Recommendations for the underwater noise monitoring procedure

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Summary

1. Abstract

Document describes the underwater noise monitoring system, pre-deployment preparation, deployment, recovery and redeployment of instrument using bottom mounted system.

2. Purpose of the underwater noise monitoring

The main objective of the project is to create a cross-border technical, scientific and institutional cooperation to face together the challenge of assessing the impact of underwater environmental noise on the marine fauna and in general on the Northern Adriatic Sea ecosystem. At this stage, in fact, there are no extensive data on underwater noise in the area and the knowledge on noise pollution and its impact on biodiversity is very limited.

Therefore, according to the project work plan the network of the underwater noise monitoring stations will be set up in the Northern Adriatic Sea (Activity 3.2). The continuous underwater noise produced by anthropogenic activities such are marine traffic (both commercial and recreational) and hydrocarbon exploitation will be monitored.

The monitoring results will be used to fill the knowledge gap about underwater noise levels in the Northern Adriatic Sea but also to support setting up and validating the soundscape model (Activity 5.2).

3. A generic single channel continuous underwater noise monitoring system

A generic single channel continuous underwater noise measuring system, shown in

Figure 1, consists of a hydrophone, signal conditioning electronics, A/D convertor, data storage and/or data transmission device.

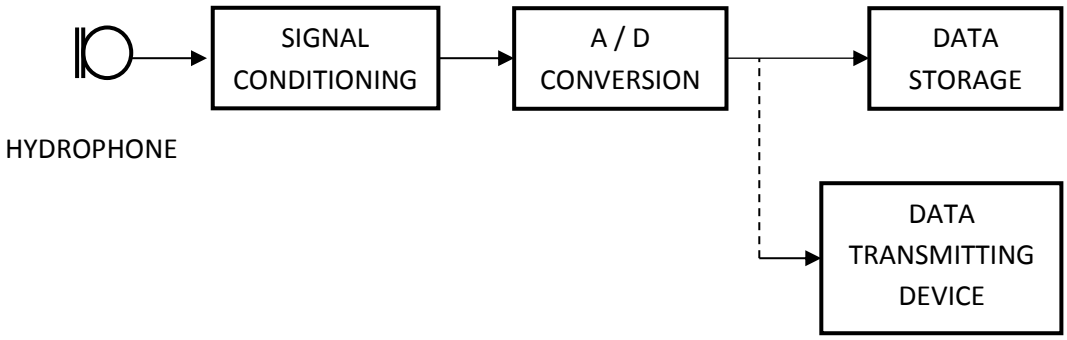


Figure 1 A generic single channel continuous underwater noise measuring system

Hydrophone is an electro acoustic transducer which, in case of passive (listening) systems, converts variations in the underwater pressure caused by underwater noise sources to variations in electrical voltage on its output. The output of the hydrophone is impedance matched, amplified and frequency shaped (filtered) by the signal conditioning electronics. At the high end of the spectrum the filtering is needed to avoid aliasing (low pass filtering). At the low end of the spectrum filtering is needed to avoid low frequency pressure variations not related to underwater noise but mainly to deployment related issues (high pass filtering). A/D converter converts analogue conditioned signal from hydrophone to digital form of data. Low pass filtering is sometimes done in the A/D convertor according to its sampling settings. Data in the digital form are then stored in the memory from which can be downloaded, or transmitted directly (e.g. by cable or radio) to external computer for final storage and processing. Recordings can be continuous when system records the underwater noise throughout the entire deployment period. In order to extend deployment period which is limited by memory and battery capacity, recording can be intermittent (on-off) which means that data are recorded for some period (on) following by the standby period (off) in which the system is idle. In that way battery life and memory usage are improved thus extending deployment period available. The active and standby periods are set up in the way that all essential characteristics of the underwater noise are captured throughout deployment period. Although continuous and intermittent recordings differ in recording periods, in both cases recordings (while

recording is active) consist of number of shorter parts (time bins) in which the sound pressure level is averaged.

In the broader sense a generic underwater noise measuring system would include equipment for the deployment and recovery of the measuring part of the system. This equipment depends on the specific methodology used (e.g. drifting, bottom) and may include acoustic releasers, anchors, cable and cable drivers, drogues etc.

