Workshop Title: Upcoming and recent changes to PAMGuard software and an open discussion on desired changes and direction

Patrick Lyne[1] and Douglas Gillespie[2]

[1]Irish Whale and Dolphin Group, Merchants Quay, Kilrush, Ireland

patrick.lyne@iwdg.ie

[2]Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, Scotland

dg50@st-andrews.ac.uk

Workshop held during the World Marine Mammal Conference, Barcelona, Saturday 7 December 2019.

Report available April 2020.

Introduction

The workshop consisted of a short description of the use of long term spectral averaging followed by a description of changes that may be coming to PAMGuard software (Gillespie et al., 2008) in the next year. This was followed by a description of the use of signature whistles for density estimation of small populations of geographically isolated resident dolphins and how PAMGuard or other acoustic software might be employed in this project was discussed. This was followed by a discussion of various aspects and functionality of PAMGuard including the Autosave function, Help files, You Tube tutorials, Whistle and Moan detector changes, bug reporting, expectations of software, training requirements, click classifier optimization and usage, importing GIS maps, Bluetooth headphones, 3D localiser and Java support.

20 participants attended, whose names are listed in appendix I.

Long term spectral averaging (LTSA) – Lorenzo Scala

The Long Term Spectral Averaging (LTSA) provides an overview of the soundscape from large time-series data where trends and events can be identified. It has been widely used with ARP (Acoustic Recording Package) and HARP (High Frequency ARP) projects with Triton software (Wiggins et al., 2010) and is now integrated into PAMGuard. It permits rapid review and identification of sounds and periods of interest from processed audio which can be displayed in PAMGuard Viewer Mode. Detector overlays (Whistle and Moan Detector) and quick spectrogram annotation permit marking detections and events, as well as

links to raw spectrogram display, which in Viewer mode the user can scroll through to the timestamp identified on LTSA.

The LTSA can be used to give a brief overall picture of the acoustic profile of the marine environment in a location of study. Reviewing long-term data offline can be a laborious, time consuming task and LTSA provides a quick high level summary of the acoustic data recorded. In some ways this is best suited to static acoustics where there is little or no noise due to deployment. Towed arrays are subject to noise from the towing vessel, as well as cavitation noise as a result of the array being pulled through the water. However LTSA is usefully employed in both static and towed acoustic systems. It can be used to identify anthropogenic acoustic impacts in particular frequency ranges as well as marine mammal vocalisations over a sustained period.

Short acoustic signals such as echolocation clicks of harbour porpoise may not show on LTSA plots since the energy of the clicks is averaged with all the noise between clicks, thereby reducing the signal to noise ratio. Even the clicks of louder species such as sperm whales may not show well on LTSA, particularly when using towed hydrophone data. This may make the method unsuited to identification of animal presence of particular species due to vocal habits, particularly on towed arrays where detections may be over a brief time interval. However LTSA can provide a useful summary method of displaying anthropogenic noise impacts in a marine environment as well as help identify seasonal marine mammal presence and occurrence.

A number of issues may cause false positives in LTSA, such as noise during deployment of the system or system self-noise, particularly common in towed arrays. But such noise is normally limited to frequency bands and many marine mammal calls can be outside of the frequencies of background noise. Such unwanted background noise may be reduced by use of filters, or by restricting detection events by use of detector parameters. LTSA can be used to identify common sources of false triggers and improve the parameters used in automatic detectors.

LTSA can be useful in baseline studies of marine mammals to identify seasonal activity and assist the careful planning of industry activities and temporal mitigation. It can also be used to assess the impact of industrial operations on long-term trends in marine mammal activity, as well as part of a wider soundscape study to measure industrial noise emissions.

PAMGuard upcoming changes – Doug Gillespie

Since 2006 PAMGuard development has resulted in the generation of an average of 87 lines of code per day.

