations of a first attempt to record humpback whale mother-calf pairs in the DR with a new version of a synchronised video/audio array.	Based on our previous recoding system we developed an adaptable advanced video/audio recording device that consisted of a 6k resolution camera (z-cam E2S6) with an ultrawide angle lens (170 degree FOV , 4 hydrophones (Reson 4013 with custom in-line amplifiers) a data acquisition card with a sampling rates of 400 kSamples/second/channel, custom second-stage amplifiers and custom power management. The system was housed in a 6-inch diamter custom-built aluminium tube with a Nauticam fisheye dome port in the front plate and control switches and LEDs in the back plate. Attached to the housing were 3 aluminium arms extending out to form an equilateral triangle with three of the hydrophones in each of the corners and the camera in the center of that triangle. A fourth hydrophone was mounted with a 30 cm offset of the plane of the other hydrophones to eliminate a possible front/back ambiguity for localisation of sources. Different length arms could be attached to the housing to form smaller and larger arrays – this allowed us to make a large enough array (120cm hydrophone separation) to record and identify low frequency sources (humpback whale mother/calf pairs). This system was deployed for the first time in the waters of the Dominican Republic (Naviad Bank and Silver Bank) in March of 2021. We report here the first attempts of deployment and recording with this system and the analysis of the results.
Hom-Weaver, Cory (1); Sakai, Taiki (1); Rankin, Shannon (3)	(1) Contractor with Environmental Assessment Services for Southwest Fisheries Science Center. (2) Southwest Fisheries Science Center	An automated approach to the detection and classification of fin whales in the California Current Ecosystem using open source software	To identify the presence of fin whales throughout the California Current Ecosystem we analyzed acoustic recordings that were collected in the summer and fall between 2018 and 2019 from 14 different locations. A total of 30.7 days of duty-cycled recordings (2 min on/18 min off) were analyzed with PAMGuard acoustic software. Recordings were decimated to 200Hz, and a click detector was applied to classify 20Hz fin whale pulses. At this low sample rate the pulses are similar in structure to odontocete clicks. Using the R package PAMpal, each two-minute wav file was defined as a fin whale event if the file contained one or more 20Hz pulses. We manually validated 20% of the events (and 10% of non-events) from each site to identify false positives and negatives. A hierarchical random forest acoustic event classifier (BANTER) was then developed using the validated data to classify fin whale events. The BANTER model correctly classified 80% of the events with 20Hz fin whale pulses. The short duration of our duty cycled recordings likely complicated our ability to measure inter-note-interval (INI), which is an important variable in the classification of fin whales. Future work will include developing a BANTER classifier for longer duty-cycles (> 2 min files) to allow for the proper measurement of INI. Slight improvements to the classification accuracy of this model may result in a highly automated approach for detection and classification of fin whales within larger datasets, along with the ability to detect fin whales independent of call density.

Hursky, Paul	Applied Ocean Sciences LLC	Using Doppler as a cue to identify and track individual animals	Using passive acoustic monitoring of dolphins by tracking their vocalizations is a valuable complement to visual observations. Dolphin calls include whistles and clicks that are wideband and high in frequency. Although whistles are "narrowband" in that they have an instantaneous frequency, they are wideband waveforms over their duration, with a large time-bandwidth product that yields time-of-arrival accuracies comparable to LFM/HFM active sonar waveforms. Although they move through the water at moderate speeds, the high frequency and wide bandwidth of their calls result in readily observable Doppler. Unless we have an acoustic tag on the animal, we typically do not have a (Doppler-free) replica of their calls, to be used in a matched filter. However, observing an animal from two directions provides two Doppler-shifted copies of their call which can be cross-correlated to produce both a time difference of arrival and relative Doppler. Dolphins typically travel in groups. Whistles have distinct "melodies", so we can readily associate individuals whistles with individual animals. However, we cannot so easily associate clicks with individual animals, or even to multipath arrivals. The clicks are too similar. The Doppler observed at different observers enables us to associate clicks from overlapping sequences of clicks to individual animals. We will present how to estimate the location and velocity of individual animals, by processing clicks and whistles from separated hydrophones with 2D correlators that reveal both time differences of arrival and relative Doppler. We will discuss how this impacts dolphin tracking and counting.
Indeck, Katherine L. (1); Gehrmann, Romina (2); Barclay, David (2); Baumgartner, Mark F. (3); Nolet, Veronique (4); Davies, Kimberley T. A. (1).	(1) University of New Brunswick; (2) Dalhousie University; (3) Woods Hole Oceanographic Institute; (4) Transport Canada Innovation Centre	Spatial variation in baleen whale calls within and near shipping lanes detected by mobile and stationary recorders	Passive acoustic monitoring (PAM) has become an integral tool for determining the presence, distribution, and behavior of vocally active cetacean species. Acoustically equipped underwater gliders programmed with detection and classification software are becoming a routine monitoring platform because of their ability to relay data to shore-based analysts in near-real time, overcoming the accessibility limitations of many traditional archival recorders. Indeed, this technology has proven useful in triggering dynamic management actions in areas with a high degree of overlap between vessel traffic and whales. More research on site- and system-specific factors that influence effective detection of cetacean calls is needed. For this study, three PAM systems were deployed simultaneously in the Honguedo Strait and associated traffic separation scheme in the Gulf of St. Lawrence, Canada, in 2019. These included two autonomous multi-channel acoustic recorders (AMARs; one located directly underneath the southern shipping lane, one 20 km outside the lanes) and a glider that repeatedly transited across the shipping lanes and over both AMAR moorings. All systems monitored continuously for low frequency (<1 kHz) baleen whale vocalizations, including those from North Atlantic right, fin, and blue whales. The systematic sampling scheme was designed to study relative spatial variation in species-specific detection rates and ranges between high versus low ship noise environments, as well as between moored and mobile acoustic platforms. The results of this research provide a foundation for evaluating and refining near-real time analysis protocols in this region to best inform management decisions aimed at minimizing ships strikes of endangered whales.
Jang, Junsu; Snyder, Eric; Meyer, Florian; Wiggins, Sean; Baumann-Pickering, Simone; and Hildebrand, John	Scripps Institution of Oceanography	Toward automated tracking of marine mammals in 3-D using volumetric hydrophone arrays	Tracking marine mammals based on their bio-acoustic signals can reveal key insights on behaviors underwater that otherwise would remain unexplored. However, automating the tracking process remains a challenge, and currently, human operators are required to manually inspect acoustic data, make decisions on the presence of marine mammals, and select promising detections. With the goal to reduce the involvement of human operators, we propose a signal processing and parameter estimation approach for automated tracking of marine mammals in 3-D. As a case study, the capability to automatically identify and track a single Cuvier's beaked whale (Ziphius cavirostris) from data provided by two volumetric hydrophone arrays is demonstrated. In a first processing step, our approach computes the time difference of arrival (TDOA) of the echolocation clicks between pairs of hydrophones on each array using a generalized cross-correlator that is designed to suppress instrument noise. Next, for each pair of hydrophones, the TDOA detections are extracted, and a graph based multitarget tracker approach is used to close long gaps of missing detections and reject clutter. The resulting estimated TDOAs are then fused across hydrophone pairs by a multisensor Bernoulli filter to generate a track of the beaked whale in 3-D. The estimated 3-D track is compared with a track generated with the aid of a human operator to confirm agreement with the current state-of-the art. Future work includes an extension to datasets with multiple beaked whales and scenarios with different species of marine mammals.

Jarvis, Susan; Carroll, Alexandra	Naval Undersea Warfare Center, Newport	Automated Acoustic Monitoring and Classification of North Atlantic Right Whales on the Jacksonville Shallow Water Training Range	The severely endangered North Atlantic right whale (Eubalaena glacialis, Eg) inhabits the Atlantic Ocean primarily between 20 and 60 degrees north latitude. During the winter months, the population is known to migrate down the east coast of the US to an area NOAA has designated as the Southeast U.S. Critical Habitat, which runs along the coast from Cape Fear, NC to Cape Canaveral, FL. The U.S. Navy's Jacksonville Shallow Water Training Range (JSWTR) facility is installed approximately 95 km east of Jacksonville, FL, in an area just east of the identified southeastern critical habitat. The newly complete range is comprised of 258 bottom-mounted broadband (0-48kHz) hydrophones The density, permanence and invariance of this sensor field offers a unique resource for passive acoustic monitoring of NARW. Since December 2019, a Marine Mammal Monitoring on Navy Ranges (M3R) system has been archiving low frequency (0 to 3kHz) spectrogram data from 128 of the JSWTR hydrophones covering an area of approximately 850 km2. Additionally, 100+ hrs of broadband (0-48kHz) recordings from the 128 hydrophones have been taken during the winter months. To date, we have observed multiple presumed NARW calls on M3R displays and even automatically localized "gunshot" sounds using the spectrogram data. We are engaged in a systematic review of both the spectrogram data and full bandwidth recordings to identify and extract NARW calls to serve as training and test data sets. These data will augment the NARW data sets available from past DCLDE conferences and be used to extend existing approaches to NARW classification using techniques for unbalanced machine learning problems. Automated NARW classification is so difficult largely because it is inherently unbalanced. Across any interval of time and for any level of effort expended, NARW calls are much less likely to be present than calls from confusion species. However, one way to build confidence in the classification of a rare event, like a NARW call, is to become confident in what it is not. We will present a multi-class classification approach that builds pairwise classifiers for NARW calls versus calls from common confusion species and anthropogenic sounds. The aggregate results from the pairwise decision functions are scored to determine the class present. The goal is to establish a robust, persistent, fully-automated passive acoustic monitoring system for NARW at the Jacksonville Shallow Water Training Range.
Kaney, Nick (1); Yack, Tina M. (2); Schick, Rob (2); Nowacek, Douglas P. (1); Yu, Nathan (1); Davis, Genevieve (3); Baumgartner, Mark (4); Gillespie, Douglas (5); Palmer Kaitlin (6); Tyack, Peter (7)	(1) Duke University, Nicholas School of the Environment; (2) Duke University, Marine Geospatial Ecology Lab, Nicholas School of the Environment; (3) NOAA, Northeast Fisheries Science Center; (4) Woods Hole Oceanographic Institution; (5) University of St. Andrews, Sea Mammal Research Unit, School of Biology, Scottish Oceans Institute, St Andrews; (6) SMRU Consulting; (7) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews	Assessment and comparison of algorithms for North Atlantic right whale (Eubalaena glacialis) upcall detection and classification	North Atlantic right whales (Eubalaena glacialis) (NARW) have been declining since the early 2010s with a current total population estimate of 336 individuals due to a myriad of anthropogenic issues. One of the most important and successful tools for conservation and research on right whales is passive acoustic monitoring (PAM). The biggest drawback of PAM is that manual cataloging can take large amounts of time to process, even for a trained analyst. In order to combat this, several automated classifiers have been developed to help automate PAM data analysis. A few detectors and classifiers have been created for NARW upcalls, herein we evaluate the PAMGuard NARW Edge Detector, the PAMGuard LeNet, and the IDL Low Frequency Detection and Classifier System (LFDCS). To compare, we are using 7 trial days from the DCLDE 2013 dataset off Stellwagen Bank, Massachusetts. This data was manually analyzed by 3 trained analysts in order to determine the accuracy of the automated detection and classification algorithms. One analyst evaluated the entire data set directly, while the other two assessed detected upcalls using PAMGuard's edge detector as true or false. To compare the LFDCS, an analyst then used IDL software to confirm the individual LFDCS upcall detections. We will provide an evaluation of the performance of the PAMGuard edge detector, PAMGuard LeNet classifier, and the IDL LFDCS algorithm to better inform future conservation and research while simultaneously adding in an evaluation of inter-analyst variability.