A generic single channel continuous underwater noise monitoring system can be implemented in various ways with various methodologies, configurations and procedures. In case of continuous underwater noise monitoring for Soundscape project (Activity 3.2), **bottom mounted system using autonomous passive underwater acoustic recorder (APUAR) is used.**

3.1 Bottom mounted systems using APUAR

In case of the bottom mounted systems a generic continuous underwater noise measuring system is deployed on the sea bottom. All system parts except the hydrophone are placed into the waterproof pressure resistant housing (container) to ensure their functionality under the water. The hydrophone is packed separately but close to the container to which it is elastically connected with a short cable. The power is supplied from battery pack also placed inside the container. The system stores (records) the underwater noise data for the period of its deployment. After it is recovered from the bottom, data are downloaded to the external computer for final storage and processing. The memory media used are memory cards and the downloading is done by removing memory card(s) from the container and direct downloading to external computer. Direct downloading is used to enable data downloading of large amounts of data (hundreds of Gbytes) within acceptable time.

The design of the system is the trade-off between anticipated amount of data (which is the function of the deployment period required, resolution and sampling), memory size and battery power available. Also the logistic issues (e.g. does data downloading and battery replacement/charging can be done on the service vessel or the system has to be taken ashore?) influence the system design and functionality.

In the acoustic sense, the hydrophone employed in the bottom mounted system has to record the direct sound (noise) only and to be clear of any significant reflections from the bottom, container and /or deployment gear. The geometry of the bottom mounted system including the deployment gear depend on frequency range (wavelength) of the signal recorded, dimensions of the container and deployment gear and the bottom type.

The bottom mounted systems for continuous underwater noise measurements will use deployment and recovery equipment that can include anchor, anchor line, acoustic releaser and flotation(s) as illustrated in Figure 2. The system container is packed together with flotation in the form of the collar around the container or flotation cylinders or spheres.

If the spheres above the hydrophone are used as flotation, the shading of the hydrophone should be avoided. To do so, **do not use large spheres close to the hydrophone**. If you need higher buoyancy **use smaller diameter spheres instead one large and place them away from the hydrophone**. The shading cone above hydrophone **should be smaller than 15°** so that combination of sphere diameter and the distance from the hydrophone should be adjusted accordingly (e.g. sphere with the diameter of 25 cm mounted 100 cm from the hydrophone).

This pack is hooked up to the anchor via acoustic releaser. The acoustic releaser is an oceanographic device used for the deployment and recovery of instrumentation from the sea floor, in which the recovery is triggered remotely by an acoustic command signal. A typical releaser consists of the hydrophone, the battery and the signal conditioning and processing electronics housing, and a hook which is opened to release the anchor by high-torque electrical motor. Each releaser has (or can be set to) unique acoustic command, and after receiving it, opens the hook and releases the measuring system and itself from the anchor. Owing to the flotation attached, the measuring system and releaser rises to the sea surface.

The alternative to acoustic releaser, but for the shallow deployments only, can be a diver who can release the measuring system from the anchor and let it surface owing to the flotation attached. The anchor weight and shape are adjusted to the bottom type and expected strain to the. Anchor can be made in various shapes and material to best suit deployment procedures.