Beam Forming

As part of a Sound and Marine Life JIP (International Association of Oil and Gas Producers, Joint Industry Programme) funded project a beam forming module has been added to PAMGuard. The beam former implementation is a “Frequency Domain” beamformer, which takes output from an existing FFT module applies appropriate time delays (phase shifts in the complex spectrum) and sums the data to create any number of beams as configured by the user. Whereas a normal spectrogram display shows a

spectrogram for each input channel and will contain sound data arriving from all angles, the beamformer display will show a spectrogram for each beam, with each beam using data from all hydrophones, but only including energy from sounds arriving from a particular angle.

The output of the beam former can be viewed in a spectrogram like display and can be used as input to any PAMGuard detector that would normally take FFT data as it's input.

The advantage of beamforming, is that because each beam is only listening in a specified direction, the signal to noise ratio of sounds within that beam is improved, therefore increasing the chances of detection. This is particularly useful when highly localized noise sources, such as vessel propulsion systems, are masking animal sounds, since it becomes possible to listen to other directions, effectively ignoring sound energy coming from the vessel.

However, for a beam former to have significant gain, a large number of hydrophone channels are required (in uniform noise, the gain is $10 \times \log_{10}$(n hydrophones) = 6dB for a four hydrophone array and 12dB for a 16 hydrophone array). The angular resolution of the beams is also a function of both frequency and hydrophone spacing, so careful consideration is required when developing a hydrophone array for particular applications and types of sound.

Bearing Calculator

As part of the beam forming development, a new bearing calculation module was implemented which can be used with any type of data within PAMGuard. Older versions of PAMGuard estimated bearings to sounds detected by the click and whistle detectors, but would not estimate bearings to other data, such as annotation marks made by the operator on the spectrogram display. The bearing calculator module can take any input type and will estimate bearings in either one dimension (for linear arrays) or two (horizontal and elevation angles for volumetric arrays). Both Time of Arrival Difference (TOAD) and beam forming algorithms are available within the module. Generally, TOAD algorithms execute more quickly, but if a many hydrophone array is available, beam forming algorithms will benefit from array gain and may give more accurate results. The TOAD methods implement the improvements to TOAD calculations discussed in (Gillespie and Macaulay, 2019).

Both the beam former and bearing calculator modules will become available in a spring 2020 PAMGuard release.

QA Module

A Quality Assurance module has been developed for PAMGuard and will be released in 2020. Often during PAM operations it is difficult to judge how well a PAM system is working and if no animals are detected it may not be clear whether this was due to a genuine absence of animals or that noise levels were too high to permit detection or the PAM system was unsuitable or poorly configured. The QA module works by injecting artificial sounds into the system and mixing them with the real noise coming from the hydrophones. It then tests to see whether those sounds were detected and also whether or not the human operator noticed them. The module is then able to automatically generate reports in MS Word format, including graphs of detectability of different sound types as a function of range. These

reports can act as a guide to the PAM operator who may try to improve the configuration or deploy their hydrophones array in a less noisy location and can be fed back to equipment providers and regulators.

Possible Future Enhancements

While much of PAMGuard funding has in the past come from the oil & gas industries, the PAMGuard team attempt wherever possible to get funding form other sectors. We have recently submitted a number of proposals to the US Office for Naval Research Living Marine Resources Program for a number of enhancements to PAMGuard. If funded, these are:

1. Integration with Tethys database (Roch et al., 2013). The Tethys data base (https://tethys.sdsu.edu/), developed by Marie Roch at San Diego State university is designed to handle metadata from marine mammal surveys using Passive Acoustics. By integrating with Tethys, backend management of data from PAMGuard will become better standardized and more compatible with data formats used by many research groups in the US and around the world. Regulators will find it easier to combine and assimilate data from multiple surveys if it is all in a consistent Tethys compatible format.
2. Improved Batch Processing. Increasing numbers of autonomous recording devices with large memory capacity are now available for modest cost and PAMGuard is often used to post-process data from these devices. We hope to improve the efficiency of the processing of large datasets, including the possibility of using multiple processing machines to reduce data turn-around times from archival recorders.
3. Interfacing to other programming languages such as Matlab and Python. Interfacing to Matlab will allow for more rapid algorithm prototyping and easier integration of algorithms developed by non-Java specialists. Python is the language most commonly used by the machine learning community, allowing the future integration of deep learning algorithms into PAMGuard.

