Survey Results

Hydrophones in Wildlife Conservation

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This report presents the results of the hydrophone survey, performed between 26th November 2020 and the 20th December 2020. The survey was carried out on Google Forms, with a total of 80 participants. The results aim to establish preliminary user requirements by: (i) defining the main user groups, (ii) evaluating existing equipment, (iii) defining the environmental characteristics in which hydrophones are operated, (iv) identifying the goals of the user community, and (v) identifying user tasks.

1 Hydrophone users

The survey is intended to discover the context in which hydrophones are used in conservation research. Part of this survey identified different groups within the conservation practitioner profile. The conservation user groups included university level students, researchers, employees of conservation organisations, employees and volunteers at local councils or governments, employees of marine and freshwater protected areas, local community conservationists and others, including sound artists and hobbyist field recordists.

University/institution level conservation students/researchers make up 54% of all participants. These individuals typically practise conservation research as part of their university program or with support from government research councils. This group perform the majority of published research in the area of conservation. Their research contributes to establishing the frameworks on which conservation is carried out by other groups.

Employees of government institutions and councils make up 5% of participants. The majority of individuals in this group are generally office based, with advisory roles towards governmental conservation policy. Examples of these institutions include the Joint Nature Conservation Committee (JNCC) and Natural England in the UK, and internationally, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and United Nations Environment Program (UNEP). They also actively manage some types of conservation area and employ government 'performers' to carry out field work. As such, they represent only a small proportion of hydrophone users and act more as a focal point of contact and advice for all stakeholders in marine and freshwater conservation.

The third group, comprising 14% of the survey participants, are employees and volunteers of conservation organisations, such as Ocean Conservancy, Oceana, the Zoological Society of London and the World Wildlife Fund. They run mission-oriented and time-limited projects with goals that demonstrate tangible improvements in the functioning or state of ecosystems, habitats or the status of species. This group rely on the conservation organisation supplying equipment for their monitoring projects.

Marine protected area (MPA) conservationists comprise 4% of the survey participants. They actively sustain and restore habitat, often in conjunction with a government institution or conservation NGO. They include the managers of government run MPAs, individual fishers who are incentivised by governments to protect marine habitats at sea and for-profit companies utilising marine and freshwater resources in their business.

Sound artists make up 22% of all participants. They compose and use natural sounds in their art work. Although not necessarily viewed as traditional conservationists, their work improves public visibility of nature, which successively helps biodiversity policy by increasing public engagement to those not necessarily engaged in conservation (Rose et al., 2018).

Other users constitute 8% of survey participants. These include local communities, such as those that reside near coastal or freshwater habitats, including anglers, local maritime clubs and societies. This group are generally located near important conservation areas. Technology would either be used for hobbies, or donated by other organisations to enable this group to participate.

2 Existing equipment

The majority of marine and freshwater bioacoustics projects use stored datasets to uncover environmental

Figure 1: *The B&K 8103 miniature, an example of a piezoelectric ceramic cylinder external hydrophone. Image from https://www.bksv.com/*

insights. These datasets are often collated from audio recordings taken on either external hydrophones tethered to a recording device above the water - used by 75% of survey participants - or submersible standalone battery powered units with built-in hydrophones. These are known as autonomous recording units (ARUs), which are used by 44% of survey participants. Other types of ARUs - used by 10% of survey participants - include acoustic receivers, buoyed hydrophones and hydrophone equipped autonomous vessels. Each type of hydrophone has specifications for bandwidth, depth and hydrophone sensitivity. ARUs have additional specifications for memory capacity, signal to noise ratio (SNR), weight and battery life.

2.1 External hydrophones

External hydrophones use long wired cable assemblies attached to piezoelectric ceramic cylinders (Figure 1). The hydrophone cable is then attached to a recording device, such as a handheld dictaphone. There are many off-the-shelf external hydrophones available. In addition, the components to build bespoke hydrophones are low-cost and readily available. In this report we will only focus on those hydrophones stated by survey participants and omit the bespoke type (Figure 3). The most commonly used model of external hydrophone is the Aquarian Audio H2a series. This brand is low-cost, with specifications including a sensitivity of -180 dB re 1V/µPa, depth rating of 80 m and bandwidth of 10 Hz to 100 kHz. The price of the Aquarian Audio H2a is approximately $200 USD. See Table 1 for a comparison of the survey participants external hydrophones.