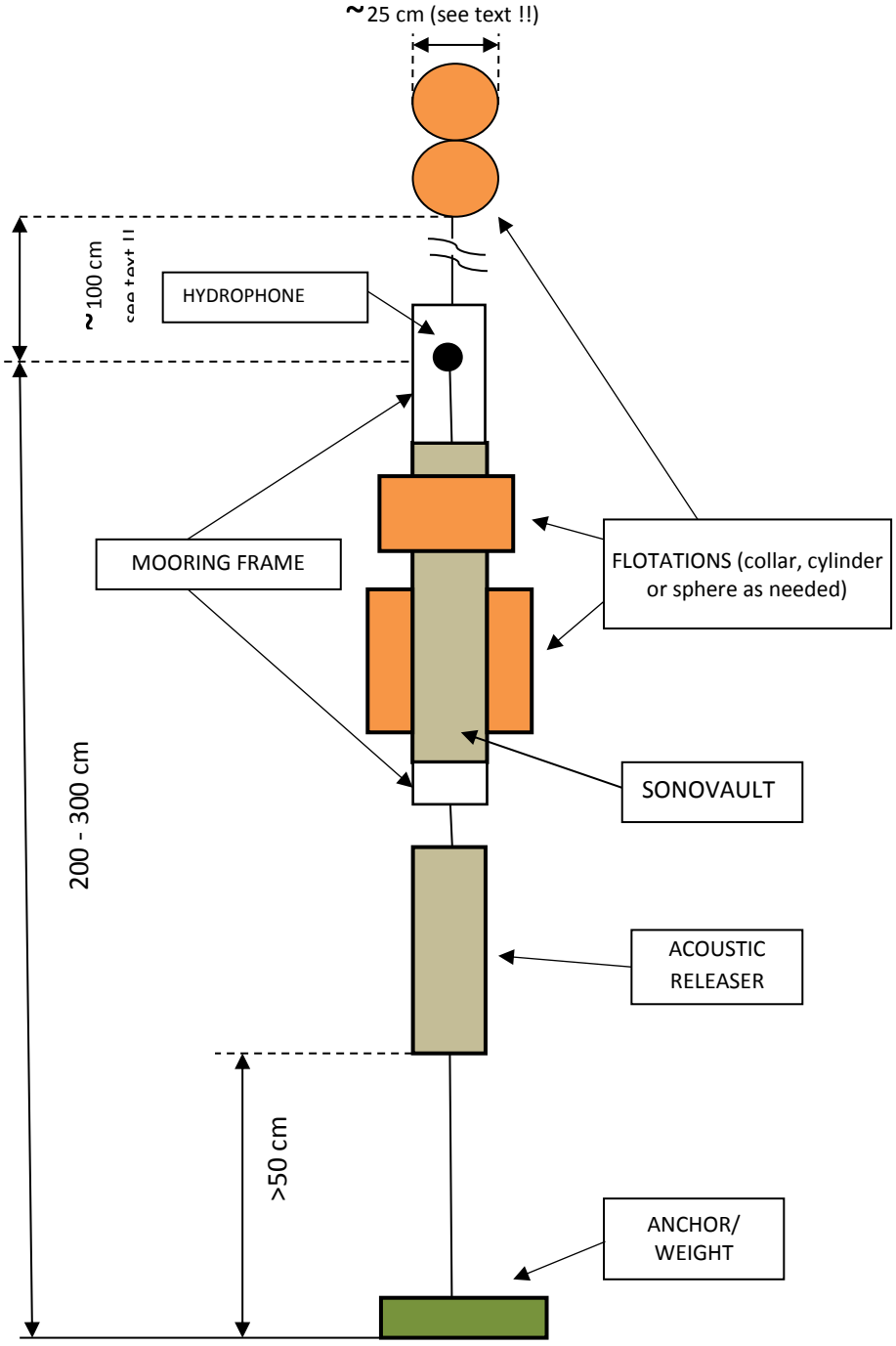


Figure 2 Continuous underwater noise measuring system setup using acoustic releaser for employment

4. Recommended procedure for the continuous underwater noise monitoring with bottom mounted autonomous passive underwater acoustic recorder (APUAR)

4.1 Pre deployment preparation

- **Assign ID to each piece of equipment**. It can be manufacturer's serial number, but one can choose more simple ID. It is important that each piece of the equipment has unique ID and cannot be mixed up.
- **Prepare and set-up APUAR and acoustic releaser according to manufacturer's instructions** (manual, training notes etc.). Pay special attention when opening and closing the casing. Make sure O-rings and connectors are clean and not damaged.
- **Use only new (unused) batteries**, **check voltage** which should not be less than 1,5 V for alkaline and 3,6 V for lithium.
- **Test each memory card before using it** and use only tested ones. **Do not use untested memory cards even they are new (unused)!**
- **Set the internal clock to UTC**. Although all monitoring stations are in the same time zone it helps avoid confusion with e.g. summer and winter time. It is possible that internal APUAR clock will drift, so it is recommended that the internal clock is synchronized with UTC and then checked after some time. Time drift should be known for each APUAR to avoid confusion in possible data comparison as the measurement period will be relatively long (2-3 months)
- **Check the calibration data** and be sure APUAR is calibrated. If not known, calculate calibration coefficient(s) to convert wav.units which will be recorded to SPL (dB) which should be reported.
- **Test the APUAR with pistonophone** and check that the recording and calibration are correct.
- **Prepare the deployment and recovery datasheet**.
- **Pack the equipment for the transportation**. Make sure that the equipment, especially hydrophone is protected from shock and vibrations as well as from extreme temperatures.

4.2 Preparation of deployment rig

- **Calculate the buoyancy that is required**. From the data on anchor weight, weight of APUAR, batteries and releaser in the water, calculate the buoyancy needed.

