The Mini-Buoy handbook

to assess hydrological site suitability for mangrove restoration

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General Introduction:

The Mini Buoy is a tool to assess hydrological site suitability (inundation and tidal currents) for mangrove restoration.

The components are readily available, and the data can be analysed in an online application.

The Mini Buoy can be used as a single deployment to assess inundation characteristics against set targets or as a comparative deployment, where one Mini Buoy installed at the restoration site or site of interest is compared to a Mini Buoy installed at a reference site.

Reference sites are, for example, sites where the target mangrove species has naturally colonized recently, or past restoration sites that have achieved the desired outcome.

LINK TO PUBLICATION:

1. The Mini-Buoy and it's components

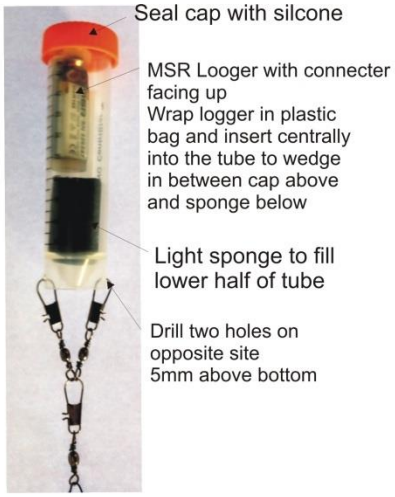
The Mini-Buoy is a small bottom mounted float with an acceleration datalogger inside. The data logger measures acceleration along 3 axes relative to the earth's surface and can therefore determine the angle of its position or direction of motion. Using this information and a calibration function the Mini Buoy can determine:

1) start and end of inundation/ inundation duration/ inundation-free periods between events

2) current velocity near the bed above 0.1 m/s

All components of the Mini Buoy are readily available. The acceleration data logger used in this handbook is a MSR145 B4 model https://www.msr.ch/en/product/msr145/ which fits inside the centrifuge tube and is waterproof. We recommend sealing the cap with a silicone or a strip of parafilm/sealing tape when closing the cap. The logger itself should be wrapped with a light plastic to keep the logger centred in the tube and avoid internal movements (not shown on the photo).

Materials and specifications:



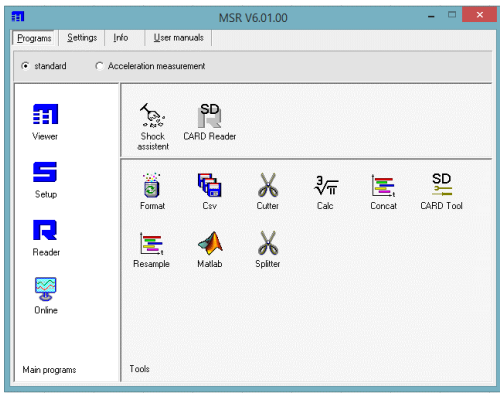
It is important that the connector of the logger is facing up, this will record y acceleration as -1 when the logger is stationary in the upright position.

Components and dimensions	**Size**	**Weight**
Corning® 50 mL PP Centrifuge Tubes, Self-Standing CentriStar™	114.9mm (L)	14.6g
Accelerometer MSR 145 B4A (MSR Electronics GmbH, Switzerland)	20 x 14 x 62 mm (W x H x L)	18g
3x Interlock Snap Fishing Swivel with Barrel*	55mm (L)	1.9g
Foam to insert at bottom of logger, plastic bag to wrap accelerometer, tape, silicone seal or parafilm seal	various	< 4g
	TOTAL	42.3g

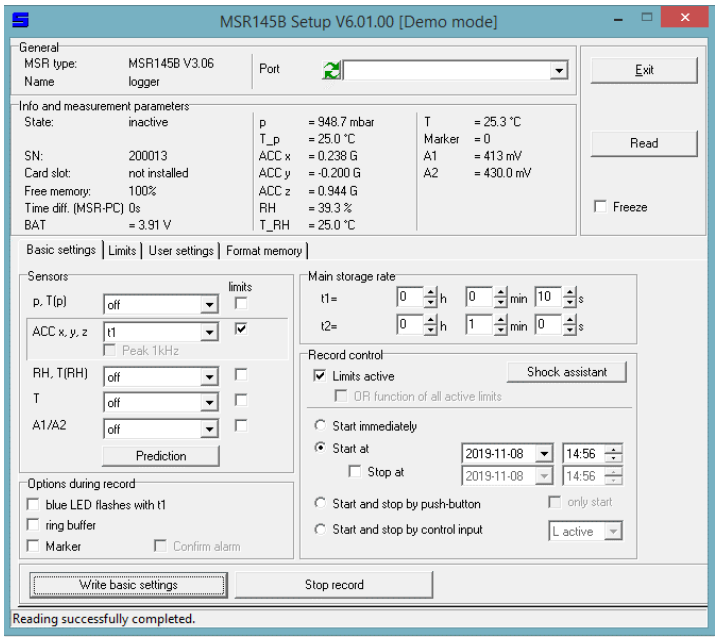
*It is important to not vary the length of the swivels