2.2 Standalone hydrophones

There have been numerous standalone hydrophones or ARUs in the past (Sousa-Lima et al., 2013). However, in this report we will focus on those declared to be used by survey participants. Standalone hydrophones include simple battery powered units with built-in hydrophones and some of the more custom units, such as buoyed hydrophones, click detectors and acoustic receivers. These devices are often required to monitor long-term environmental events, they are rugged in

Figure 2: *SoundTrap, an example of a standalone hydrophone. Image from http://www.oceaninstruments.co.nz/*

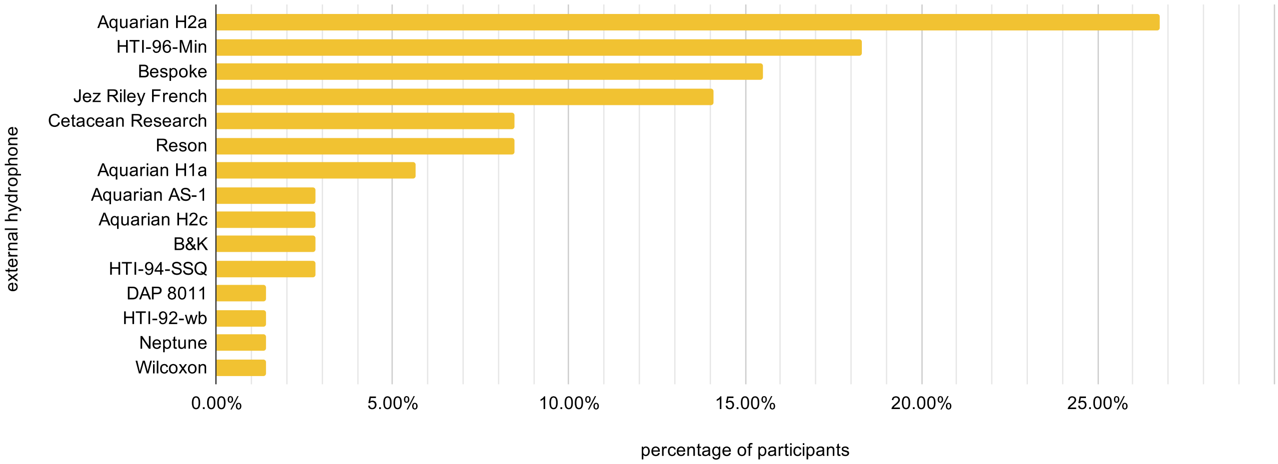

Figure 3: *Survey results showing the external hydrophone models and distribution of users using them*

Model	Sensitivity	Bandwidth	Depth	Cost
HTI-96-Min	-201 dB re 1V/µPa	2 Hz - 30 kHz	500 m	$800
Aquarian H2a	-180dB re 1V/µPa	10 Hz - 100 kHz	80 m	$200
Aquarian H1a	-190dB re 1V/µPa	1 Hz - 100KHz	80 m	$150
Cetacean R. C75	-180 dB re 1V/µPa	3 Hz - 250 kHz	920 m	$5000
Reson TC4032	-164 dB re 1V/µPa	5 Hz - 120 kHz	600 m	$2500
Jez Riley French	unknown	unknown	unknown	$90
Aquarian AS-1	-208 dB re 1V/µPa	1Hz - 100kHz	200 m	$395
Aquarian H2c	-180 dB re 1V/µPa	10 Hz - 100 kHz	80 m	$169
B&K 8106	-173 dB re 1V/µPa	3 Hz - 80 kHz	1 km	$3095
HTI-94-SSQ	-198 dB re 1V/µPa	2 Hz - 30 kHz	6 km	unknown
HTI-92-wb	-180 dB re 1V/µPa	2 Hz - 50 kHz	1 km	unknown
Neptune D60	-200 dB re 1V/µPa	1 Hz - 100 kHz	1.5 km	unknown
Wilcoxon H505L	-160 dB re 1V/µPa	2 Hz - 10 kHz	250 m	unknown

Table 1: *Comparison of survey participants' external hydrophone models*

design and can be left unattended for months.