Buoyancy needed would be: weight of APUAR in air + weight of batteries in air + weight of releaser in air (if used) + weight of fixing accessories in air – buoyancy of APUAR – buoyancy of releaser (if used) + positive buoyancy needed.
Buoyancy of APUAR and releaser is internal volume filled with air.
Alternately, if the weight of APUAR, batteries and releaser in the water are known, buoyancy needed would be: weight of APUAR in water + weight of batteries in water + weight of releaser in water (if used) + weight of fixing accessories in water + positive buoyancy needed.
The buoyancy calculated is realized as the volume of flotation(s) of any form suitable, as in Fig. 2.2
Positive buoyancy of 5-8 litres is recommended for the smooth, slow and secure submersing and emerging.
Important note: *The calculation would be approximate due to the possible uncertainties of weight and volume data.* ***It is strongly recommended to perform the test deployment in the shallow water to test and adjust buoyancy.***

- **Prepare the anchor**. Adjust the anchor weight and shape to the bottom type and expected strain to the system (e.g. currents or waves in case the surface buoy is used). If the bottom is mud, small and heavy anchor (e.g. lead) can gradually be buried into the bottom together with the lower part of the rig thus compromising the part of the recording period and also causing problems with recovery. On the other hand, hard bottoms would ask for heavier anchors as the friction between anchor and the bottom is small. In any case the **anchor weight is recommended to be not less than 25 kg** to ensure stable positioning on the seabed. **If the seabed is soft, use anchor with the larger surface and leave at least 0,5 m from the releaser bottom to the anchor.**

Note: *The anchor which is left on the sea floor can be environmentally unacceptable. Two possible solutions can be implemented. The first is to* ***use the small container in which thin strong (e.g. Kevlar) rope which is winded inside the container*** *and attached to the anchor with one end, and to releaser with the other as shown in Figure 3. After the system is released, the rope unwinds from the container and brings the other end on the surface. The anchor then can be lifted and used again.*
The alternative is ***not to use solid anchor (concrete, lead or iron) but to use biodegradable (e.g. jute) sacks filled with the sand or gravel.*** *Such an anchor (or better to say deadweight) will remain on the sea bottom but will degrade and left only natural material (sand or gravel).* ***If the diver will be used for the recovery (not releaser) this is not relevant as the whole rig with the weight will be recovered.***