Kirsebom, Oliver S. (1); Bergner, Steven (2); Campbell, Dave (3); Dowd, Michael (4), Frazao, Frazao (5), Joy, Ruth (6); Nguyen Hong Duc, Paul (7); Padovese, Bruno (8); Randon, Marine (9); Riera, Amalis (10); Sakib, Sadman (11); Veirs, Scott (12); Veirs, Val (13); Wladichuk, Jennifer (14); Yurk, Harald (15)	(1,5,8,10,11)) MERIDIAN, Institute for Big Data Analytics, Dalhousie University; (2) Computing Science, Simon Fraser University; (3) School of Mathematics and Statistics, Carleton University; (4) Department of Mathematics and Statistics, Dalhousie University;(6) School of Environmental Science, Simon Fraser University; (7) School of Mathematics and Statistics, Carleton University; (9) School of Environmental Science, Simon Fraser University; (12) Orcasound, Beam Reach; (13) Orcasound, Beam Reach; (14) University of Victoria, JASCO Applied Sciences; (15) Fisheries and Oceans Canada	Open-source deep learning models for acoustic detection and classification of orcas	Current efforts to acoustically study and monitor killer whales in British Columbia (BC), including the endangered population of Southern Resident killer whales (SRKW), are hampered by the lack of sufficiently accurate sound detection and classification algorithms. Recently, several research groups have reported significant improvements in algorithm performance utilizing deep neural networks. However, for most practitioners, these novel tools remain out of reach. To bridge this gap, we are developing a set of open-source deep learning models for acoustic detection and classification of BC's killer whales. These models will be made publicly available along with expert-curated training and test sets to facilitate further development and applications. We are collaborating with Orcasound to deploy the models on their live data. We are also working together with the PAMGuard developer team to ensure that our models can be seamlessly integrated into PAMGuard, a widely used open-source software platform for passive acoustic monitoring. In this contribution, we will provide an overview of our deep learning methodology and present preliminary results on model performance, with particular attention to the model's ability to handle diverse and variable acoustic environments and generalize to new 'unseen' environments
Kügler, Anke (1); Lammers, Marc (2); Tenorio-Hallé, Ludovic (3,4); Meyer, Florian (3); Gruden, Pina (5); Thode, Aaron (3)	(1) Marine Biology Graduate Program, University of Hawaiʻi at Mānoa; (2) Hawaiian Islands Humpback Whale National Marine Sanctuary; (3) Marine Physical Laboratory, Scripps Institution of Oceanography; (4) NOAA Southeast Fisheries Science Center; (5) Cooperative Institute for Marine and Atmospheric Research (CIMAR), University of Hawaiʻi	The singing behavior of humpback whales off Maui, Hawaiʻi revealed through acoustic localization with vector sensors	Male humpback whales produce an elaborate acoustic display known as 'song' during their breeding season. Previous studies with bottom-moored acoustic recorders off West Maui, Hawaiʻi showed strong diurnal patterns in chorusing levels. These patterns were observed by calculating root-mean-squared sound pressure levels (RMS SPL) from the ambient sound generated by numerous whales singing in an asynchronous chorus. RMS SPLs increase at night at near-shore sites and decrease during the day, while an off-shore site showed a correlated inverse pattern with an increase in chorusing during the day. It remains unclear whether these patterns reflect diurnal movement of singers between shallow and deeper waters or a behavioral change in singing activity. Recent land-based visual observations in the same area suggest that adult whales, but not mother-calf pairs, on average move further offshore as the day progresses. However, conclusions are guarded as those surveys were limited to primarily morning hours and by the inability to reliably identify singers. Acoustic localization of individual singers is challenging in places where the aggregation of whales is so large that individual sound units overlap so much that techniques using time-domain cross-correlation become impractical. In March 2020, a pilot study was conducted with three bottom-moored DASAR (Directional Autonomous Seafloor Acoustic Recorder) vector sensors off West Maui making it possible to localize multiple whales singing simultaneously. This has allowed us to infer the spatial patterns of singers in the area over time and is helping us better understand their diurnal singing behavior.
Lammers, Marc (1); Goodwin, Beth (2); Kuegler, Anke (3); Harvey, Matt (4); Zang, Eden (1); Martinez, John (5); Hatch, Leila (6)	(1) Hawaiian Islands Humpback Whale National Marine Sanctuary; (2) Jupiter Research Foundation; (3) University of Hawaii at Manoa; (4) Google, Inc.; (5) Papahānaumokuākea Marine National Monument; (6) Stellwagen Bank National Marine Sanctuary	Along for the glide: humpback whale presence in Papahānaumokuākea Marine National Monument revealed by a Wave Glider autonomous surface vehicle	The occurrence of humpback whales in Papahānaumokuākea Marine National Monument (PMNM) remains poorly understood. Previous vessel-based surveys for humpback whales in the Monument have been limited due to harsh winter month conditions. The National Oceanographic and Atmospheric Administration (NOAA) and the U.S. Navy are co-managing a multi-year effort (SanctSound) to monitor underwater sound within the National Marine Sanctuary System, including PMNM. Through this project, a partnership with The Jupiter Research Foundation was established to conduct a passive acoustic monitoring survey in PMNM waters using a Wave Glider between January and March 2020. The Wave Glider transited 2,627 nautical miles and made 92,408 1-minute recordings throughout the survey. The occurrence of humpback whale song in recordings was established using a machine-learning algorithm developed in partnership with Google. Analyses of the data revealed that humpback whale song was present at nearly every bank or shoal that the glider visited. Middle Bank, which lies just outside the boundaries of PMNM and is closest to the main Hawaiian Islands, had the highest prevalence of whale song. Song occurrence remained high between Nihoa and French Frigate Shoals before waning substantially at Gardner Pinnacles. Song occurrence increased again at Raita Bank, remaining high between Maro reef and the Northampton Seamounts. The results suggest a broad but somewhat clustered distribution of humpback whales across PMNM. It can be concluded that, like in the main Hawaiian Islands, the shallow banks and shoals of PMNM represent important winter breeding habitat for the north Pacific humpback whale population.

Lê, Hoàng-Ân (1, 2) ; Pham, Minh-Tan (2) ; Lefèvre, Sébastien (2) ; Heerah, Karine (1)	(1) France Énergies Marines ; (2) IRISA, Université Bretagne Sud	Performance of off-the-shelf computer vision deep neural networks on spectrogram-based marine mammal detection	Marine mammals such as blue and fin whales can be detected from the spectrogram of their acoustics. Spectrograms have different properties and characteristics than ordinary optical images. Therefore, detection methods designed for computer vision tasks may find difficulty in working efficiently on spectrogram data. In this paper, state-of-the-art deep neural network models implemented by the Detectron2 library are experimented using a subset of the DCLDE 2015 LF dataset. In particular, the Faster RCNN and RetinaNet model with various backbone architectures such as ResNet50, ResNet101, and FPN are examined. The data subset composes of 50 consecutive hours of the CINMS18B file, recorded within the Channel Islands National Marine Sanctuary and starting on the 23th June 2012, whose calls are annotated with time-frequency bound by Paul Nguyen et al. (2021) The experimental results show that the network can recognize a large number of calls. However, the capacity in classifying call types is still limited. We believe this work would be instrumental in bridging the domain gap of bioacoustics and computer vision, hence facilitate automatic recognition of marine mammals from their acoustics.
LeBlond, Taylor (1); Yurk, Harald (1)	(1) Fisheries and Oceans Canada	Automatic Detection and Identification of Various Cetacean Calls Using Music Information Retrieval Techniques	PAMGuard's Whistle and Moan Detector (WMD) module is a frequently-used tool for detecting whale calls in the Salish Sea, especially those of killer whales. However, many if not most of the detections produced by the WMD are not actually killer whale calls, as the module does not have any means of automatically classifying the species of each detection. These false detections are generally caused by either vessel noise, environmental noise, humpback whales, or Pacific white-sided dolphins. Overlapping sound frequency ranges between the species and strongly varying background noise levels provide an additional challenge. This paper describes the progress made in the creation of a machine learning classifier that takes WMD detection data as input and attempts to determine the source of the noise that produced each detection. While it would appear that many recent similar projects primarily use spectrogram image analysis, this project primarily uses techniques that are common in the field of music information retrieval (MIR) and uses features derived directly from the audio or contour metadata. Recent preliminary test results produced a prediction accuracy of 71.8%. This is considered to be relatively high considering that the dataset is far from complete and currently only consists of audio from one location over a span of a month and a half. Expansion of the dataset with audio from new locations is expected to increase this number. To which extent additive background noise skews the results is currently being investigated, thus, this paper also discusses noise reduction techniques.
Lechner, David; Vignola, Joseph; Guan, Shane; Turo, Diego	The Catholic University of America	Acoustic Energy Maps for Marine Mammal Localization Using Comprehensive Test Ban Treaty (CTBT) Data	This paper presents the adaptation of the Cross Ambiguity Function Mapping (CAF-Mapping) algorithm for use in acoustics to create real-time maps of acoustic energy. The CAF-Mapping algorithm provides a useful means of generating a geographic visualization of acoustic energy. Modifications of the algorithm for use in acoustics are explained, including use of acoustic modeling to generate propagation time differences, nonlinear grid spacing for frequency differences, location seeding using either three sensors or two sensors and two data samples, and frequency normalization. The algorithm allows discrimination between multiple acoustic signals with spatial or velocity vector variance. The presentation compares simulation results for CTBT data, then provides results that track a likely group of pygmy blue whale (Balaenoptera musculus brevicauda) off the coast of Australia. An approach for applying the algorithm to the 2022 DCLDE Data sets will be presented, along with results if successfully applied.
Li, Pu (1); Liu, Xiaobai (1); Fleishman, Erica (2); Cholewiak, Danielle (3); Gillespie, Douglas (4); Helble, Tyler (5); Nosal, Eva-Marie (6); Roch, Marie A. (1); Klinck, Holger (7);	(1) San Diego State University; (2) Oregon State University; (3) NOAA Northeast Fisheries Science Center; (4) St. Andrews University; (5) US Navy, Naval Information Warfare Center Pacific; (6) University of Hawai'i; (7) Cornell University	Training whistle extraction algorithms with multi-stage generative adversarial networks	Frequency contour extraction aims to measure time-frequency variation in tonal calls such as toothed-whale whistles. Such information can contribute to estimating cetacean abundance, species identity, and social activities. The demand for effective automated whistle extraction algorithms has increased in the last few decades with the increasing affordability of long-term recording systems. Automated whistle extraction is still challenging, especially when the signal-to-noise ratio is low and multiple whistles overlap. Our recent deep-learning-based method demonstrated superior performance extracting whistles under varying levels of noise (Li et al. 2020 IJCNN). However, training such a system requires a large amount of labor-intensive analyst annotation, which is not available for many species. To address this limitation, we present a three stage-wise generative adversarial network (GAN) model that learns to generate synthetic examples of whistles in noise that can augment training sets. The first two stages learn to generate whistle contours and background noise independently. A third stage learns to merge synthetic whistles and background noise into a composite spectrogram. The third stage can generate training data from small sets of annotated data, and in principle can be adapted to new noise regimes. Our stage-wise architecture outperformed traditional GAN synthesis models. Application of our method to a 2,500 sample four-species subset of the DCLDE 2011 data and generated examples improved F1 score from 83.0±0.7σ to 84.7±0.7σ.