The most popular type, out of both external and standalone hydrophones, is the SoundTrap with a sensitivity of -171 dB re 1V/µPa, bandwidth from 20 Hz to 150 kHz, depth rating of 500 m and a price of $4000 USD. The benefits of using SoundTrap are summarised in the the following participant comments:

"I most often use SoundTraps (by Ocean Instruments, NZ); easy to use, entire recording chain is in one sleek package"

— Student

"Standalone like the soundtrap is great. no hassles with cables or glitchy connectors. even for daily boat deployments . Only con is you can't hear in real time but we rarely do that anyway with a hti/zoom set up (headphones often crackle and potentially biases the recs)"

— Post-doc

The main standalone hydrophones highlighted by the survey were SoundTrap, Loggerhead DSG Ocean and JASCO AMAR (Figure 4). The additional features of these hydrophones are compared in Table 2.

Model	Battery	Memory
SoundTrap	13 days	256 GB
AMAR	60 days	10 TB
DSG	60 day*	512 GB

Table 2: *Comparison of additional features on survey participants' standalone hydrophone models. *13 days constrained by memory*

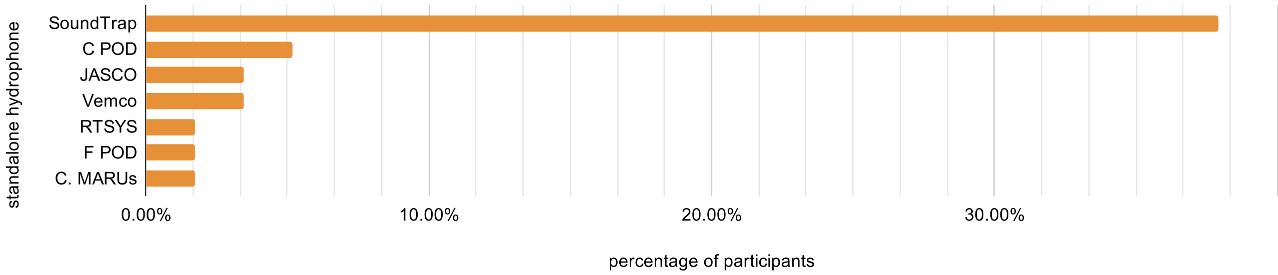

Figure 4: *Survey results showing the standalone hydrophone models and distribution of users using them*

Model	Sensitivity	Bandwidth	Depth	Cost
SoundTrap	-171 dB re 1V/µPa	20Hz to 150kHz	500 m	$4000
CPOD	click detector	0Hz - 160kHz	100 m	$4022
AMAR	-210 dB re 1V/µPa	20Hz - 150kHz	500 m	$40,000
Vemco	receiver	69kHz	500m	unknown
FPOD	click detector	0Hz - 160kHz	100 m	$4022
DSG Ocean	-201 dB re 1V/µPa	2Hz - 30kHz	500 m	$6000
Rockhopper	future product	unknown	surface	unknown
RTSYS	unknown	3Hz - 500kHz	unknown	unknown

Table 3: *Comparison of survey participants' standalone hydrophone models*

3 Environmental characteristics

Hydrophones are designed to withstand the environmental conditions imposed by water. These include salinity, density and temperature. Water in general causes severe problems for uncovered electronics used in hydrophones, therefore, all hydrophones need to be enclosed. Salinity in sea water conducts ions which speed up rusting. Therefore, enclosures should avoid using metals containing iron. External forces under water cause pressure on the hydrophone enclosures, therefore they need to be designed to withstand crushing forces as depth increases. Survey results show shallower deployment depths above 30 m are most common (Figure 5). At 30 m the kilogram-force pressure is 4.2 kgf/cm^2. Depending on location water has extreme temperature variation. Higher temperatures can cause electronics to overheat and malfunction and lower temperatures can reduce battery capacity. The survey results show that most participants deploy between 6°C and 25°C (Figure 6).