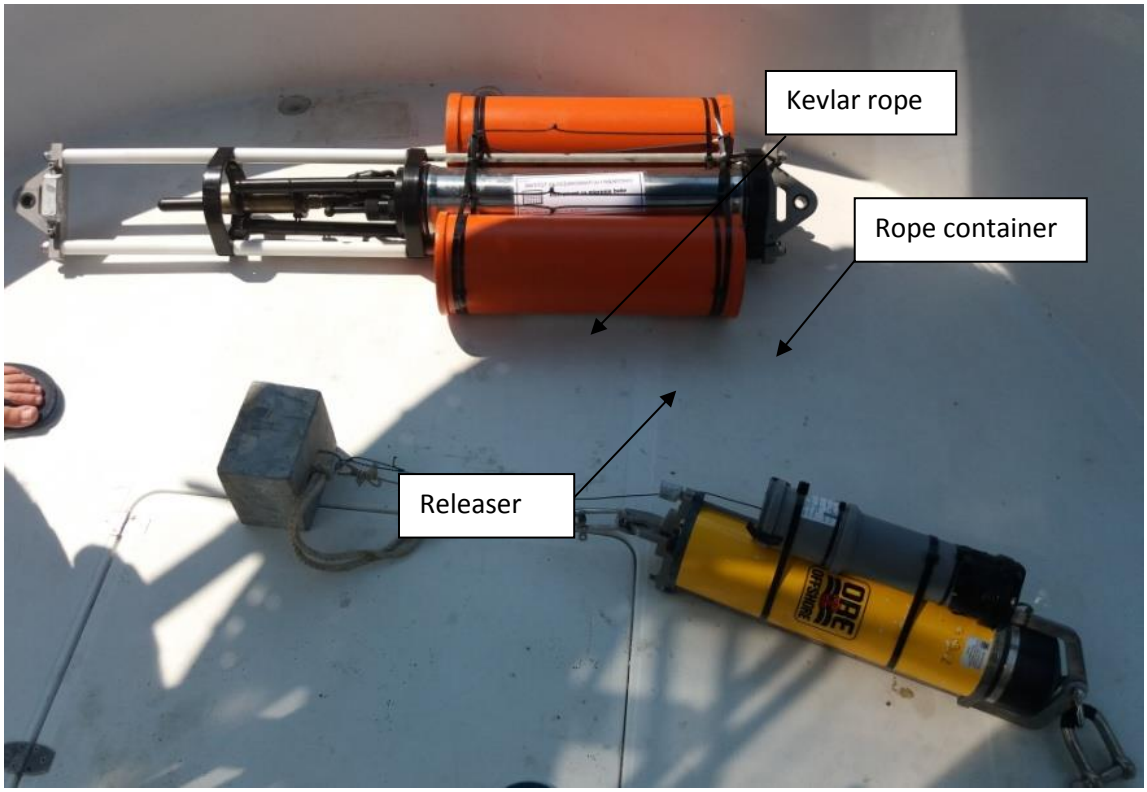


Figure 3 One option for the lifting of the anchor (weight) from the seabed using thin rope

- **Label clearly the equipment in the rig** with sticker stating clearly contact information in case of rig loss or damage.
- **Prepare necessary flotation(s) with the buoyancy according to the calculation**. You may divide flotation into more than one part (as in Figure 24)
- **Prepare all fixing accessories** needed (ropes, shackles, eyes etc.).
- **Assemble the rig as in the Figure** 2.

Due to the close proximity to the hydrophone, ***deployment gear on the rig can generate unwanted sound****. This is especially true for the fixtures of the anchor rope to the anchor, acoustic releaser and system container, which are usually stainless steel shackles and eyes.* ***Metal fixtures should be avoided or somehow isolated (e.g. rubber or plastic sleeve) from the direct contact*** *that can produce sound. Some examples are shown in Figure 4.*

Figure 4 Examples for reducing unwanted sound from the deployment gear

The hydrophone on the assembled rig should be at 2-3 m height from the seabed to minimize seabed reflections. If possible that height can be higher.

It is strongly recommended to perform the test deployment in the shallow water to test all connections and fixtures as well as buoyancy. As the additional batteries will be used it is possible that the exact weight in the water will not be known and some adjustment would be necessary. Therefore, it is important to test the rig for the buoyancy to avoid problems in real deployments.

Biofouling can be an issue for longer deployments on some locations. If it is the case, **it is recommended to wrap equipment in transparent adhesive foil used in households.** After the recovery, foil is cut and unwrapped leaving clean surface below. **Be sure not to cover hydrophones (for both APUAR and releaser) as they have to be unobstructed for the clear and free reception of acoustic signals.**

4.3 Deployment

The rig can be assembled either prior to the field or on the deck of the vessel used for the deployment.

- Before the deployment, **double check all connections and fixtures** of the assembled rig to avoid potential decomposition and/or loss of the rig parts.
- **Power on the equipment and activate the recording**.
- **Record the short (30 – 40 seconds) calibration file** with the pistonophone.
- **Deactivate the recording and activate it again** (this is to keep calibration file separate)

  The deployment procedure would depend on the vessel used e.g. available space, stuff experience etc. Having in mind all that and with the assembled rig on the deck, the procedure has to be planed and agreed upon with all stuff involved. ***It is highly recommended to do that on the test deployment****.*

- **Check the position and depth of the seabed on the deployment location.**
- **Deploy the rig in the water**

  The deployment would depend on the resources of each partner (e.g. vessel size, available space, stuff experience etc.) but generally can be recommended as follows:

  Pull the rope through appropriate eye on the top of the rig. It can be the top of the mooring frame or flotation buoy or else, depending on the arrangement of the flotation in the rig. Fix one end on the vessel and the other will be eased up to enable sinking of the rig. Make sure that the rope is sufficiently long (2 x deployment depth)

  Attach additional rope in the same manner (one end fixed, other loose) to the anchor to help handle and balance the anchor weight. The anchor is than lowered into the water first, additional rope removed and the rest of the rig is slowly lowered in the water with the long rope. After the rig reaches the bottom, the long rope is pulled out.

  Make sure to avoid any hit or hard impact of equipment with other hard parts on the rig or vessel. Take special care of the hydrophone which is highly sensitive to rough handling.