2. Programming the Mini-Buoy with the MSR software

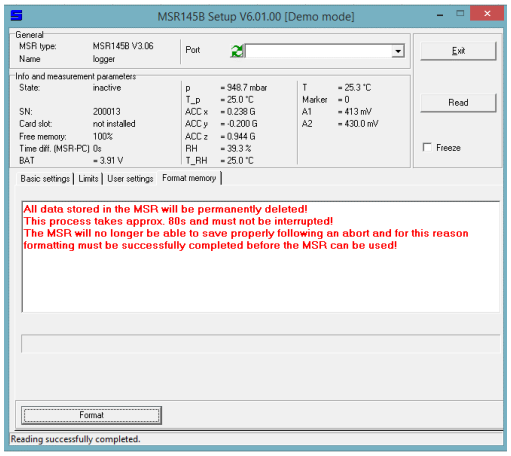
The MSR145 comes with USB charging cable and software. Connecting the MSR logger to your computer will charge the internal battery and will allow you to program the logger and download any data. In the following steps the suggested settings for long-term deployment of the Mini Buoy will be explained (several weeks). We suggest a 10-second measurement interval or shorter and to deactivate x and z acceleration by setting the limits as shown below.



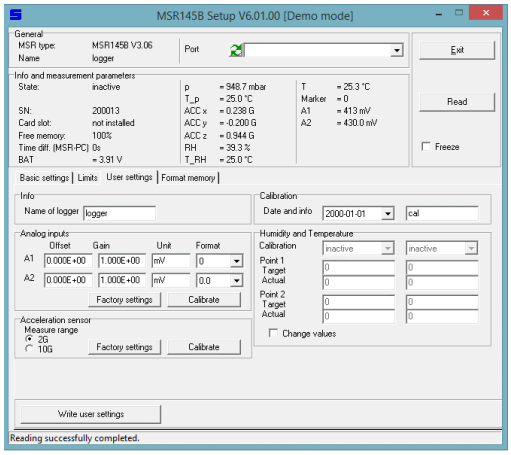
Download, install and open the MSR software and click **Setup**



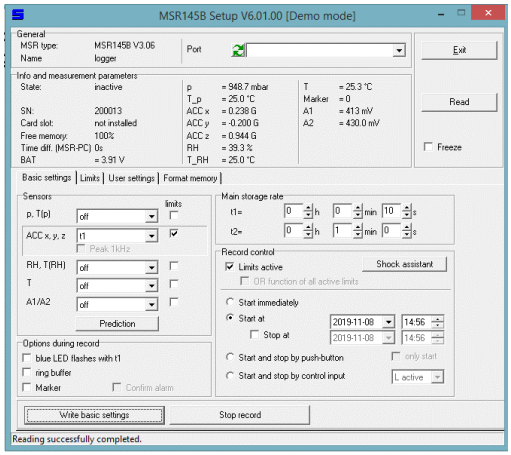
This is the setup window



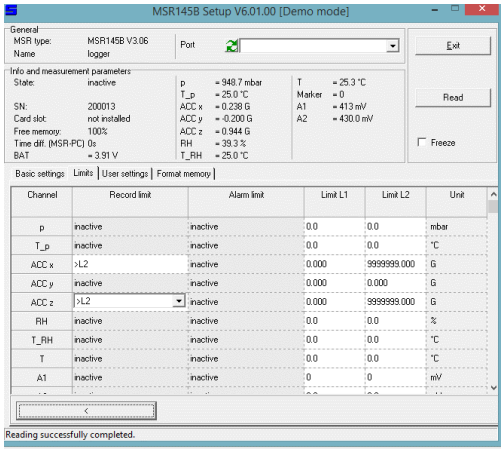
Format the memory if the logger has been used before