Madhusudhana, Shyam (1); Shiu, Yu (1); Klinck, Holger (1); Fleishman, Erica (2); Liu, Xiaobai (3); Nosal, Eva-Marie (4); Helble, Tyler (5); Cholewiak, Danielle (6); Gillespie, Douglas (7); Širović Ana (8); Roch, Marie A (3)	(1) K. Lisa Yang Center for Conservation Bioacoustics, Cornell Lab of Ornithology; (2) College of Earth, Ocean, and Atmospheric Sciences, Oregon State University; (3) Department of Computer Science, San Diego State University; (4) Department of Ocean and Resources Engineering, University of Hawai'i at Mānoa; (5) US Navy, Naval Information Warfare Center Pacific; (6) Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA; (7) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews; (8) Marine Biology Department, Texas A&M University at Galveston	Temporal context improves automatic recognition of call sequences in soundscape data	Many animals rely on long-form communication, in the form of songs, for vital functions such as mate attraction and territorial defense. The ability to accurately detect sequences of calls has implications for conservation and biological studies. During manual analyses, analysts often utilize prevailing temporal patterns in call sequences to improve detection accuracy. In this study, we explored the prospect of improving automatic recognition performance by using the temporal context inherent in song. Convolutional neural networks (CNNs) are commonly used for detecting stereotyped calls, such as song notes, in short-duration audio segments. We show that the recognition performance of such a CNN can be improved by combining it with a recurrent network designed to process sequences of learned representations from the CNN. The combined system of independently trained CNN and long short-term memory (LSTM) network models operates on a longer time scale and exploits the temporal patterns between song notes. We demonstrate the technique using recordings of fin whale (Balaenoptera physalus) songs, which comprise patterned sequences of characteristic notes. We evaluated several variants of the CNN + LSTM network. Relative to the baseline CNN model, the CNN + LSTM models reduced performance variance, offering a 9–17% increase in area under the precision-recall curve and a 9–18% increase in peak F1-scores. Much of the observable performance differences manifested under conditions of low and variable signal-to-noise ratio. The results show that the inclusion of temporal information can offer a valuable pathway for improving the automatic recognition and transcription of wildlife recordings.
Manabe, Kei; Nosal, Eva-Marie	Ocean and Resources Engineering, School of Ocean and Earth Science and Technology, University of Hawaiʻi at Mānoa	Counting clickers: Using inter-click-interval maps based on complex autocorrelation to estimate the number of clicking odontocetes	It can be difficult/impossible to know how many animals are vocalizing when multiple odontocetes of the same species click simultaneously. An estimate of the number of clicking animals can be useful directly, or as a first step in source separation algorithms. We use a rhythmic analysis approach that relies on the slowly-varying nature of inter-click-intervals (ICIs) within a click train. We form ICI maps based on the complex autocorrelation function, on which click trains with different ICIs appear separately. From the ICI maps, we can estimate the number of click trains and get an estimate of the (evolving) ICI of each train. We explore this approach and apply it to overlapping sperm whale click trains from the DCLDE 2005 and 2022 datasets.
Marques, Carolina S. (1); Gkikopoulou, Kalliopi C. (2); Marques, Tiago A. (1,2) ; Prieto Rui (3), Oliveira Claudia (3); Silva, Mónica A. (3); Hickmott Leigh S. (4)	(1) Centro de Estatística e Aplicações da Universidade de Lisboa, Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa; (2) CREEM, University of St Andrews; (3) Ocean Sciences Institute - Okeanos, Universidade dos Açores & IMAR – Instituto do Mar, Horta, Portugal; (4) Open Ocean Consulting	Estimating cue rates from tags without acoustic data	Estimating animal density from passive acoustic monitoring data has seen a strong development in recent years. One of the main possible approaches to do so is cue counting, where the number of detected cues is converted to a cue density, which then is converted into an animal density by dividing it by a cue rate. Therefore, reliable and accurate estimate of cue rates are fundamental. The best way to obtain cue rates is arguably using animal borne tags with acoustic sensors, allowing one to identify the time of the emission of all sounds produced by the tagged animal. However, for some species, non-acoustic tag data might contain considerable information about cue production in other data streams, which if used might lead for more robust cue rate estimates. We build on a dataset of sperm whale tags collected in the Azores to illustrate the approach: we model cue production in DTAG as a function of depth, and then use depth profiles from time-depth record TDR tags to predict, based on the DTAG derived model, cue rates for the TDR tags alone. We further investigate whether including DTAGs from just the Azores or from other locations is preferable when modelling the DTAG data alone. We compare several modelling approaches to model cue rates, including generalized estimating equations, generalized additive mixed models, and temporal point patterns.
Martin, Cameron (1); Guazzo, Regina (2); Helble, Tyler (3); Alongi, Gabriela (4); Durbach, Ian (5); Martin, Stephen (6); Matsuyama, Brian (7); Henderson, Elizabeth (8)	(1-3, 8) Naval Information Warfare Center Pacific; (4,6,7) National Marine Mammal Foundation; (5) Centre for Research into Ecological and Environmental Modelling	Minke Whale Call Rate Increases When Calling Conspecifics Are Nearby	The central North Pacific minke whale boing call has a strong bimodal call rate with a more common "nominal" rate that averages one call every 7 min and a more "rapid" rate averaging 0.6 min. We used passive acoustic recordings from 47 bottom-mounted hydrophones at the Pacific Missile Range Facility's instrumented range off the coast of Kauai, Hawaii to test the hypothesis that minke whales call more rapidly when closer to other calling conspecifics. A total of 599 days of data were recorded between August 2012 and July 2017 and were automatically processed to detect, classify, and localize calls. Localized calls were semi-automatically tracked and manually validated, resulting in 502 individual tracks composed of 36,033 calls within a 14.4x38.9 km study area. We utilized Hidden Markov Models (HMMs) to quantify the relationship between call rate and the distance to the nearest calling conspecific. Overall, the probability that the rapid call rate would occur increased as the distance to the nearest conspecific decreased, and the probability of the nominal call rate occurring increased as the distance to the nearest conspecific increased. Case studies have shown that minke whales exhibit multiple responses (i.e. increased speed, changes in heading, and cessation of calling) when nearby conspecifics are calling at the rapid rate. These findings help to better understand the challenges associated with cue rate-based density estimation of baleen whales, as well as providing new information about minke whale calling behavior on what are likely their breeding grounds.

Matei, Madalina (1); Wood, Jason (2); Janik, Vincent (1); Oswald, Julie (1);	(1) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews; (2) SMRU Consulting	KillerClick: Automatic detection and classification of the echolocation clicks of the Southern Resident killer whales (Orcinus orca)	Passive acoustic monitoring techniques have been widely used to study vocalising animals in their natural environments, and automated classifiers can enhance the monitoring process by finding signals of interest in large datasets. This study presents a set of automated detectors and a trained machine learning classifier designed to identify the echolocation clicks of the Southern Resident killer whales (SRKWs) from the North-eastern Pacific Ocean. A set of click and click train detectors customised in PAMGuard identifies signals of interest and the waveforms stored in PAMGuard's binary files are used for feature extraction and classification. Twenty-eight features are extracted from the time and frequency domain using a custom routine in Matlab which are then used as input to a random forest classifier that was trained using equal samples of 13,000 observations for three distinct classes: SRKW clicks, vessel cavitation noise, and other impulsive sounds. The classifier achieved an accuracy of 82.7% on a test dataset. Depending on the minimum classification confidence level set during performance tests, precision and recall reached values up to 0.63 and 0.77, respectively, when tested on data from the same recording system used for training, and 0.79 and 0.67 when tested on data from a distinct recording system deployed at a shallower depth in a different geographic location. The feature extraction and classification routines were integrated into a graphical user interface which can be used for near-real time monitoring or offline analysis, and could be adjusted to collect training data and make predictions for other echolocating species.
McCullough, Jennifer L. K. (1); Simonis, Anne E. (2); Sakai, Taiki (3); Oleson, Erin M. (1)	(1) Pacific Islands Fisheries Science Center, NOAA; (2) Contractor w. Ocean Associates for Pacific Islands Fisheries Science Center; (3) Contractor w. Environmental Assessment Services, LLC for Southwest Fisheries Science Center	Acoustic Classification of False Killer Whales in the Hawaiian Islands Based on Comprehensive Vocal Repertoire	Underwater passive acoustic recordings can be valuable for monitoring protected species; however, robust classification systems are needed to identify encounters to the species level. Towed hydrophone array acoustic recordings were collected as part of the Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) in 2017 (DCLDE 2022 dataset). A suite of routines designed to efficiently detect cetacean sounds, extract features, and classify detections to species is described using visually-verified detections of false killer whales (Pseudorca crassidens) collected during the HICEAS effort. We evaluated models trained on multiple potential species labels, as well as a two-case scenario where all species except false killer whales were considered under an aggregated label. Both models included features from clicks, whistles, and burst pulses. The multi-species model produced a 100% correct classification rate for PC with an 82.96% overall correct classification across all species, including some encounters incorrectly classified as false killer whales. The two-case model performed best, producing a 99.57% overall correct classification. Both models were then applied to visually-verified detections of false killer whales to examine performance during other data collection efforts, including winter surveys in Hawaii in 2019–2020. This case study illustrates the use of these tools to build classifiers for any group of cetacean species, which can then be used to assess classification confidence when visual confirmation is not available. All of the detection, feature extraction, and classification tools are open-source, and the methods we demonstrate here can easily be applied to other regions, taxa, and call types.
Mehta, Kunal (1); Giraldo, Jose (2); Saltijeral, Jorge Rodriguez (3); Lopez, Jesse (4); Veirs, Val (5); Veirs, Scott (6); Staneva, Valentina (7)	(1) University of Colorado, Boulder; (2) AAC Acústica+Lumínica (3) Ecole polytechnique fédérale de Lausanne; (4) Axiom Data Science; (5) Beam Reach; (6) Beam Reach; (7) University of Washington	Active Listening and Learning for Efficient and Interactive Marine Sound Annotation and Classification	Over the last years there has been a rise in availability of vast passive acoustic data streams collected by hydrophones, however, the process of annotating/automatically detecting marine mammal calls in them is still largely labor and time consuming. To streamline this process we have built an active learning system combining the advances in machine learning for audio analysis and the expertise of trained bioacousticians. The system visualizes predictions of a machine learning algorithm on raw data and allows input from the user to verify and correct them, thus supplementing the existing training dataset and also engaging the user in the annotation process. We discuss several strategies for selecting samples for annotation from the large data streams. First we show that by labeling only observations for which the algorithm has high uncertainty, we can improve the performance of a Convolutional Neural Network algorithm on a two-category classification problem (presence/absence of an orca call) even with very few extra annotations: the F1-score increased from .83 to .84 with 50 new annotations (~3% increase of the labeled dataset). Further, we demonstrate how a more complex diversity sampling strategy allows selecting samples different from the ones already in the dataset and can be useful for exploration or discovery of subclusters of sounds. We have designed the system flexible to incorporate other algorithms and facilitate result comparison within the community. It is also open source and can be deployed on diverse computing infrastructures.