Use of Signature Whistles in Density Estimation – Jack Fearey

Jack Fearey, a masters student at the University of Cape Town, is using PAMGuard for his project which is attempting to use passive acoustic monitors and signature whistles to study bottlenose dolphin density, abundance and movement patterns on an individual level. Using static passive acoustic monitors has a number of advantages to the previous method of photo-id, including being more cost-effective and offering continuous monitoring. Data has proven to be difficult to analyse due to number of whistles to extract, variability in contours, and signal to noise ratio. The PAMGuard whistle and moan detector (Gillespie et al., 2013) has been used in conjunction with the quick annotation module, however whistles are then manually evaluated in Raven-pro (Program, 2011). We discussed a way to automate signature whistle identification. MATLAB software, Beluga and ARTwarp has been used to extract whistle contours and categorize them based on unsupervised neural networks. Other ideas that might help to automate the analysis process included re-tooling Image recognition software, R script, Banter, or PAMR (a library for opening PAMGuard files in R).

The best way to develop complete processing paths for the project were discussed, from data collection to final acoustic classification and animal density estimation. While PAMGuard clearly has an important role in data collection and initial data screening and sound detection, the final stages of analysis are often best conducted in Matlab or R using more bespoke and flexible tools. For instance, (Rankin et al., 2017) describe a system whereby PAMGuard is used for initial data processing, then functions mostly written in the R language are used for species classification and latter stages of analysis. The flexibility required in these latter stages of analysis often make it impractical to implement those function in PAMGuard where it becomes difficult for researchers to modify them to their specific needs. To support such efforts the PAMGuard team and researchers at the NOAA South West Fisheries Science Centre have provided libraries that allow PAMGuard data files to be loaded into both Matlab and R. These are available through the PAMGuard website.

Conclusion: MATLAB and R can be better for specific projects as it allows flexibility and coding which cannot be built in to PAMGuard. No direct changes to PAMGuard will be pursed, however, it is possible to load binary files into previously written MATLAB script like ARTwarp, so recoding ARTwarp for this project would provide a potential solution.

Maintenance and Bug Fixing – Doug Gillespie

As Computers and operating systems change and improve (or just change!), PAMGuard often needs modification to keep up with those changes. Areas in which the PAMGuard team are actively working to keep up with changes to hardware and software are;

High DPI Screens: users have been reporting that font and button sizes are too small to see on modern high resolution display screens. This is a problem inherent in the graphics libraries used by PAMGuard in Java 8 but has been rectified in Java 12. However, parts of Java 12 are incompatible with or don't support some other functions in PAMGuard. We are therefore working to resolve these issues and switch PAMGuard over to Java 12 early in 2020

Java changes: PAMGuard releases up to V 1.15.16 required the user to separately download and install Java from the Oracle website. This was the most common way of distributing Java programs, it being anticipated that a PC would have a single version of Java used by multiple programs, thereby reducing the size of individual downloads and reducing disk space requirements. Due to incompatibilities between Java 8 and Java 12+ the above course of action is no longer recommended and (given how much disk space a modern PC has and the speeds of downloads) it is now more common to bundle a specific version of Java with an application. In addition, Oracle have started to charge for downloads of their Standard Edition. The PAMGuard team are therefore in the process of switching over to what remains a free version of Java (OpenJDK) and are bundling Java binaries with the PAMGuard installers. A considerable maintenance effort is going into the switch to Java 12+. Following the switch over though, we are confident that less maintenance will be required to support future Java releases (13, 14, etc. …). When this work is complete, it will solve the problems of high DPI screens mentioned above, make PAMGuard easier to install and ensure that PAMGuard remains free to use for the long term. As we

make this change, it is likely that we will stop making installers for 32 bit computers. The PAMGuard user base will be consulted before that happens.