- **Fill in all necessary data into the deployment datasheet**.
  The location should be noted in ***WGS84 datum*** *and* ***time in UTC****. The positions should be noted in format:* ***degree, decimal minutes (e.g. 43°24,528').***

4.4 Recovery & re-deployment

If possible, prepare spare APUAR and acoustic releaser as recommended in the section on pre-deployment preparation.

- **Make sure you are on the right position**.
- **Ping the releaser with test function** from the deck unit (usually releaser answers with the distance from the vessel).
- After making sure the rig is on position and the releaser is working, **send the release code**. Usually the releaser will acknowledge with the answer and release rig from the anchor. Observe the surrounding, **spot the rig after emerging on the surface and pull it out on the deck**.
  ***If the releaser is not used**, after you are sure that you are on the right position, **send the diver to find the rig and tight a rope to the weight**. Pull the weight carefully out and recover the whole rig.*
- When on the deck, **inspect the rig for the possible damages**.
- **Deactivate the recording, power the equipment off, remove the protective foil (if used), rinse and clean with fresh water (use detergent if needed). Dry the APUAR thoroughly**.
- **Remove (de-assemble) APUAR from the rig and open it carefully**. When opened, look for any trace of water in the casing and the condition of the O-rings.
- **Power APUAR on and activate the recording.**
- **Record the short (30 – 40 seconds) calibration file** with the pistonophone.
- **Deactivate the recording, power it off and remove the memory cards.**
- **Check the content of the memory cards and handle the data as in the section on data handling**.
- **Fill in all necessary data into the recovery datasheet**.
  *The location should be noted in **WGS84 datum** and **time in UTC**. The positions should be noted in format: **degree, decimal minutes (e.g. 43°24,528').***
- **Replace the batteries and memory cards with new ones** as recommended in the section on pre-deployment preparation.
- **Inspect O-rings and clean and grease if necessary.**
- **Close the casing carefully.**
- **Assemble APUAR back in the rig and set the releaser as in the manufacturer's instruction.**
- Again, **before the deployment double check all connections and fixtures of the assembled rig** and make sure nothing is damaged or compromised.

Note*: APUAR may have the sacrificial anode to prevent galvanometric discharges. Check the condition of the anode and clean it or replace if necessary.*

- **Power on the equipment and activate the recording**.
- **Record the short (30 – 40 seconds) calibration file** with the pistonophone.
- **Deactivate the recording and activate it again** (this is to keep calibration file separate).
- **Re-deploy the rig as recommended in the section of deployment.**
- **Fill in all necessary data into the deployment datasheet**.
  *The location should be noted in **WGS84 datum** and **time in UTC**. The positions should be noted in format: **degree, decimal minutes (e.g. 43°24,528').***

4.5 Data handling

The whole process of measurement is designed to obtain data on levels of the underwater sound. A lot of effort and resources have been invested in getting those data. Therefore, the data should be considered precious and treated accordingly. **Any compromise, corruption or even loss of data should be reduced to absolute minimum levels.**

- After recovery, **memory cards should be removed from APUAR, labelled, write protected and immediately backed up to a secondary device**.
- **The quick quality check of the secondary copy is recommended while still in the field**. The number and size of the files recorded should be checked, as well as does the start and stop time of the recording correspond to the real time when the recording was started and stopped.
- If possible**, open calibration files that were recorded prior the deployment and after the recovery and check the calibration levels** which should be equal and correspond to the calculated ones.
- If time allows, it is **recommended to open randomly one of raw wav.files and check the data visually, perform the quick spectrum analysis** and check if the content is as expected.
  If something does not match, maybe there is possibility, while still in the field, to correct it (e.g. one forgot to take out one or more SD cards from the recorder) or, if possible, exchange the recorder for one that is functioning.
- The primary (retrieved from the recorder) and secondary (on the secondary device) set of raw data **should be packed and kept separately until brought to the laboratory**.
- In laboratory, it is **recommended to make another copy of the primary memory to have two separate backup copies of the original raw data sets**.