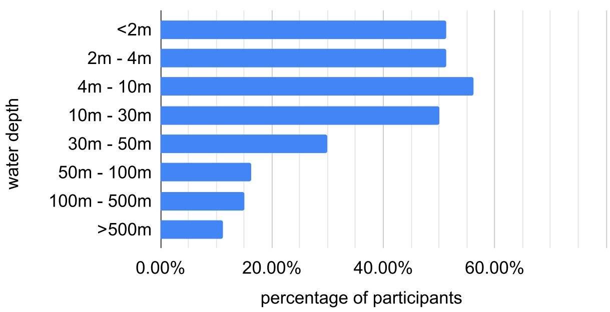

Figure 5: *Survey results showing the distribution of participants deploying hydrophones at certain depths*

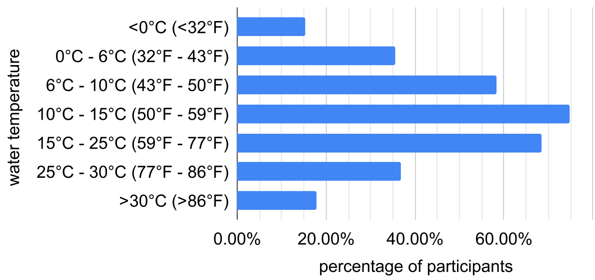

Figure 6: *Survey results showing the distribution of participants deploying hydrophones at certain water temperatures*

4 User goals

Figure 7 shows the types of sound sources that the survey participants capture in their conservation studies, thus giving an indication of user goals. Individual species are commonly recorded in conservation projects. These can be grouped into animal types,

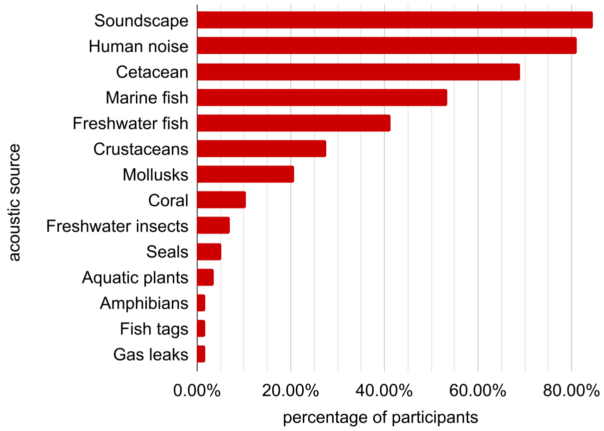

Figure 7: *Survey results showing the distribution of participants recording certain types of sound source*

such as marine fish, freshwater fish, crustaceans, mollusks, coral, freshwater insects, seals, aquatic plants and amphibians. 70% of participants recorded an animal group called cetaceans. This group are aquatic mammals, such as dolphins, whales and porpoise. All cetaceans communicate with sound and some echolocate in ultrasonic frequencies (André et al., 2011). The most common sound sources recorded by 85% and 80% of participants were soundscapes and human noise respectively. For soundscapes, the entire underwater environment is often recorded without a particular need to monitor an individual species. Soundscapes are recorded to identify all acoustic events in a location. The differences observed in these acoustic events identify changes in those environments over time (Lindseth and Lobel, 2018). Data is recorded over a broad frequency bandwidth and captured sound can be used to assess biodiversity and ecosystem health. Human noise is typically monitored to assess the human impacts on an environment. This could be boat engine noise, industrial noise, blast fishing or illegal human activity. This activity often occurs at lower frequency bandwidths (Merchant et al., 2016).

5 User tasks

Hydrophone users perform a set of complex tasks before, during and after deployments. This section simplifies these tasks into a few categories: device setup, involving bandwidth configuration and calibration; deployment, involving how hydrophones are physically deployed, and how long participants leave hydrophones unattended; and finally, the analysis techniques used on the captured data.