Mellinger, David K. (1); Fregosi, Selene (1,2)	(1) Cooperative Institute for Marine Ecosystem and Resources Studies, Oregon State University; (2) Ocean Associates, Inc., under contract to NOAA Pacific Islands Fisheries Science Center	A deep-learning system for detection, classification, and reporting of harbor porpoise sounds	Tidal turbines are being tested in high-current locations as non-fossil-fuel energy sources. These are primarily coastal marine sites, which are also prime habitat for harbor porpoises (Phocoena phocoena). To study impacts of turbines on porpoises, sound was recorded in Minas Passage, Bay of Fundy, Canada, which has extreme daily tidal flows of ~10 knots. Recordings were analyzed to detect and classify harbor porpoise echolocation clicks (~110 140 kHz) and reject interfering sounds. Candidate clicks were detected in Ishmael using ratios between the porpoise frequency band and a lower guard band, then reviewed by humans to label correct candidate clicks. Because more "correct" instances were needed, data were augmented by mixing porpoise clicks with known noise, producing 20,000 "click present" labeled instances. Additionally, 20,000 "non-click" instances were extracted from false detections in “noise recordings”, which were scanned to ensure no porpoise sounds were present. Labeled instances were made into 0.5-s equalized spectrograms for training deep-learning networks using TensorFlow. Training was done using 90% of the spectrograms, with the remaining 10% for testing. Of the network architectures tried, the best-performing was a convolutional neural network with pooling and fully connected layers, achieving 99.1% accuracy. User-friendly software ("FindPorpoises") was made in MATLAB and Python to pre-process raw files, detect candidate clicks, use the trained network to sort candidate clicks into correct and incorrect instances, and plot and tabulate the results by time of day, tide cycle, and month. The system is being adapted for false killer whales. [Funding: Nova Scotia Offshore Energy Research Association]
Merkens, Karlina (1), McCullough, Jennifer (2), Malinka, Chloe (3), Oleson, Erin (2)	(1) Contractor to NOAA MNFS PIFSC, Saltwater Inc., Portland, OR, USA; (2) NOAA NMFS PIFSC, Honolulu, HI, USA; (3) SMRU Consulting, St. Andrews, Scotland	Further Exploration of Click Parameters of Kogia spp.: Insight from and comparison of data between oceans and recording configurations	Despite their global distribution in temperate and tropical waters, the two species of the genus Kogia remain elusive and difficult to study. Recent advances in passive acoustic monitoring technology combined with Kogia-focused research efforts have greatly enhanced characterization of the sounds generated by these two species, further enabling acoustic detection and classification. Here we present an expanded description of the clicks of Kogia spp., collected at depths of 100-200 m, using two different recording systems to detect more than 80 encounters: a multi-channel vertical array in the Atlantic (clicks = 8636; fs = 576 kHz) and a two-channel drifting recorder in the Pacific (clicks = 8629, fs = 288 kHz). While average click parameters across encounters from both data sets are quite similar to previously published parameters, (e.g. peak frequency ~120 kHz, -3 and -10 dB bandwidths of 6 and 13 kHz, respectively), variability within encounters was quite large, with peak frequencies ranging from 90-125 kHz, and -3 dB bandwidths varying by 8 kHz or more. Additionally, the Pacific data suggest a diel trend in diving behaviour, with slightly deeper dives at night (below the array at 150 m), which may impact the characteristics of the sounds being generated, and therefore should be further understood and considered for acoustic density estimation survey design. The multi-channel data from the Atlantic further demonstrate the click parameter variability in on- and off-axis clicks, including changes in duration, bandwidth and peak frequency, which may explain at least some of the variability within encounters observed in the Pacific.
Morrissey, Ronald (1), (2); DiMarzio, Nancy (3) Dolan, Karin	Naval Undersea Warfare Center, Newport, RI	Ambient Noise on US Navy Ranges	Ambient noise has been increasing in the Northeast Pacific and Indian Ocean basins, particularly in the lower frequencies typically associated with shipping traffic (Hildebrand 2009, McDonald et al. 2006, Chapman and Price 2011, Miksis-Olds et al. 2013). Ambient noise level trends in other ocean basins are unknown; however, increases in seismic activity in the Atlantic Ocean are likely impacting ambient noise levels in that ocean as well (Klink et al. 2012, Nieukirk et al. 2012, Miksis-Olds et al. 2014). The Marine Mammal Monitoring on Navy Ranges (M3R) program has collected multi-year datasets at three of the U. S. Navy’s undersea ranges, the Atlantic Undersea Test and Evaluation Center (AUTEC), the Southern California Tactical Training Range (SCTTR), and the Pacific Missile Range Facility (PMRF). These deep water ranges are located in the Atlantic and Pacific ocean basins. This paper documents a method for estimating ocean ambient noise from M3R binary archive files. The method is applied to selected data and results tabulated.

Mouy, Xavier (1), Black Morgan (2), Cox Kieran (2), Qualley Jessica (2), Dosso Stan (1), Juanes Francis (2)	(1) University of Victoria, School of Earth and Ocean Sciences; (2) University of Victoria, Biology Department	Comparison of three portable volumetric arrays to localize and identify fish sounds in the wild.	Fish sounds could be used to non-intrusively detect the presence of fish over broad spatial and temporal scales. However, many fish sounds have not yet been associated to specific species, which limits the usefulness of this approach. In this paper, we propose three portable volumetric audio/video arrays capable of identifying species-specific fish sounds in the wild. Each array can record fish sounds, acoustically localize the fish in three-dimensions (using linearized or fully non-linear inversion), and record video to identify the fish and observe their behavior. The design of each array addresses specific habitats, logistical and financial constraints, covering a range of nearshore habitats and applications. The first platform is composed of six hydrophones, an acoustic recorder, and two video cameras secured to a 2 x 2 x 3 m PVC frame. Hydrophone placement is defined using simulated annealing to maximize localization accuracy. The second platform uses a single video camera, four hydrophones, and an acoustic recorder on a one cubic meter PVC frame. It can be deployed on heterogeneous substrates but has lower localization capabilities. The third platform consists of four hydrophones connected to an acoustic recorder mounted on a tethered underwater drone with built-in video. It allows remote control and real-time positioning in response to observed fish presence but with reduced localization capabilities. The three platforms were deployed off British Columbia, Canada, and used in the localization, identification and description of sounds from quillback rockfish, copper rockfish, and lingcod. The strengths and weaknesses of each array will be discussed.
Muniz, Alexander (1);	(1) Naval Undersea Warfare Center Division Newport 1;	Spatial and Temporal Distribution of Possible Deep-sea Fish Detections at AUTEC	The presence of deep sea fish, specifically cusk eels, at the Atlantic Undersea Test and Evaluation Center (AUTEC) have likely been detected. Using a dataset that covers a wide temporal distribution, and a spatial sampling that is representative of the entire range (1500 km2), 135 detections of possible deep sea fish were made using a two stage energy detection scheme. The observed signals appeared to be short pulse trains and an event is denoted as signal-present if the peak signal to noise ratio exceeds a certain set threshold, and there are a set number of peaks above this threshold within a time window. Two types of sounds were detected. Type 1, had a duration of 0.882 +/- 0.227 seconds and peak pulse energy at a frequency of 927 +/- 41.7 Hertz and an inter pulse interval (IPI) of 0.026 +/- 0.005 seconds. Type 2, had a duration of 0.263 +/- 0.031 seconds and peak pulse energy at a frequency of 548 +/- 26.2 Hertz and an IPI of 0.029 +/- 0.006 seconds.
Myers, Hannah (1); Olsen, Dan (2); Matkin, Craig (2); Konar, Brenda (1)	(1) College of Fisheries and Ocean Sciences, University of Alaska Fairbanks; (2) North Gulf Oceanic Society	Year-round calling rate of a southern Alaska resident killer whale pod	Density estimation of marine mammals using passive acoustics requires fundamental research on vocalization rates and their relationship with factors such as season and group size. However, obtaining calling rate data is logistically challenging over time and across various behaviors and social settings. In this study, we capitalize on the unique social structure and dialect use of resident killer whales (Orcinus orca) to assess year-round calling rate across three passive acoustic monitoring sites in the Gulf of Alaska and in the presence of other killer whale groups. We used recordings of the AD16 pod because this pod is made up of a single matriline, meaning that when AD16 calls are recorded, all 12 animals are present. Calling rate was highly variable throughout the year, and the presence of other pods influenced calling rate. We expect this result to be applicable to the southern Alaska resident killer whale population (over 1,000 animals). These results provide insight into how pulsed call rate can be realistically applied as a cue rate for acoustic density estimation of this population throughout the year. This work further provides an example of how a species' unique social attributes can be used to assist with acoustic density estimation techniques.
Palmer, Kaitlin (1); Turner, Jesse (1); Tabbutt Sam (1); Gillespie, Doug (2); Thompson, Jessica (1); King, Paul (1); Wood, Jason (1)	(1)SMRU Consulting; (2) Sea Mammal Research Unit, Scottish Oceans Institute University of St Andrews	Evaluation of the Coastal Acoustic Buoy for Offshore Wind for real time mitigation	A recent Incidental Harassment Authorization requires monitoring for North Atlantic Right Whales with passive acoustics within a 10 km zone before and during pile driving. We have built the Coastal Acoustic Buoy for Offshore Wind (CABOW) to address this need. Each CABOW consists of; a bottom lander with three hydrophones; data acquisition system; and onboard computer running PAMGuard. CABOW detects potential calls and relays clips to a base station for classification, bearing estimation, and human validation. Here we present the bench testing and field evaluation of the systems. Bench testing characterized ideal detector performance and measured bearing accuracy as a function of SNR. Field trials in Maryland, USA used playbacks of simulated right whale upcalls to evaluate the detection probability with respect to the range and signal excess of the call; estimate bearing accuracy; and test the range and stability of the radio communications. During field trials 3,536 simulated upcalls were played back to five CABOWs providing a total of 17,680 data points for analysis. This resulted in the effective detection radius exceeding 8 km when the signal excess was greater than 70 dB and less than 1 km when the signal excess was lower than 30 dB. Last, we used a simulation to compare true and false alarm rates of the CABOW to an equivalent single sensor system for monitoring a fixed area. Simulations show that incorporating bearings could provide a substantial improvement in false alarm rates relative to single sensors if properly placed with respect to potential noise sources.