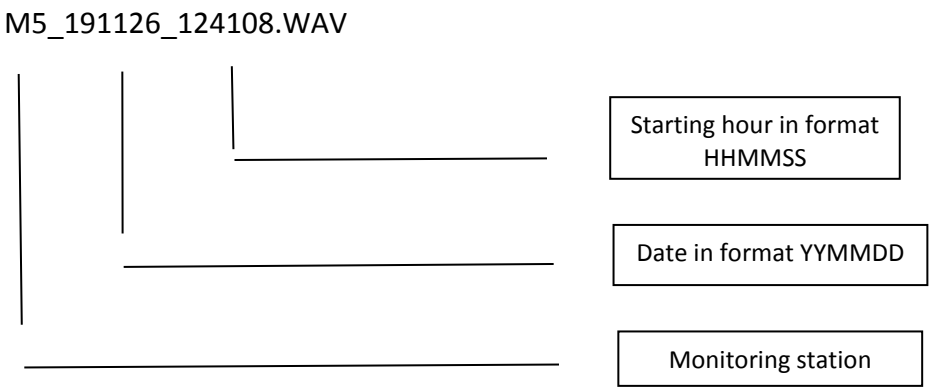
- **Never use those backup copies to work with**. To ensure this, **make these backups read only**. For all work on further processing the raw data, **make a working copy of the relevant file(s) from the backup copy and work with it.**
- **The original (primary) memory should be kept at least to the moment the thorough quality check and/or pre-processing of the raw data is performed and the quality of the backup data is confirmed**. If it is possible, it is recommended that the original (primary) memory be kept even after that, for a period of time considered appropriate.

The number of the auxiliary data or **metadata** (other than noise levels) **should be also recorded and kept together with noise levels raw data** to allow noise data to be, without ambiguity, linked to position, time period, type of equipment used, environmental conditions etc. **Those data are defined with the deployment and recovery datasheet** and include name, geographic position and the depth of the measurement site, start and stop time for each recording, equipment type, ID number and set up data, calibration data and weather conditions. These metadata should be included in the header of raw noise level data files in the preprocessing, thus keeping it together.

If possible, it is recommended that metadata (or at least those crucial for the identification of the noise data file) be recorded (inputted) while still in the field and included in the initial quick quality check. In that way one can be sure that raw noise level data file is correctly identified and attributed to the corresponding auxiliary data. It is self-evident that each backup copy should contain all auxiliary data.

4.6 Recommendation for the naming convention of the audio files

The naming convention for each one of the audio files that allows unique identification is given as follows:



The file “M5_1_191126_124108.WAV” corresponds to the deployment at monitoring station M5 (Susak). Recording started on the 26th of November 2019 at 12:41:08 UTC time.

Metadata should be stored with the same name but different extension (e.g. txt or pdf) in same folder.

ANNEX I Deployment and recovery datasheets

	UNDERWATER NOISE MONITORING **DEPLOYMENT DATASHEET**	*Deployment ID*

DEPLOYMENT	*Location name*		*Date*	
	Position (WGS 84)			*Depth*
	LAT(ϕ)	N LON(λ)	E	
	Start recording time (UTC)		*Deployment time (UTC)*	
	Deployment gear			
	Weather conditions			

*The location should be noted in **WGS84 datum** and **time in UTC**. The positions should be noted in format: **degree, decimal minutes (e.g. 43°24,528')***

EQUIPMENT	***Autonomous passive underwater acoustic recorder (APUAR)***			
	Type		*ID*	
	Hydrophone			
	Type		*ID*	
	Acoustic releaser			
	Type		*ID*	
	Additional equipment			

SETUP	***Autonomous passive underwater acoustic recorder (APUAR)***				
	Record duration	*Sleep duration*	*Sampling frequency*	*Resolution*	*Gain*
	Calibration file ID				
	Acoustic releaser				
	Transmitting frequency	*Receiving frequency*	*Activation code*	*Release code*	
	Additional equipment				
Remarks:					
Prepared by		*Signature*			

	UNDERWATER NOISE MONITORING **RECOVERY DATASHEET**	*Deployment ID*

RECOVERY	*Location name*		*Date*	
	Position (WGS 84)			*Depth*
	LAT(ϕ) N	LON(λ) E		
	Recovery time (UTC)		*Stop recording time (UTC)*	
	Weather conditions			

*The location should be noted in **WGS84 datum** and **time in UTC**. The positions should be noted in format: **degree, decimal minutes (e.g. 43°24,528')***

EQUIPMENT	***Autonomous passive underwater acoustic recorder (APUAR) status and condition***
	APUAR's memory status
	Hydrophone status and condition
	Acoustic releaser status and condition
	Deployment rig parts status and condition
	Calibration file ID

Remarks:					
Date		*Prepared by*		*Signature*	