5.1 Device setup

Figure 8 shows the frequency bandwidths participants capture during typical deployments. Over 50% record frequencies below 48 kHz, indicating a maximum sam-

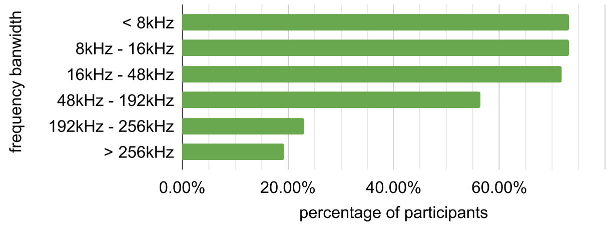

Figure 8: *Survey results showing the distribution of participants recording certain sound frequencies*

ple rate of 96 kHz. Calibration was highlighted by some participants as an important prerequisite to a usable monitoring tool. The main benefit being that decibel source levels can be achieved, enabling the calculation of distance to source. User perspectives of calibration are summarised in the following participant comments:

> *"There is a large potential market for a reliable recorder that can do calibrated continuous recordings up to 20 kHz and at the same time detect ultrasonic clicks (dolphins, porpoises etc) up to 180 kHz."*
>
> — Post-doc

> *"An affordable calibration service is a major gap in the market. Not just isolated hydrophone element but whole chain together incl preamps etc to reportable dB value"*
>
> — Ecologist

> *"Most hydrophone producers provide calibration data for only 1 or a couple of frequencies. However, it is imperative to provide this for the entire Nyquist frequency range of the hydrophone."*
>
> — PhD fellow in bioacoustics

Nevertheless, 51% of participants never calibrate their hydrophones. Approximately 23% of participants calibrate frequently or before every single deployment, and the remaining 26% occasionally calibrate.

5.2 Deployment

Deploying hydrophones in water is varied and has many challenges, generally requiring a vessel to take conservation practitioners over the water surface to locations of interest. Keeping track of and finding a deployed hydrophone requires navigation equipment

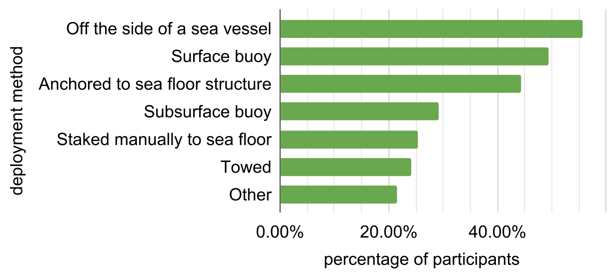

Figure 9: *Survey results showing the distribution of participants using different deployment techniques*

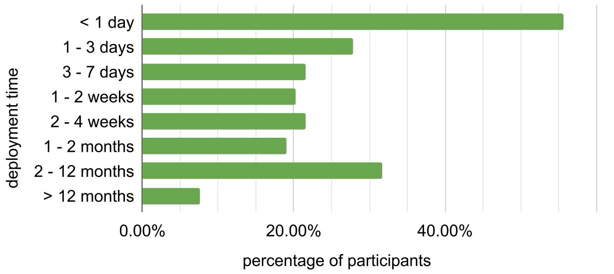

Figure 10: *Survey results showing the distribution of participants waiting a certain period of time between maintenance visits*

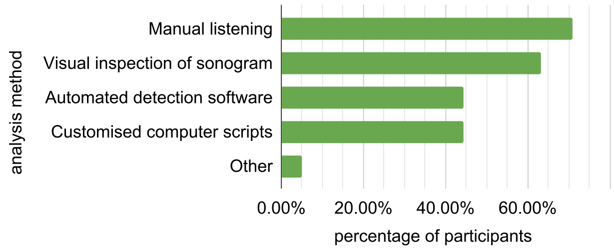

Figure 11: *Survey results showing the distribution of participants using certain analysis methods on their captured hydrophone data*