Paro, Alexandre D. (1), Rossi-Santos, Marcos (2), Wedekin, Leonardo (3), Oswald, Julie N. (4) Coutinho, Ricardo (1)	(1) Marine Biotechnology Program, Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM); (2) Laboratório de Ecologia Acústica e Comportamento Animal (LEAC); (3) Socioambiental Consultores Associados; (4) Scottish Oceans Institute, Sea Mammal Research Unit, School of Biology, University of St. Andrews	Towards using whistles as a dolphin species identification tool in cetacean surveys in the Southwest Atlantic Ocean	Although dolphins' whistles have species-specific characteristics, efforts to build classifiers for species in the Southwest Atlantic are a work still in progress. To address this, we used a dataset of whistles collected using a towed hydrophone array in Brazil (23°-28°S). Data came from 13 line-transect cetacean visual and acoustic surveys between 2015-2020 (PMC-BS/Petrobras) in an area of 350,000km2 (30-2500m depth). Acousticians recorded dolphin encounters in real time. Visually confirmed single-species encounters composed our dataset. Whistles were manually selected and 50 parameters were extracted using ROCCA in PamGuard. Each encounter was considered an independent sample. The training dataset was balanced across species, resulting in 142 encounters and 721 whistles from 7 species (Stenella frontalis, S. longirostris, S. attenuata, S. clymene, Steno bredanensis and Delphinus sp.). Four classification models were tested: discriminant analysis, classification tree, bagging, and random forest. For each encounter, whistles were run through all four models. The highest proportion of whistles classified as one species, based in the results from all models combined, was the criteria to classify the encounter in that species. A preliminary evaluation of the results, shows that when the proportion of whistles classified as one species was as low as 0.3, classifications were correct. Using this approach, 17 encounters out of 22 in the test dataset were correctly classified. The development of regional classifiers such as this makes passive acoustics a valuable tool. The successful application of such classifiers will improve the sample size of detections, and will allow more effective sampling during night hours.
Pereira, Andreia (1); Romagosa, Miriam (2); Corela, Carlos (1); Silva, Mónica A. (2); Matias, Luís (1)	(1) Instituto Dom Luiz (IDL), Universidade de Lisboa; (2) Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores & IMAR – Instituto do Mar	Assessing the detection range of two types of fin whale calls in the Azores	Acoustic monitoring of fin whales is usually based on the 20-Hz call, the most common sound produced by these animals. Other fin whale signals, such as the 40 Hz call, are also being tested for PAM when 20 Hz calls are less produced. The feasibility of using the 40 Hz call and other fin whale signals for PAM is still uncertain because there is few knowledge about this signal's occurrence, characteristics, and propagation. This study aimed to estimate the detection range, i.e. the distance at which 20 Hz and 40 Hz fin whale calls could be detected by two types of recording instruments, and assess its monthly and instrumental variability. Calls were detected and located from hydrophone data obtained with ecological acoustic recorders (EARs) and ocean-bottom seismometers (OBSs) in the Azores. The detection range of each call type was estimated using the sonar equation, knowledge about signal source level, SNR, frequency bandwidth, ambient noise levels and signal transmission loss models. Estimates of detection ranges in the Azores area ranged from 85.2 to 175.2 km for the 20 Hz call and from 14.8 to 111.9 km for the 40 Hz call. The factors that contributed to a higher variability of detection ranges were the type of recording instrument, bathymetric transect and ambient noise level. Monthly changes in the sound speed profiles did not affect the detection ranges estimates. Studying the detection range of fin whale calls is crucial to understanding its influence in choosing different location methods and animal abundance estimates.
Premus, Vincent E.; Abbot, Philip A.; Kmelnitsky, Vitaly; Abbot, Ted A.; Freise, Jacob; Browning, John	Ocean Acoustical Services and Instrumentation Systems, Inc	Experimental results of an autonomous, real-time, passive acoustic marine mammal monitoring system using a towed hydrophone array deployed from an unmanned surface vehicle	An unmanned surface vehicle, the ThayerMahan Outpost system, comprised of a waveglider instrumented with a low-power towed hydrophone array and embedded digital signal processor, is demonstrated as a viable tool for the advanced passive acoustic monitoring of marine mammals. In this paper we focus on the performance benefits associated with the use of a high-spatial resolution towed hydrophone array, as well as some of the key enabling design elements behind the success of the waveglider based system. Using at-sea data collected during a simultaneous deployment of three waveglider-based acoustic detection systems just outside Stellwagen Bank National Marine Sanctuary in September 2019, the capability of a 32-channel, low-frequency towed hydrophone array to spatially reject noise, and resolve baleen whale vocalizations from anthropogenic acoustic clutter, is demonstrated. Model predictions for the continental shelf environment south of Martha's Vineyard showing the detection range and area coverage advantage of the towed array over a single hydrophone against the North Atlantic right whale upcall are also shown. Finally, some preliminary results illustrating the use of a spectrogram correlator—based on a kernel library derived from training data distributed at the 2013 St. Andrew's DCLDE Workshop—to detect North Atlantic right whales on the waveglider towed array system, are presented.

Rankin, Shannon (1); MacAulay, Jamie (2); Ferguson, Elizabeth (3); Simonis, Anne (4); Fregosi, Selene (5)	(1) Marine Mammal & Turtle Division, Southwest Fisheries Science Center, NOAA Fisheries; (2) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews; (3) Ocean Science Analytics; (4) Contractor for Ocean Associates with Marine Mammal & Turtle Division, Southwest Fisheries Science Center, NOAA Fisheries; (5) Contractor for Ocean Associates with Pacific Islands Fisheries Science Center, NOAA Fisheries	Bioacoustics Stack Exchange: Creating a community-led platform for questions & answers will increase both quality and equity in science	Bioacoustic research is expanding across the globe yet the majority of the institutional knowledge resides in wealthier communities. While hardware and software technologies are becoming increasingly user-friendly, there remains a high barrier to entry that complicates adoption of these tools. How can we, as a scientific community, lower the barrier of entry to the field of bioacoustics to allow researchers from underserved communities to apply these rapidly changing technologies in a scientifically sound manner that ultimately serves our collective conservation needs? Crowd-sourced question and answer platforms such as Stack Exchange allow the community of users to not only ask and answer questions related to the platform topic, but to provide citations and links, commentary, alternative considerations, and an archive for future reference. Scientific progress thrives with the inclusion of diverse, creative perspectives; a community platform will encourage cross-pollination of ideas, experiences, and perspectives. While the Stack Exchange platform has great potential, there are a series of challenges that must be met in order to launch a topic-specific platform for Bioacoustics and we need help from everyone in the bioacoustics community to turn this need into a reality. Once created, the site is naturally self-regulated and will serve as a repository for all people interested in bioacoustics across the globe. Here we provide guidance and specific links to allow each workshop attendee to participate in this proposal at a level that suits their interest.
Rideout, Brendan Pearce (1) (2); Nosal, Eva-Marie (1)	(1) Dept. of Ocean and Resources Engineering, University of Hawaii at Manoa; (2) Defence Research and Development Canada - Atlantic Research Centre	Long-range single hydrophone passive acoustic ranging of air guns and fin whales at Station ALOHA	This paper presents a technique for passive acoustic range estimation using data from a single ocean-bottom fixed hydrophone. This technique builds upon previous localization approaches which use the time of arrival of direct and interface-reflected acoustic ray paths connecting source and receiver. In this case, measured time differences between direct and interface-reflected paths are compared with pre-calculated model-predicted time differences such that the labels of the paths (e.g., direct, surface bounce, bottom bounce, etc.) are not needed. The modeled set of time differences which best matches the measured set indicates the estimated range for the source in question. This comparison is readily automated for efficiently processing large data sets. This approach is demonstrated using air gun and 20-Hz fin whale (Balaenoptera physalus) calls recorded by the ALOHA Cabled Observatory, located ~100 km North of Oahu in 4782 m of water.
Roch, Marie A. (1); Fleishman, Erica (2); Liu, Xiaobai (1); Li, Pu (1); Madhusudhana, Shyam (3); Palmer, Kaitlin (1); Shiu, Yu (3); Cholewiak, Danielle (4); Gillespie, Douglas (5); Helble, Tyler (6); Nosal, Eva-Marie (7); Klinck, Holger (3);	(1) San Diego State University; (2) Oregon State University; (3) Cornell University; (4) NOAA Northeast Fisheries Science Center; (5) St. Andrews University; (6) US Navy, Naval Information Warfare Center Pacific; (7) University of Hawai'i	The Deep Context Project	We present an overview of a research program that incorporated both contextual information and deep learning into several detection and classification systems. We show that in comparison to previously published research, deep learning can provide large advances. An example is reliably detecting migrating animals (north Atlantic right whales) from data gathered in their feeding grounds with high recall and low-enough false positive rates to permit cost-effective quality control processes. This detector has since been incorporated into PAMGuard and is being trialed for real-time right whale detection at prospective wind farm sites. We illustrate that, when coupled with information that leverages either near-term or long-term contextual information, deep learning is capable of providing additional large performance gains. For example, deep learning improved the F1 score of a traditional target-tracking whistle extraction system by a factor of nearly 1.4. In another study, we used temporal context in the form of neural network representations of neighboring fin whale song notes to better predict notes that would have been otherwise too faint or obscured by noise to predict correctly. This provided an F1 improvement of 1.3 over a standard convolutional neural network detector. All of these systems are open source and publicly available (www.pamguard.org, github.com/MarineBioAcousticsRC/silbido, and github.com/shyamblast/TemporalContext-2021).