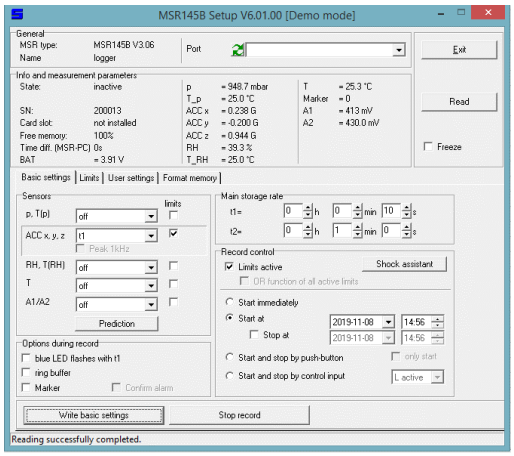
Set acceleration sensor range to 2G under the User settings tab and click **write user settings** to save



Go to the Basic settings tab and set **ACC** to t1 and tick the **limits** box, set **Main storage rate** t1 to 10s and t2 to 1 min, tick **Limits active** box, set **Start at** to a time shortly after your planned deployment.



Set the limits for ACC x and ACC z to values that will never be exceeded such as >L2 9999999. This will deactivate the x and z components of the acceleration and allow your logger to store more data. The data analysis later will only require y acceleration data.



Double check your settings in the Basic settings tab. You can check the possible duration of your deployment using the **Prediction** button. The memory capacity will be underestimated as it does not include the limit settings. Save your settings by clicking **Write basic settings**. This is your logger all set and ready to deploy in the field for several weeks!

3. Installation of the Mini Buoy in the field

The Mini Buoy should be fixed to a soil anchor which we recommend is of metal and has a drilled hole in the top 1 cm to attach the swivel. The length of the soil anchor/metal stake depends on the softness of the mud on the tidal flat. In soft mud stakes of >100 cm are recommended. The stake should protrude 1 cm from the sediment surface and the buoy can be attached either using cable ties or bolts and nuts. Make sure the swivels can freely move. Move the Mini Buoy 360° around the anchor to check if it is obstructed in any way by vegetation or other obstacles. Remove any obstacles/vegetation to allow the Mini Buoy to dip into all directions upon inundation and rest flat on the mud when not inundated. The deployments should ideally last more than 15 days (better 30 days) to cover spring and neap tide variability.

Single and comparative deployment:

Site of interest

Always deploy the Mini Buoy at a representative location of your restoration site away from tidal channels. At sites with clear elevational gradients deploy the Mini Buoy at the lowest and highest elevation where restoration is to be carried out. Single deployments at the site of interest will provide information of inundation duration, inundation free periods and current velocities which can be compared to known target conditions for each species.

Comparative deployment

Where target conditions are not known and to account for local variations, a second Mini Buoy can be deployed at a reference site where natural colonization of the target species has recently occurred. The Mini Buoy app will automatically calculate differences between both sites.

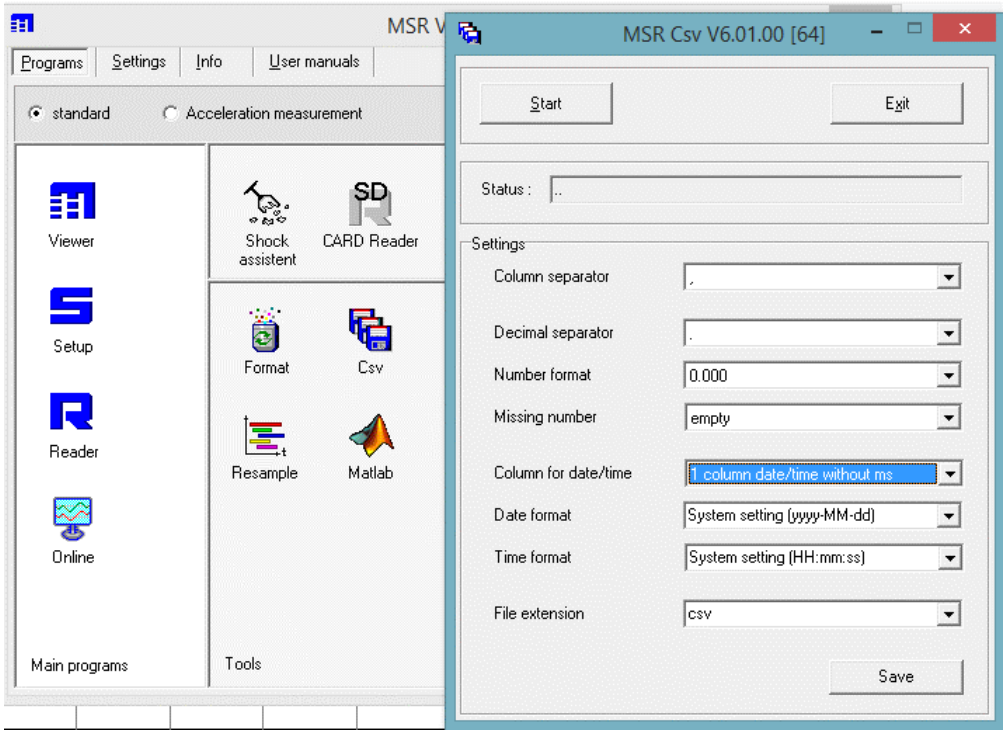
Examples of where to deploy the Mini Buoy