and physically deploying hydrophones might even require scuba equipment. Keeping a hydrophone in one location in deep waters requiring further equipment, such as rope, anchors and buoys. Figure 9 shows the distribution of hydrophone deployment methods used by survey participants, with Figure 10 showing the amount of time the hydrophones are left in the water before maintenance or collection. Approximately 55% of participants deploy their hydrophones from the side of a vessel and for less than one day. This correlates with those participants using external hydrophones, which require an external recording device above the water that cannot be left overnight. Approximately 50% of participants use surface buoys to hold their hydrophones and 45% anchor hydrophones to the water floor. All other deployment types, except towing, deploy for more than 1 day, with 2 - 12 months being the most likely deployment period. Approximately 23% of participants indicated that they occasionally use scuba equipment for deployments, with 9% stating that it is frequently or always required. Approximately 68% of participants deploy hydrophones without physically submersing themselves into the water.

5.3 Analysis

The last user task is data analysis. Recording sound produces large quantities of data that requires users to store, sort, filter, and analyse. The main types of analysis include manually listening to data, visually inspecting spectrograms, using custom software such as PAMGuard, and developing custom computer scripts using tools such as python and R. The analysis techniques performed by participants are summarised in Figure 11, with manual listening and visual inspection being the most popular analysis techniques.

6 Other insightful comments

Below are some extra insightful comments from survey participants, which were extracted from the answers to survey question: ‘Is there anything else you would like to tell us about how you use your hydrophone?’.

“*In combination with video/ROVs, etc. Need for simultaneous above and below water recordings and sync with video. Simultaneous video and audio processing (with spectrograms, etc.)*”

— Ecologist

“*Low cost acoustic releases are a big need for deep water work.*”

— Whale biologist

“*Flexibility in memory and battery sizing is really important and is eliminating any possible stray noise from the actual enclosure.* ”

— NGO/MPA employee

“*We often use onboard detection algorithms for high frequency dolphin and porpoise clicks. This allows us to record raw data at lower frequencies (e.g. 96kHz to detect delphinid whistles) decreasing storage requirements. For raw data we also use an onboard x3 compression algorithm. In typical underwater noise profiles this result in four times lossless compression for high frequency recordings. Harbour porpoises are the UK’s most common cetacean. They echolocate at 130kHz peak frequency and so a usually a minimum 384kHz sample rate recorder is required for marine PAM in the UK and many other countries.*”

— Marine acoustics software developer/researcher

“*Often deploy and collect hydrophones every day or so to rotate between sites as we are limited by equipment. With more equipment we would aim to leave these deployed for longer (weeks to months). My own work has focused a lot on the use of acoustic indices from recordings.*”

— Student

“*I often need to perform acoustic localization. Having a low cost multi channel (4hp) recorder would be a game changer for studying fish sounds.*”

— Acoustic consultant and PhD candidate

“*I would like a hydrophone that can deployed alongside active acoustic devices and can detect transmitted* *signals and monitor the environment (seals, whales) in the high Arctic.*"

— NGO/Student

"*Increasingly critical to record both above and below water sounds simultaneously, especially in FW and Estuarine habitats.*"

— Post-doc

"*Depth and orientation are often important ancillary data. Almost always use hydrophone pairs, increasingly larger arrays, so ability to make multi-track recordings and/or synchronise units important. Size and shape of recorders influences housing practicalities.*"

— NGO/Post-doc

"*I also use it as a contact microphone for low frequencies. I am surprised in your temperature range that you only go up to 30°C - I have successfully used my Aquarian hydrophone in the hot springs of Iceland!*"

— Sound artist

"*Freshwater most of the time; attended recordings from the shore into MixPre-6 II; biggest issue is self-noise of the hydrophones in my budget!*"

— Biologist

7 Next steps

This report represents the survey results and current context in which hydrophones are used for conservation, uncovering insightful user experiences. However, the report does not necessarily inform us of the final user requirements. Some of the participants' answers could have been swayed by the technological limitations caused by budget constraints or the specifications of the technology currently available.

To this extent, the next step is to further investigate what these limitations are and what minimum requirements conservation practitioners need to improve their research. To do this, we will follow up with survey participants by carrying out an online workshop on 29th January 2021.

8 Acknowledgements

Thank you to all the survey participants.

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