Romagosa, Miriam (1), Sharon Nieukirk (2), Irma Cascão (1), Tiago A. Marques (3,4), Robert Dziak (5), Jean-Yves Royer (6), Joanne O'Brien (7), David K. Mellinger (2), Andreia Pereira (8), Arantza Ugalde (9), Elena Papale (10), Giuseppa Buscaino (10), Marianne Rasmussen (11), Luis Matias (8), Rui Prieto(1) and Mónica A. Silva (1)	(1) Instituto de Investigação em Ciências do Mar - Okeanos; (2) Cooperative Institute for Marine Ecosystem and Resources Studies, Oregon State University; (3)Centro de Estatística e Aplicações, Departamento de Biologia, Faculdade de Ciências, Universidade de Lisboa; (4) Centre for Research into Ecological and Environmental Modelling, University of St Andrews,; (5) NOAA Pacific Marine Environmental Laboratory; (6) Univ Brest, CNRS, Laboratoire Geosciences Ocean; (7) Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology; (8)Instituto Dom Luiz (IDL), Universidade de Lisboa; (9) Institute of Marine Sciences, ICM-CSIC; (10) Institute for the Study of Anthropic Impacts and Sustainability in the Marine Environment of the National Research Council of Italy (CNR-IAS); (11) University of Iceland's research center in Húsavík	Changes in fin whale song inter-note intervals: implications for density estimation using PAM	Male fin whales produce highly stereotyped and repetitive songs believed to function as a reproductive display. These songs consist of single repeating 1-s downsweeps centred around 20 Hz, or of two or three alternating notes with different downward-sweeping character. Acoustic features of fin whale songs vary among geographic areas and inter-note intervals (INIs) were found to be best the predictors of region, and have been used to differentiate stocks or populations. We measured INIs of fin whale songs recorded from seven regions in the Central and Northeast Atlantic Ocean over two decades. Our results show a rapid replacement of INIs (from 19s to 12s) across a vast area of the Northeast Atlantic in just four winter seasons. During the transition period, the two types of INIs co-existed with hybrid songs (including both INIs), and there was a clear spatial gradient in the percentage of song types. After this drastic change, INIs started to increase gradually over time in the entire sampled area. Changes in INIs can affect the estimation of call rates (i.e., number of calls per unit time) one of the parameters included in acoustic density estimation, and preclude comparisons between estimates obtained in different years and regions.
Sakai, Taiki (1); Rankin, Shannon (2)	(1) Environmental Assessment Services, LLC (2) Southwest Fisheries Science Center, NMFS/NOAA	FOSSA: Simple open-source software to simplify DCLDE workflows	There have been significant efforts to improve signal processing methods for the Detection, Classification, and Localization of marine mammals, but the reality of implementing these methods is often a long, convoluted analytical process that impedes adoption and replication. Analyzing passive acoustic data is messy, but it doesn't need to be that way. FOSSA (Free Open-Source Software for Acoustics) is a series of R packages developed with the goal of making analysis easier by increasing accessibility, reproducibility, and standardization. PAMpal (one of the packages) is designed to work with the output from PAMGuard, providing an end-to-end open source workflow for data analysis. PAMpal vastly simplifies the process of loading PAMGuard output into R. It provides a standardized set of descriptive measures for all clicks, whistles, and burst pulses with a few keystrokes, and users can also add their own custom measures with a single function. Ancillary data (species identity, GPS coordinates, and environmental variables) can be matched to the appropriate detections, each with a single line of code. All data and metadata are saved in a standardized structure; any models designed to work with PAMpal output can be readily adopted by all PAMpal users. Standardized datasets analyzed in PAMpal and saved on open data platforms can provide a common test case for developing and comparing novel analytical methods using real-world examples. Here we present an overview of the basic functionality of PAMpal, as well as a few case studies showcasing how it has helped streamlined a variety of analyses.
Seger, Kerri D. (1); Al-Badrawi, Mahdi (2); Liang, Yue (3); Foster, Christopher M. (3); and Kirsch, Nicholas J. (3)	(1) Applied Ocean Sciences; (2) CARE, University of New Hampshire; (3) ECE, University of New Hampshire	Revisiting Empirical and Variational Mode Decomposition on detecting and classifying a variety of underwater signals with various sampling rates	In 2018, we illustrated how Empirical Mode Decomposition (EMD) could provide unique identities to a variety of tonal and some pulsive signals in data from the Bering and Chukchi Seas. EMD acts as a dyadic filter that decomposes a time-series waveform into a set of Intrinsic Mode Functions (IMFs). These IMFs can be interpreted as the outputs of the waveform passed through overlapped bandpass filters. This filtering behavior of EMD easily separates tones but has challenges differentiating pulsive sounds. These broadband sounds, such as self-noises from the moorings, spread across most of IMFs, thus jeopardizing the efficacy of uniquely classifying them. To test the robustness of EMD, a variety of datasets from rivers and oceans that used different instruments and a broad range of sampling rates were assessed. The limitation of EMD to separate pulsive sounds was addressed via the use of Variational Mode Decomposition (VMD), which was successful even with dolphins having very similar peak and notch patterns in their clicks. EMD still holds merit in classifying different sounds that are well separated in the frequency domain (occupy different acoustical niches). This presentation will step through the current state of the EMD/VMD detection and classification process that has been developed. This includes using inspiration from EMD in both the detector and the classifier and providing a VMD option for pulsive signals to advance classification of dolphin clicks in files where contextual whistles are not available.

Soldevilla, Melissa (1); Frasier, Kaitlin (2); Frouin-Mouy, Heloise (1, 3); Garrison, Lance (1); Gracia, Adolfo (4); Hildebrand, John (2); Hodge, Lynne (1,3); Le Henaff, Matthieu (5); Ortega-Ortiz, Joel (1,5); Serrano, Arturo (6); and Wall, Carrie (7)	(1) NOAA Southeast Fisheries Science Center; (2) Scripps Institution of Oceanography, UCSD; (3) University Corporation for Atmospheric Research, University of Colorado Boulder; (4) Universidad Nacional Autonoma de Mexico; (5) Rosenstiel School of Marine and Atmospheric Studies, University of Miami; (6) Universidad Veracruzana; (7) NOAA National Centers for Environmental Information, University of Colorado Boulder	LISTEN GoMex: Long-term Investigations into Soundscapes, Trends, Ecosystems, and Noise in the Gulf of Mexico	In 2010, the Deepwater Horizon (DWH) oil spill had unprecedented impacts on the Gulf of Mexico ecosystem, including the twenty cetacean species inhabiting the oceanic waters of this semi-enclosed large marine ecosystem. In the following ten years, results from broad-scale ship-based visual and acoustic surveys and long-term moored passive acoustic moorings in US waters of the Gulf suggest ongoing density declines in numerous cetacean species, but data are lacking from the southern Gulf. Due to the impacts from DWH oil, restoration projects focused on oceanic cetaceans are being enacted in the Gulf, which require basic information on species' spatiotemporal density patterns, Gulf-wide movement patterns, Gulf-wide population sizes, long-term abundance trends, and species' response to oceanographic and anthropogenic processes. To address these needs, we initiated a comprehensive, long-term, multi-scale PAM program throughout US and Mexican Gulf waters in 2020 to collect data needed to develop predictive habitat models to assess the processes driving seasonal, interannual, and decadal trends in spatial distribution, density, and abundance of oceanic cetaceans. The study combines: a) long-term sampling to identify temporal trends and variability at reference sites over the study period; b) short-term sampling over a broad area of the Gulf to capture spatial trends and variability in cetacean density and environmental processes; and c) targeted sampling using arrays to obtain acoustic behavior data for density estimation. Predictive habitat models are being developed for up to 20 cetacean species throughout the Gulf to support conservation actions that promote the recovery of these species from DWH impacts.
Spiesberger, John (1)	Department of Earth and Environmental Science, University of Pennsylvania	Dimension Reduction in Location Estimation—the Need for Variable Propagation Speed	Calling mammals, ships, and many other objects have been commonly located during the last century with two-dimensional (2D) models from measurements of a signal's Time Differences of Arrivals (TDOA) when the objects are not on the 2D surface. The overwhelmingly common method for locating signals with 2D models takes signal speed as constant and location is derived by intersecting hyperbolas. However, when correct locations are required for 2D models, the speed used to derive location must depend on the geodesic distance along the 2D model surface between the object and the instrument. For example, when this distance is zero, the speed needed for correct location must also be zero. The dimension reduction from three to two introduces large errors in 2D models both near and far from the instruments unless the variable speeds induced by the dimensional reduction are explicitly accounted for. In light of these findings, methods are derived for generating extremely reliable confidence intervals for estimated locations in 2D models and identifying regions of the 2D model where a 3D model is needed. Because speeds needed for correct location are spatially inhomogeneous in the extreme, isodiachrons emerge as a natural geometry for interpreting location instead of hyperbolas. These issues are caused by choice of coordinates, and the same phenomena occur when coordinate transformations are applied in other fields of physics.
Spiesberger, John (1), Berchok, Catherine (2), Iyer, Pranav (1), Schoeny, Alexander (1), Sivakumar, Krishna (1), Woodrich, Daniel (3), Yang, Eloise (1), and Zhu, Sophia (1)	(1) University of Pennsylvania (2) Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA; (3) Cooperative Institute for Climate, Ocean and Ecosystem Studies, University of Washington.	Bounding the number of calling animals with passive acoustics and reliable locations	When n animal calls are passively detected at n different times, the number of animals producing the sounds is anywhere between one and n unless more information is available. When extremely reliable confidence intervals of location are also available for each call, the upper bound is still n, but a lower bound can be derived. The lower bound exceeds one when it is physically impossible for an animal to travel quickly enough to go from one reliable location to another within the temporal call interval. When many calls are detected, it may be too complicated or numerically prohibitive to determine the minimum number of animals responsible for the calls in space and time by inspection or brute force methods. Instead, it is advantageous to use graph theory. The lower bound for the number of calling animals can be derived using 100% confidence intervals of each call's location. Mathematical theorems guarantee the lower bound is correct: a lesser value is impossible to obtain. Guaranteed bounds for the abundance of calling animals are useful for conservation in the presence of environmental stress and studying behavior.