Example of an abandoned aquaculture pond: Install the Mini Buoy at a representative elevation for the restoration site. Deployment of more than one Mini Buoys would be beneficial here to consider potential elevational gradients of the site (see for example red circles for deployment of two Mini Buoys). Do not place the Mini Buoy directly in the tidal channel as the conditions will not be representative of those on the mudflat.

Example of open coast deployment: Install the Mini Buoy at the lowest elevation within the envisaged site for restoration. When used as a reference site, install the Mini Buoy at the lowest elevation of natural seedling recruitment of the target species (see red circle). Avoid tidal channels or other uneven surfaces such as scour holes.

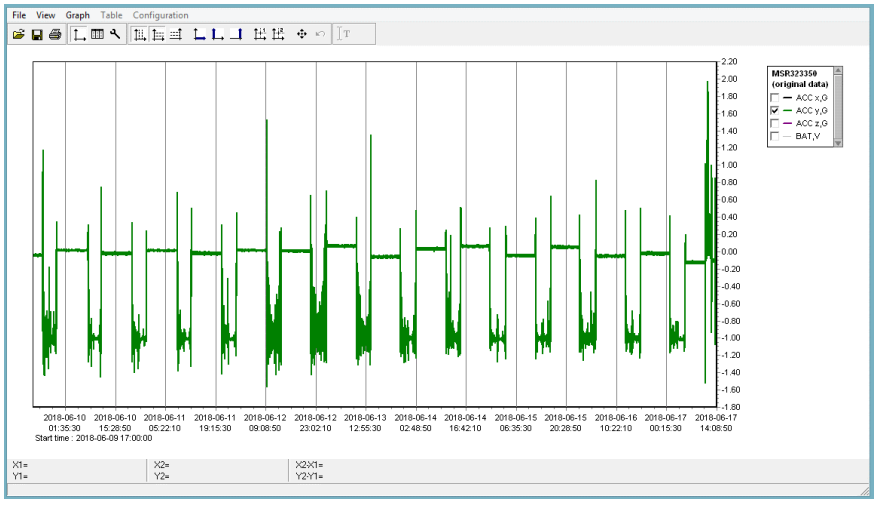
4. Exporting the time series data table

Once you have removed the data logger after deployment, the data can be read out and stored as a .csv data table using the MSR software. It is important to save your data in the data format that can be recognized by the Mini-Buoy App. In order to set the correct format you need open the csv settings tab in the MSR software.