(Update April 2020. This work is now largely complete and a 64 bit Java 13 version of PAMGuard, with required Java components bundled with the installer is now available).

Discussion

A general open discussion was held about features that might be desirable to users.

Autosave of configuration

Occasionally PAMGuard is liable to crash, particularly when making changes while the software is running. This can lead to the complete corruption of the configuration file and usually this will happen at a time when you want PAMGuard to be running. Without a backup it can take several minutes to rewrite a new configuration file that will work and will need probably some fine tuning later to get it back to the state prior to the program crash. This can be avoided by backing up configuration files regularly. It was suggested that PAMGuard could automatically save its configuration whenever it's started, however some users said they would NOT like this since they sometimes want to get rid of changes. DG (Doug Gillespie) pointed out that PAMGuard already automatically places a timestamped backup of configurations in the binary data folder every time PAMGuard starts. Few users were aware of this suggesting that improvements are needed in documentation (see below).

Improved Help Files

It was acknowledged that help files may be in some cases out of date and that these could be looked at and improved. It was also generally agreed that the online help information could be augmented by the addition of a library of YouTube tutorials or similar, which would be of particular benefit to inexperienced users in mitigation.

Version Compatibility

While configuration files are usually supplied by PAM equipment suppliers, these don't always work as they may only be compatible with a specific PAMGuard release.

The PAMGuard team do everything possible to ensure backwards compatibility, but sometimes this is not possible or something inadvertently changes without us noticing. Configuration suppliers should ideally specify which version of PAMGuard their configuration has been tested with, or better ship PC's with equipment which have a functioning version of PAMGuard and appropriate configuration files set up, tested, and ready to run.

Different Setup Menus

It was found that sometimes when setting up the PAMGuard configuration file that it was necessary to access different drop down boxes in different places to complete the setup of features under PAMGuard. It was asked if the software could be altered to allow this to be done once for all feature setups. DG pointed out that PAMGuards modular structure can make it very difficult to avoid this, since it's hard for any one module to know which options may be available in a different module. However, in

recent years the PAMGuard team have been trying to address this issue by making more generic 'options sets' which can found and used by different modules across PAMGuard.

Whistle and Moan Detector Settings

The frequency range of whistle searches sometimes resets to zero Hz. DG said that if it's zero the software will automatically note this and set it to the full frequency range of the available data as soon as PAMGuard starts. This is therefore either a documentation issue or an issue of making the user interface more friendly rather than an operational problem.

Forum

Creation of a forum was suggested for peer support and PAMGuard support for issues. This could be a location through which video training could be accessed and possibly would encourage better bug reporting. It was pointed out that video training was already offered by organizations such as Seiche. Bug reporting is extremely useful for the support of PAMGuard and is currently not engaged in by many users. Possibly this is because of a lack of experience and a forum may provide a better way to engage with the PAMGuard user community.

User Expectations

The creation of a simplified version of PAMGuard for less competent users was discussed. Where to draw the line between options that an inexperienced user should be able to change and those which should only be changed by an expert is a difficult decision. It was pointed out that most, if not all, equipment suppliers provided configuration files to users and that these provide for basic mitigation operation. However it was emphasised that users should be properly trained and competent and inexperienced PAM operators should work in tandem with more experienced users to allow skill transfer and to ensure effective mitigation.

Click (and other) Classifiers

The use of click classifiers was discussed with optimization for signal to noise ratios. Use of generic classifiers from MATLAB or Python was discussed and may be the topic of a future request for funding (see future enhancements above).

Maps

It would be useful to simplify and enhance the map module in PAMGuard to allow the import of GIS maps.