Spiesberger, John (1), Garcia, Marissa (2), Klinck, H. (2), and Shiu, Yu (2)	(1) Dept of Earth and Environmental Science, U. Pennsylvania (2) K. Lisa Yang Center for Conservation Bioacoustics, Cornell Lab of Ornithology, Cornell University	Extremely-reliable locations and calling abundance of right whales in Cape Cod Bay derived with passive recordings of their calls with un-synchronized clocks	Extremely reliable 100% confidence intervals of location (CIL) were derived from upcall vocalizations produced by North Atlantic right whales (Eubalaena glacialis) in Cape Cod Bay, Massachusetts from recordings on five Marine Autonomous Recording Units (MARUs). One Maru was placed near the center of a rectangle-like array whose vertices were 6 to 11 km from the center.The MARUs continuously monitored the underwater soundscape from February 17, 2019 to June 12, 2019 for a recording period of 116 days. Upcall vocalizations — a contact call universally vocalized by right whales of all ages and sexes — were manually annotated and associated in Raven Pro software across all five acoustic channels. Locations were derived from measurements of the (TDOA) of sounds. The receiver's clocks were synchronized using only these TDOA using a novel but data-validated technique (US patent 10,915,137), obviating the need for synchronization using expensive atomic clocks or periodic emissions of sounds from known locations. The 100% CIL are often small (https://www.scientificinnov.com/current-work). A technique was used to derive the mathematically-guaranteed fewest number of right whales responsible for the located calls (Spiesberger et al., https://doi.org/10.1121/10.0004994). The clock-synchronization/location/calling abundance technologies are now available.
Tenorio, Ludovic (1); Melissa Soldevilla (1); Lance Garrison (1); Amanda Debich (2,1); Ashley Cook (1); John Hildebrand (3); Kaitlin Frasier (3)	(1) NOAA Southeast Fisheries Science Center, Miami, FL, USA; (2) Cooperative Institute for Marine and Atmospheric Studies, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL, USA; (3) Scripps Institution of Oceanography, La Jolla, CA, USA	Passive acoustic localization of Rice's whales in the Gulf of Mexico	Previously thought to be a geographically isolated subspecies of the widely distributed Bryde's whale complex (Balaenoptera edeni), the Rice's whale (Balaenoptera ricei) has recently been identified as a distinct species endemic to the Gulf of Mexico and is protected under the Endangered Species Act due its very small population size. This species is believed to produce the low-frequency signals, referred to as "long-moans", which are regularly detected in the northern Gulf of Mexico throughout the year. These unique calls last approximately 30 seconds and are modulated in both frequency and amplitude. Here we present preliminary passive acoustic localization results using a distributed array of acoustic recorders that were deployed from May to November 2021 in the northern Gulf of Mexico. One of the goals of this project is to determine the detection range of these whales—a key parameter in passive acoustic monitoring studies— which can be inferred from localizing calls and estimating their source level. The 40 km spacing between the array sensors is such that time-difference-of-arrival localization is only occasionally feasible under favorable propagation conditions (noise level and bathymetry). As a complementary approach, we explore the possibility of using a single-hydrophone technique known as nonlinear time-warping to extract information about the range of the source.
Theriault ,James A.(1), Soares Frazao,Fabio (2), Flogeras,David (1); Evers, Claire(3); Kirsebom, Oliver S.(2); and Matwin, Stan (2)	(1) Ocean Environmental Consulting; (2) Institute for Big Data Analytics, Dalhousie University; (3) Fisheries and Oceans Canada, Bedford Institute of Oceanography.	North American Right Whale Detection and Classification with the AI-based Framework for Acoustic Sensors (AFAS)	The effectiveness of real-time or near real-time Passive Acoustic Monitoring (PAM) for cetaceans is constrained by data communications from the sensor to the decision maker. To minimize the communication demands, the detection and classification functions can be moved to the sensor package. This is particularly important when either Radio-Frequency (RF) satellite communications or underwater acoustic modems must be used to transfer information from a sensor to a decision maker. Underwater gliders ocean profiling buoys, and remote bottom sensors without cabled communications are forced into these low bandwidth communication technologies. The design goals of a remote autonomous system include minimizing cost, energy use and communications, while maximizing effectiveness (precision and recall), extensibility, and digital storage. The AI-based Framework for Acoustic Sensors (AFAS) has been developed and prototyped as an extensible architecture to investigate the effectiveness of test implementations. Prototypes include off-the-shelf components including an RS Aqua/Turbulent Research OEM Porpoise archival recorder and an adjunct processing unit. The MERIDIAN KETOS-based spectral neural-network classification package, and specifically TensorFlow, has been deployed to various single board computers and micro-controllers for integration. We compared the performance of different devices as the adjunct processing unit, namely the Raspberry Pi (RPi) 3, and RPi 4 with and without an added Tensor processing unit (Google Coral USB accelerator), the Google Coral Development Board, NVIDIA Jetson Nano, and STMicroelectronics STM32 microcontroller. The detection and classification of the North Atlantic Right Whale up-call from previously-recorded sensors at sites in Atlantic Canada are presented to demonstrate the design considerations.

Thode, Aaron (1); Tenorio, Ludovic (1); Lammers, Marc (2); Meyer, Florian (1); Gruden, Pina (3); Conrad, Alexander (4); Kim, Katherine (4), Kügler, Anke (5)	(1) Marine Physical Laboratory, Scripps Institution of Oceanography, UCSD; (2) Hawaiian Islands Humpback Whale National Marine Sanctuary; (3) Cooperative Institute for Marine and Atmospheric Research (CIMAR), University of Hawaii; (4) Greeneridge Sciences, Inc; (5) University of Hawaiʻi at Mānoa	Automatic tracking of multiple singing humpback whales off Hawaii using vector sensors	Acoustic vector sensors estimate travel direction of an acoustic wave at a single point by measuring both acoustic pressure and particle motion on orthogonal axes. A two-dimensional fix of an acoustic source can thus be determined by triangulating azimuths from at least two vector sensors. However, when tracking multiple acoustic sources simultaneously it becomes challenging to identify and link sequences of azimuthal measurements between sensors to their respective sources. This presentation illustrates how two-dimensional vector sensors, deployed off the coast of western Maui, can be used to generate azimuthal tracks from individual humpback whales singing simultaneously. Vector sensors can achieve this by using metrics called dominant directionality and acoustic transport velocity, which can be presented as time-frequency images analogous to spectrograms. Histograms of dominant directionality images, when stacked across time, yield preliminary images of azimuthal tracks. Acoustic transport velocity measurements then remove distributed noise source contamination from the tracking images. Multi-hypothesis tracking techniques (MTT) automatically extract tracks from the final images, and the tracks are then linked between sensors by cross-correlating features of their respective dominant directionality images. Once the correct azimuthal track associations have been made between instruments, subsequent localization and tracking in latitude and longitude of multiple whales can be achieved using a minimum of two vector sensors. Tracks and positional uncertainties of multiple whales are presented over several days during the 2020 and 2021 breeding season.
Thomas, Len	University of St Andrews	Overview of methods for estimating animal density from passive acoustic data	I present short introduction to methods for estimating animal density (DE) from passive acoustic data, with the main goal of helping put other presentations in the DE-related sessions into context. Density estimation involves combining counts of acoustic detections with estimates of false positive rate, detection probability (related to false negative rate) and other biological information such as vocalization rate (â€œcue rateâ€) or group size. I go through each of these components, highlighting recent progress. Hardware tuned to density estimation is beginning to appear; detection probability methods continue to develop; reliable knowledge on cue rate remains an Achilles heel but is a very active area of development. Comparisons of methods are emerging, one (at least) comparing results with known true density. Survey design tools are becoming available. Region-level PAM-DE is beginning to enter the mainstream, at least in cases where other traditional (e.g., visual) density estimation methods are problematic.
Torterotot, Maëlle (1); Samaran, Flore (1); Beesau, Julie (1); Nguyen Hong Duc, Paul (2); Cazau, Dorian (1)	(1) ENSTA Bretagne and CNRS Lab STICC; (2) School of Mathematics and Statistics, Carleton University.	APLOSE : a web-based annotation platform to assist collaborative annotation campaigns on passive acoustics datasets	In the era of big data, automated recognition methods are essential to process the huge amount of data. Passive acoustic monitoring is not left out, but identifying unfamiliar signals from a human perspective is harder than identifying cat and dog images. Ground truth annotated datasets are needed for 2 main reasons: (1) building reliable and massive training sets for supervised machine and deep learning algorithms, (2) assessing the detection performance of both supervised and unsupervised algorithms. Usually, the annotation process is performed by only one or two analysts, who could be biased by their learning methods and annotation skills. Moreover, the current annotation softwares require the annotator to have all the dataset stored on their own computer which could represent a hindrance to larger international annotation campaigns, and to build reference datasets such as DCLDE ones. APLOSE is a web-based annotation platform developed at ENSTA Bretagne, France. The aim of this platform is to enable anyone to take part in an annotation campaign. The main asset of APLOSE is that the annotators follow a common annotation protocol with standardized meta-representations of the annotation sets. We will present APLOSE and the results of two collaborative annotation campaigns conducted on this platform.
Vierling, Emily(1), (2) Veirs, Scott (3) Veirs, Val (4) Symonds, Helena (5) Spong, Paul	(1-3) Orcasound; (4-5) OrcaLab.	Non-song humpback vocalizations from the inland waters of Washington and British Columbia	Humpback whales have been detected increasingly over the last decade within the inland waters of Washington State (U.S.) and British Columbia (Canada). This “comeback” from their extirpation during the whaling era enriches the marine soundscape for community scientists who listen live via the Orcasound hydrophone network in WA and the OrcaLab hydrophone network in Johnstone Strait, BC. We present a chronology of these acoustic events, with a subset of them now available via the Orcasound open data repository. We have archived both raw acoustic data and annotations for training and testing models that we hope will eventually automatically discriminate between humpback signals and those emitted by three local ecotypes of killer whales: Southern Resident, Northern Resident, and Bigg’s. To this end, we will also discuss a standardized annotation scheme for non-song humpback vocalizations.

Vishnu, Hari (1); Soorya, V. R. (1); Chitre, Mandar (1); Koay, Teong Beng (1); Ho, Abel (1); Too, Y. M. (1);Tun Karenne (2); Lim, Karen (2)	(1) Acoustic Research Laboratory, National University of Singapore; (2) National Parks Board, Singapore	Acoustic detection of marine mammal vocalizations in snapping-shrimp infested noisy waters	The warm shallow waters near Singapore are known to be inhabited by marine mammals including dolphins, porpoises and dugongs. While sightings of their presence have been reported, a rigorous quantification of their numbers in these waters is yet to be done. Passive Acoustic Monitoring (PAM) can be used as an effective tool for quantifying their numbers in this region because acoustic data is relatively easy to acquire and store, and can provide large area of coverage. However, in Singapore waters, acoustic detection of vocalizations of marine mammals is impeded by the severe ambient noise which arises predominantly due to snapping shrimp snaps. This forms an impulsive noise background that often masks signals of interest. Shipping also contributes to the noise background. Detection in such challenging circumstances are less discussed in the literature. We have been developing a PAM that uses a machine-learning (ML) based detector designed to work in these noisy waters. The current detector shortlists sounds of interest that are potentially from marine mammals, and is trained to maximize the probability of detection at a set probability of false alarm. ML model architectures based on LeNet and VGG have been explored using training data consisting of online-available as well as locally recorded data, and their performance will be highlighted in this work. Using robust methods to deal with impulsive noise shows a dramatic improvement in detection performance, indicating that use of such techniques will be key in achieving effective monitoring in these waters.
von Benda-Beckmann, Alexander M. (1); Buis, E.J. (1); Dorant, J. (1); Toet, P. (1); de Vreugd, J. (1); Doppenburg, E. (1); Jansen, R. (1)	The Netherlands Organisation for Applied Scientific Research (TNO),	Probing the deep sea and deep space with fiber-optic hydrophones	Echolocation clicks of marine mammals and neutrinos (cosmic sub-atomic particles) interacting in the deep sea, share acoustic signatures: both are short and broadband. Large volumetric underwater acoustic telescopes are required to study high-energy cosmic neutrinos. Such an infrastructure provides interesting opportunities to study deep-diving echolocating marine mammals over large spatial and temporal scales. In order to detect rare acoustic neutrino events, an acoustic neutrino telescope would need to consist of hundreds to thousands of hydrophones. In this study we present recent developments of a novel fiber-optic hydrophone concept which was designed to detect acoustic neutrino signatures and marine mammal clicks, and is sensitive in a deep-sea environment. The objective of this development is to achieve a cheap scalable sensor that allows for efficient transportation of large data volumes to a shore station without relying on underwater power supply. The large data volumes, and low expected neutrino detection rates require the development of effective detection, classification, and localization algorithms to separate rare neutrino events from marine mammal echolocation clicks. We summarize current challenges and opportunities of realizing such an ambitious multi-disciplinary research infrastructure to study both the deep sea and the deep sky.
Westell, Annabel (1); Sakai, Taiki (3,4); Valtierra, Robert (5); Van Parijs, Sofie (2); Cholewiak, Danielle (2); DeAngelis, Annamaria (2)	(1) under contract to the Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA; (2) Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA; (3) Environmental Assessment Services, LLC; (4) under contract to the Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA; (5) Marine Acoustics Inc.	Acoustic detections of sperm whales in the western North Atlantic: insights into their foraging ecology and abundance	Sperm whales are considered endangered under the US Endangered Species Act, making it imperative we understand population trends in abundance and distribution. While previous abundance estimation has relied on visual sampling, passive acoustic surveys can improve detection of deep-diving cetaceans like sperm whales. However, accounting for dive depth may be important for producing an unbiased detection function and accurate density and abundance estimation. Here we present an innovative and effective method for using passive acoustics to detect sperm whales, localize individuals in 3D, and estimate abundance using depth-corrected perpendicular distances. From June 27 to August 25, 2016 the Northeast Fisheries Science Center completed approximately 6600 km of simultaneous visual and passive acoustic line-transect surveys along the northeast coast of the US. More than 350 hours of acoustic recordings, collected using a towed linear hydrophone array, were analyzed. 699 detections of sperm whales producing foraging clicks were classified and localized in 2D using PAMGuard's Target Motion Analysis Module. Multipath reflections of clicks were available and used to estimate 3D localizations for 274 detections. The average depth across these detections was 663 m (SD = 391 m), with 25th and 75th percentiles at 411 m and 821 m. To ascertain the effect of depth, a detection function and abundance estimate for sperm whales in the western North Atlantic will be calculated before and after the horizontal distances are corrected for depth. Results will also be compared to the abundance estimate produced from the visual line transect data.