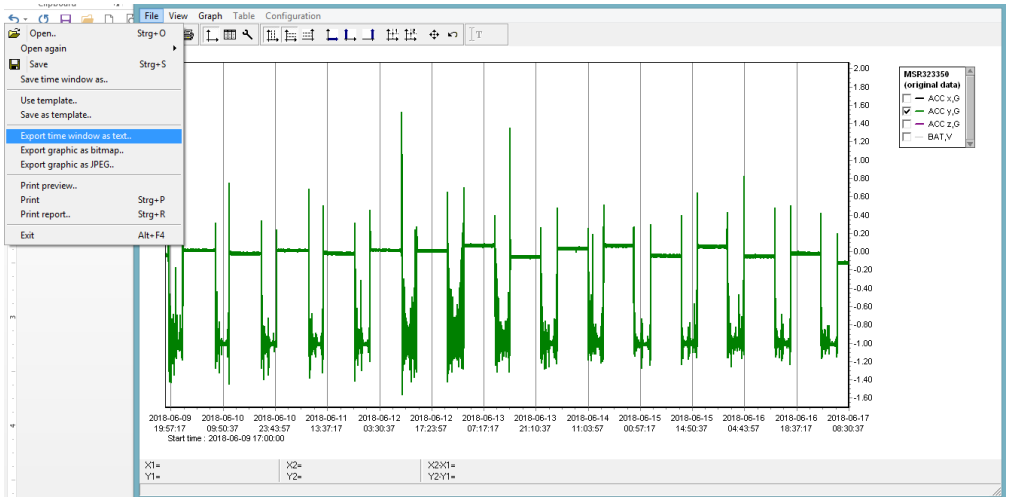


Choose the settings according to the template above and **Save**.

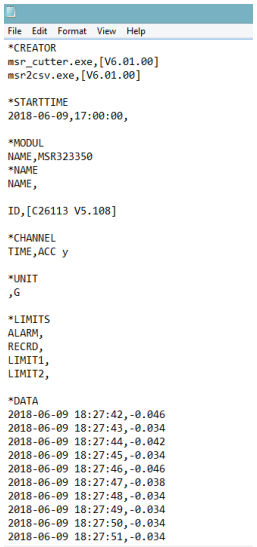
Connect your data logger with the USB cable and open the MSR software using the **Reader** button. The file will be saved as a .msr file which can be opened with the **Viewer** of the MSR software.



In the Viewer, only select the ACC y data. Your data should look similar to the graph above with low tide recorded as 0 and high tide recorded around -1. Any data at the start and end of the deployment which is not part of the desired measurement period can be removed by using the cross arrows button and selecting the period of interest. The graph should always start and end with a period of low tide (i.e. 0 y acceleration).



Once your data is selected you can export the time series as .csv file by choosing export time window as text.



The start of your .csv file should look like the example above.

5. The Mini Buoy app for data analysis

Where to get the application?

You can either use the R shiny app online:

https://mangroverestoration.shinyapps.io/MiniBuoyApp/

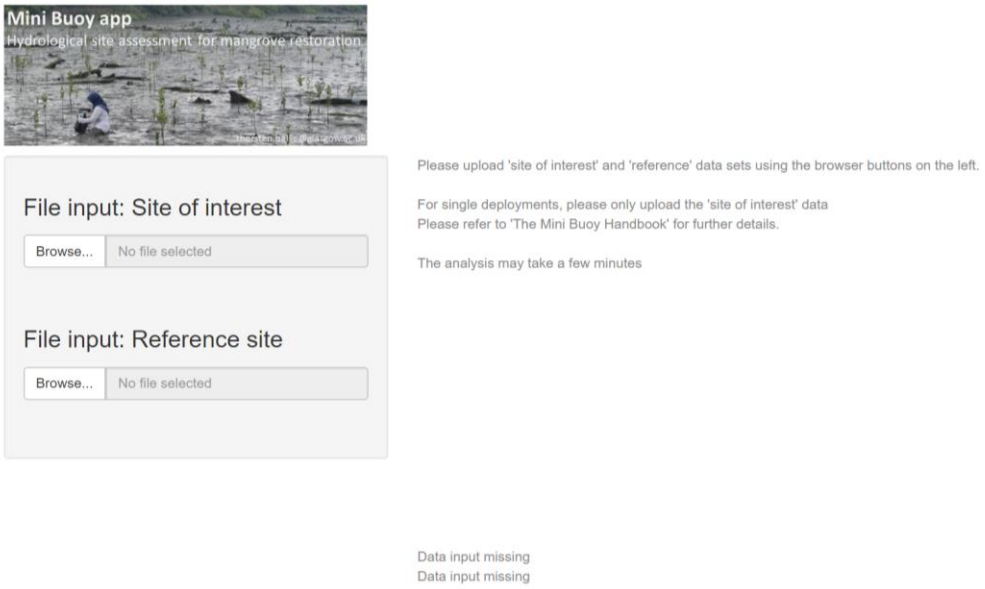
or download the R.app file and run it on your local PC. This will require you to install R, R-Studio and the rshiny package prior. The code is available from githb:

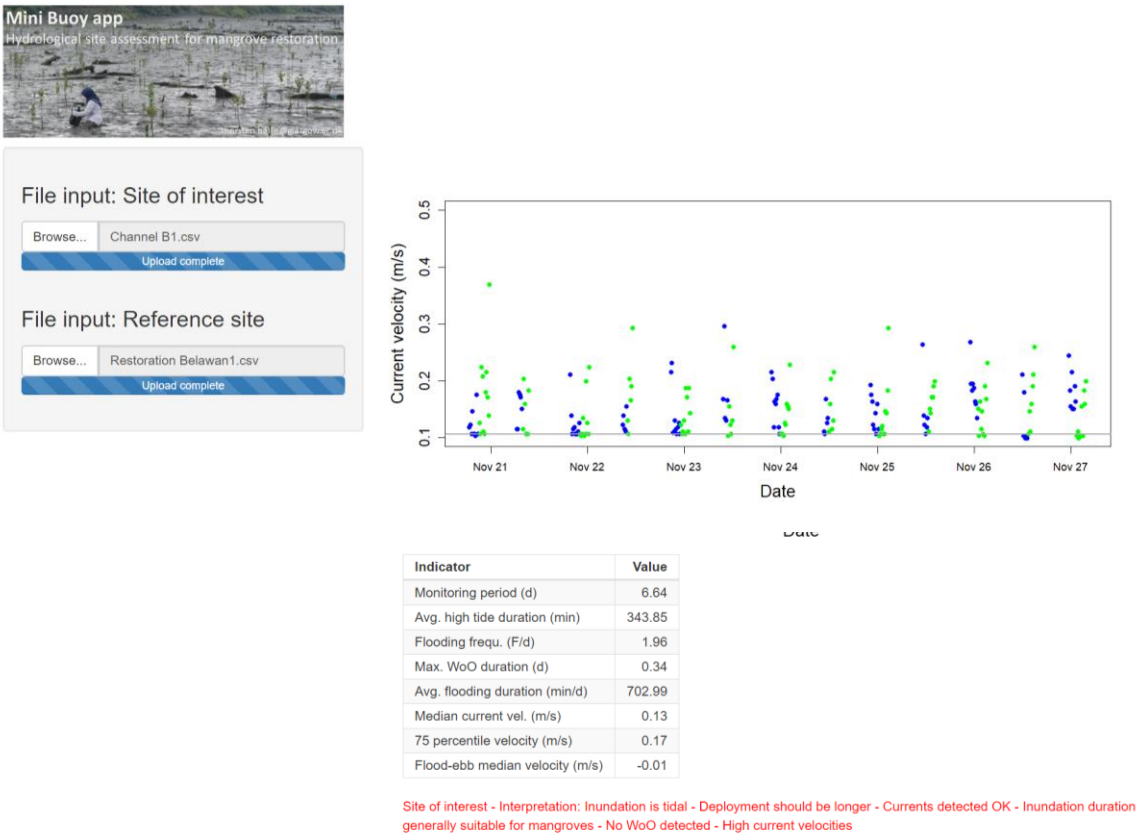
https://github.com/thorstenbalke/Mini-Buoy.git

The Mini Buoy R Shiny application:

Upload the .csv files either as single deployment (site of interest only) or as comparative deployment with a site of interest and a reference site (max. file size is 30 MB).

Startpage of the application:

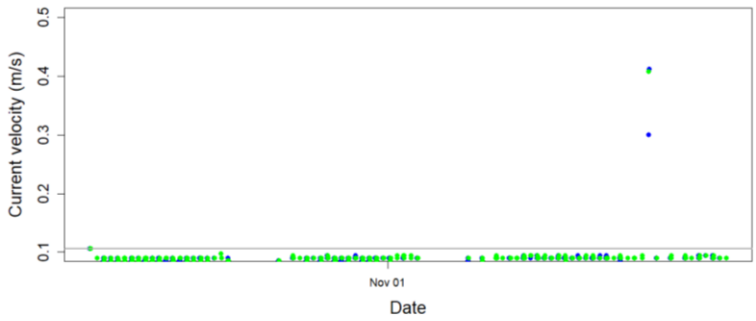




First, the site of interest time series plot and summary table will appear (this may take a while, depending on the size of the file). Each inundation event is identified and separated into the first and second half (flood and ebb tide) with blue and green colours, respectively. The current velocities are estimated for 15-minute periods. A grey line indicates the lower detection limit of current velocities around 0.1 m/s. The summary table provides statistics over the entire measurement period.