Bluetooth Headphones

Currently it is not possible to use Bluetooth speakers or headphones with PAMGuard due to the setup of output devices under Microsoft and the way that PAMGuard currently handles sound output devices by making a list of available devices when PAMGuard starts which makes it difficult for PAMGuard to manage a device which is intermittently present. On a similar note, recent versions of Windows, at least with some PC hardware, will change the list of available output devices whenever headphones are plugged or unplugged from a standard headphone socket on the front of a PC. It is therefore necessary

to update how PAMGuard manages sound output devices so that it can respond more effectively to devices which are intermittently present.

Update. Work was done to try to resolve this in January 2020. PAMGuard cannot deal with windows failing to find Bluetooth devices that go in and out of range, but when Windows does successfully connect to Bluetooth devices, PAMGuard will now switch to them if they are the default sound output device and the default device is selected for sound output.

3D localiser

Better support for 3D localiser was discussed. It seems a number of operators are now considering more sophisticated volumetric arrays that have the potential to localise sounds in 3D. 3D localization in PAMGuard has been improved in recent years, primarily driven be research at SMRU undertaking fine scale tracking of porpoises in tidal rapid and around renewable energy generators. Some of this functionality has been tested with simulated towed arrays, but needs testing with real array data. The PAMGuard team are keen to work with anyone testing such arrays in order to iron out any bugs of features in the 3D localisation modules.

Module Removing

Users sometimes try to remove a module and then reinstate it if it's been crashing. DG said that this might not work since the settings for that module are probably still in the PAMGuard configuration and will be automatically reloaded. Work would be required to prevent this / provide an option to load existing or revert to default settings.

Acknowledgements

Patrick Lyne wishes to thank the Marine Institute for the provision of a networking and travel grant funded by the Marine Institute under the Marine Research Programme with the support of the Irish Government.

References

Gillespie, D., Caillat, M., Gordon, J., and White, P. (**2013**). "Automatic detection and classification of odontocete whistles," J. Acoust. Soc. Am., **134**, 2427–2437.

Gillespie, D., Gordon, J., Mchugh, R., Mclaren, D., Mellinger, D., Redmond, P., Thode, A., et al. (**2008**). "PAMGUARD: Semiautomated, open source software for real-time acoustic detection and localisation of cetaceans," J. Acoust. Soc. Am., **30**, 54–62. doi:https://doi.org/10.1121/1.4808713

Gillespie, D., and Macaulay, J. (**2019**). “Time of arrival difference estimation for narrow band high frequency echolocation clicks,” J. Acoust. Soc. Am., **146**, EL387–EL392.

Program, B. R. (**2011**). “Raven Pro: interactive sound analysis software. Version 1.5,” Ithaca NY Cornell Lab Ornithol. 2018 Mar 1,.

Rankin, S., Archer, F., Keating, J. L., Oswald, J. N., Oswald, M., Curtis, A., and Barlow, J. (**2017**). “Acoustic classification of dolphins in the California Current using whistles, echolocation clicks, and burst pulses,” Mar. Mammal Sci., **33**, 520–540.

Roch, M., Baumann-Pickering, S., Batchelor, H., Hwang, D., Sirovic, A., Hildebrand, J., Berchok, C. L., et al. (**2013**). “Tethys: A workbench and database for passive acoustic metadata,” Oceans-San Diego 2013, IEEE, 1–5. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6741361

Wiggins, S. M., Roch, M. A., and Hildebrand, J. A. (**2010**). “TRITON software package: Analyzing large passive acoustic monitoring data sets using MATLAB.,” J. Acoust. Soc. Am., **128**, 2299–2299.

Appendix I

Georgia Atkinson, Kristian Beedholm, Benoit Berges, Olivier Boisseau, Aline Boutros de Mello, Katharina Brundiers, Mel Cosentino, Heidi Etter, Jack Fearey, Douglas Gillespie, Jonathan Gordon, Patrick Lyne, Jennifer Keating McCullough, Simon Keith, Robert Lee, Davide Michel Lelong, Jamie Macaulay, Lorenzo Scala, Jim Theriault, Veronika Wahl, Harald Yurk.