White, Ellen (1), (2) White, Paul (3) Bull, Jonathon, (4) Rische, Denise	(1) SOES University of Southampton, (2) ISVR University of Southampton, (3) SOES University of Southampton, (4) Scottish Association of Marine Science	Deep Delphinids: A transfer learning approach to efficient classification of marine sound sources in big acoustic data, relevant to marine mammal conservation.	Effective analysis of marine acoustic 'Big Data' could permit analysis of ecosystem health and species presence, if automated detection and classification algorithms are capable of discrimination between species of interest in the presence of anthropogenic and environmental noise. Advancement in extracting ecologically valuable cues from the marine environment, embedded within the soundscape are limited by the time required for manual analyses and the accuracy of existing algorithms. In this work a deep learning model is trained for multi-class marine sound source detection and classification, through the use of cloud computing and existing datasets amalgamated across geographic, temporal and spatial scales, collected across a range of acoustic platforms. Transfer learning was used to train state-of-the-art convolutional neural networks (CNNs) to detect Odontocete tonal and broadband call types and anthropogenic sound sources which span the frequency domain between 0 and 50kHz. Here we present a small-scale CNN, reporting an accuracy of 92% on our test data. This model provides a low-cost, low-computational-cost approach to automated sound source detection, and is suitable for installation onboard autonomous platforms. Our work provides a novel automated tool for mining big marine acoustic data for information on temporal scales relevant to the management and conservation of vulnerable species, anthropogenic noise and marine protected areas.
Wilcock, William (1); Abadi, Shima (2); Williams, Ethan (3); Zhan, Zhongwen (3); Bodin, Paul (4); Denolle, Marine (4); Lipovsky, Brad (4); Winebrenner, Dale (5); Wengrove, Meagan (6); Toomey, Douglas (7)	(1) School of Oceanography, University of Washington; (2) School of STEM, University of Washington; (3) Seismological Laboratory, California Institute of Technology; (4) Department of Earth and Space Sciences, University of Washington; (5) Applied Physics Laboratory, University of Washington; (6) School of Civil and Construction Engineering, Oregon State University; (7) Department of Earth Sciences, University of Oregon.	A Community Test of Distributed Acoustic Sensing on the Ocean Observatories Initiative Regional Cabled Array Offshore Central Oregon	Distributed acoustic sensing (DAS) is a relatively new observational technique that interrogates an optical fiber that is otherwise unused with repeated laser pulses and utilizes changes in the phase of backscattered light to measure the strain rate along the fiber. The method can work to distances of up to ~100 km and has a spatial resolution of a few meters and a broad frequency sensitivity. On land the method is being increasingly used to monitor seismic and anthropogenic signals and several experiments have demonstrated the potential of offshore DAS measurements for geophysical and oceanographic applications. From November 1-5, 2021, we conducted a 4-day community test of DAS on the Ocean Observatories Initiative (OOI) Regional Cabled Array (RCA) during a planned maintenance shutdown. The OOI RCA operates two telecommunication cables which extend offshore from Pacific City, Oregon, with the first optical repeaters located at distances of 65 km and 95 km. Data were collected using two OptaSense QuantX and one Silixa iDASv3 distributed acoustic sensors with measurements successfully obtained out to the repeaters. The data is currently undergoing screening by the Navy and upon release will be archived on the OOI RCA data management system where it will be available to the community for download and sharing via hard disk drive copies. Observations during the data acquisition showed that the DAS systems were able to record fin and blue whales calls out to distances of tens of kilometers indicating that offshore DAS may be a useful tool for studying baleen whales.
Woodrich, Dan (1), Stephanie Grassia (1), Catherine Berchok (2)	(1) University of Washington Cooperative Institute for Climate, Ocean, & Ecosystem Studies (CICOES) with Alaska Fisheries Science Center (AFSC) Marine Mammal Lab (MML) Cetacean Assessment and Ecology Program Acoustics Group; (2) Alaska Fisheries Science Center (AFSC) Marine Mammal Lab (MML) Cetacean Assessment and Ecology Program Acoustics Group	Performance of an Alaska region minke whale 'boing' AI detector on a Hawaiian dataset; out-of-the-box deployment and synthesized model with combined data	Minke whales seasonally occur in Hawaiian waters, where the stock structure and migratory routes of these animals are unknown. Stock structure of minke whales is similarly cryptic in the Alaska region. Although elusive to visual observers, minke whales are easily acoustically detected by their 'boing' call. One indicator of stock differentiation is the pulse repetition rate of the boing call, which is thought to distinguish animals between central and eastern North Pacific stocks. Given the importance of these calls for monitoring and population assessment, reliable detection of boing calls is essential for further research. Previously, an AI detector for minke boings was constructed with INSTINCT autodection software using call examples and training data from the Alaska region. Here, this detector will be deployed out-of-the-box to test performance of the method on the 10,000+ annotated minke whale boing detections from the HICEAS survey around the Hawaiian Islands. Additionally, the detector will be evaluated under combined region data train/test splits to explore the effect of the addition of the Hawaiian labels in training on detector performance as applied to test data from each region. Given well-known struggles of applying AI detection approaches across training domains, pooling annotations from multiple sources is a valuable technique to train AI detectors for cross-regional deployment. Availability of robust detection methods for minke whale boings will increase the depth of call libraries over a wider spatiotemporal extent, and allow for more in-depth population studies using boing call characteristics.

Yack, Tina.M. (1), (1) Schick, Robert , (2) Kaney, Nick, (2) Yu, Nathan, (3) Clark, Chris, (4) Gillespie, Doug, (5) Mayo, Stormy, (5) Mckenna, Brigid, (2) Nowacek, Doug, (6) Palmer, Kaitlin J., and (4) Tyack, Peter	(1) Duke University, Marine Geospatial Ecology Lab, Nicholas School of the Environment; (2) Duke University, Nicholas School of the Environment; (3) K. Lisa Yang Center for Conservation Bioacoustics, Cornell University; (4) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews East Sands; (5) Center for Coastal Studies; (6) SMRU Consulting.	Detection, Classification, and Localization of North Atlantic Right Whale Upcalls in Cape Cod Bay using PAMGuard Software and Co-Locating with Aerial Observations	NARW are threatened throughout their range and knowledge of animal distribution is critical to reduce impacts of multiple stressors. Researchers typically detect NARW using line transect surveys and passive acoustic monitoring. Better understanding of NARW distribution depends on assimilating these data. Center for Coastal Studies has conducted aerial surveys in Cape Cod Bay (CCB) since the 1990's for visual detection, and from 2001 2018, Cornell University deployed arrays of bottom-mounted MARU's to collect acoustic data. These data have not been analyzed jointly, and here we present an initial review of a subset of these co-located data (2008-2009). We used PAMGuard to analyze seventeen days' of acoustic data. For each day, we identified right whale upcalls using an edge detector, and subsequently, a neural-net classifier (LeNet) to assign a classification score to each upcall. We retained calls with edge detection score >= 9 (0-12 range) and classification scores >= 0.8 (0-1 range). Retained upcalls ranged from 219 on 2008-03-11 to 8,654 on 2008-04-08, comprising a total of 50,410 upcalls. A 3D simplex algorithm in PAMGuard was used to localize calls, and unique localizations ranged from 8 on 2009-05-08 to 382 on 2008-04-08. We will discuss automated detection, classification and localization methods and results and compare sighting positions with acoustic localizations. These results provide important information about the distribution of NARW over space and time as well as an important proof of concept of assembling multiple observation types to jointly model disparate data to improve our understanding of the spatiotemporal dynamics of NARW.
Ziegenhorn, Morgan A. (1); Frasier, Kaitlin E. (1); Hildebrand, John A. (1); Oleson, Erin M. (2); Baird, Robin W.(3); Wiggins, Sean M.(1); Baumann-Pickering, Simone (1)	(1) Scripps Institution of Oceanography, University of California; (2) NOAA Fisheries Pacific Islands Fisheries Science Center; (3) Cascadia Research Collective	Discrimination and classification of toothed whale echolocation clicks in the Hawaiian Islands using a machine learning toolkit	From 2008-2019, a set of passive acoustic monitoring (PAM) recordings covering the frequency band of most toothed whale echolocation clicks were collected at sites off of the islands of Hawai`i, Kaua`i, and Pearl and Hermes Reef within the Hawaiian Archipelago. Due to the size of this dataset and the complexity of species-level acoustic classification, multi-year, multi-species analyses have not been pursued. This study demonstrates the utility of a machine learning toolkit to detect and classify echolocation clicks within such a large dataset using unsupervised clustering methods and human-mediated analyses. Application of these methods resulted in ten unique echolocation click 'types' attributable to regional toothed whales at the genus or species level. In one case, a novel type was ascribed to the rough-toothed dolphin, Steno bredanensis, using auxiliary data including recordings from the current DCLDE dataset. Types defined by clustering were then used as input classes in a neural-network based classifier. Accuracy was high (>96%) across all classes and sites. Network sensitivity was high (>75%) in all cases except for one type of short-finned pilot whale, Globicephala macrorhynchus, at Kaua`i and Pearl and Hermes Reef (>66%). These results demonstrate the effectiveness of machine learning in analysis of large PAM datasets. The classifier developed here will be used on available data to create long term, multi-species timeseries, furthering analyses of spatiotemporal patterns of included toothed whales. Broader application of these methods may improve the efficiency of global PAM efforts, which is needed as these datasets continue to grow.