Text in red will appear, providing a first interpretation of the results and a number of warning messages: 1) if the average high tide duration per day exceeds 24 h, a warning will appear that the signal is likely not tidal. 2) if the measurement duration is shorter than 15 days a warning will appear that a longer deployment is needed 3) if the 75 percentile velocity is the same as the median current velocity a warning will appear that no velocity could be detected, this may be the case when velocities are <0.1 m/s. 4) Inundation free Windows of Opportunity (WoO) < 1 day and inundation durations >800 min/day or <100 min/d) will prompt warning messages that the site is likely unsuitable for mangroves (see associated publication for more information). Velocities are classified as low (≤15cm/s) and high (> 15cm/s) to allow an estimation of hydrodynamic exposure to currents.

The same plot and messages will be created for the reference site:



Indicator	Value
Monitoring period (d)	47.45
Avg. high tide duration (min)	218.29
Flooding frequ. (F/d)	1.60
Max. WoO duration (d)	3.64
Avg. flooding duration (min/d)	373.38
Median current vel. (m/s)	0.09
75 percentile velocity (m/s)	0.09
Flood-ebb median velocity (m/s)	0.00

Reference site - Interpretation: Inundation is tidal - Deployment duration OK - current velocities below detection limit - Inundation duration generally suitable for mangroves - WoO detected - Low current velocities

A difference table is created with the reference site conditions subtracted from the target site conditions:

Difference of conditions: Site of interest - reference site

Indicator	Difference
Monitoring period (d)	-40.81
Avg. high tide duration (min)	125.56
Flooding frequ. (F/d)	0.36
Max. WoO duration (d)	-3.29
Avg. flooding duration (min/d)	329.61
Median current vel. (m/s)	0.04
75 percentile velocity (m/s)	0.08
Flood-ebb median velocity (m/s)	-0.01

Further interpretation of the output:

Inundation duration per tide and inundation per day over the measurement period are key parameters to assess suitability of a site for restoration. Site of interest inundation where restoration is attempted should not be longer than the reference site inundation as this may indicate that inundation is too long for mangroves to survive under the given conditions.

Where there is no reference site the following classification can be used as a rule of thumb for South East Asia (Van Loon et al. 2007):

Inundation per day:

400-800 min/d: *Avicennia* spp., *Sonneratia* spp.

100-400 min/d: *Rhizophora* spp., *Ceriops* spp., *Brugueira* spp.

10-100 min/d: *Lumnitzera* spp. *Bruguiera* spp.

<10 min/d: *Ceriops* spp.

Current velocities may vary in time, hence it is important to compare hydrodynamics between loggers in the same deployment period. The 75 percentile gives an estimate of how strong the currents are during flood and ebb tide. If the 75 percentile velocities of loggers deployed at the same time (i.e. during the same weather conditions allowing for a relative comparison) are higher at the restoration site compared to the reference site, hydrodynamic energy may be too severe to attempt restoration and requires further investigation. This is most likely the case for seafront planting or near tidal channels.

Tidal velocities are also analysed for their ebb-flood asymmetry, this points to potential net-transport direction of sediments and propagules.

WoO (Windows of Opportunity) provide information about the length of consecutive inundation-free days between inundation events (see Balke et al. 2011). It has been shown that natural recruitment of mangrove pioneer species requires 1-5 days of inundation free periods. A maximum WoO value at the restoration site below 1 may indicate that elevation is not sufficient for natural recruitment to occur. Please note that WoO periods will depend on the duration of your measurement period and the season of the year. For a meaningful WoO analysis a deployment across seasons is recommended to cover weather and tide patterns.

Share your data for research:

The Mini Buoy has been developed as part of a research project and we would like to continue to improve the Mini Buoy data analysis. If you would like to share your data with us for research purposes please send an email to thorsten.balke@glasgow.ac.uk with the GPS location of your Mini Buoys and you will receive a link to upload your data:

6. References

Balke, T., Bouma, T., Horstman, E., Webb, E., Erftemeijer, P., & Herman, P. (2011). Windows of opportunity: thresholds to mangrove seedling establishment on tidal flats. Marine Ecology Progress Series, 440, 1–9. doi:10.3354/meps09364

van Loon, A. F., Dijksma, R., & van Mensvoort, M. E. F. (2007). Hydrological classification in mangrove areas: A case study in Can Gio, Vietnam. Aquatic Botany, 87(1), 80–82. doi:10.1016/j.aquabot.2007.02.001

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