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Range-dependent nature of impulsive noise (RaDIN)
Final report

Manual for using framework to estimate PTS – impact ranges for marine mammals

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This document describe how to use the tool to estimate PTS-impact ranges for marine mammals. The full descriotion of the model and all the processes included are given in Matei et al. Range-dependent nature of impulsive noise (RaDIN) Final report. Report number SMRUC-TCT-2024-001 provided to the Carbon Trust, January 2024 (unpublished)

1.1 General description of the tool

The movement tool consists of two parts: the movement model and an R script to analyse the outcome of the movement model (referred to as the movement analysis tool) to calculate the distance at which each animal receives sufficient noise exposure to exceed the threshold and experience permanent threshold shift (PTS).

The movement model simulates movement of animals through a soundscape and outputs position and received sound exposure levels of each modelled individual at each time step of the simulation. The R script analyses the output of the movement model, and based on the distance from the source where sound becomes non-impulsive, calculates the distance at which animals experience PTS relative to the source.

This document describes how to use the two components of the movement tool.

1.2 The movement tool

1.2.1 Running the model

The model is written in NetLogo 6.2.1 (Wilensky 1999). NetLogo is a free and open-source software available to download from https://ccl.northwestern.edu/netlogo/6.2.1/ for all main OS: Mac, Windows and Linux.

In the folder where you store 'RADIN_MovementTool.nlogo' file, create two empty folders: 'Input' and 'Output'. Make sure the folder 'Output' is empty at the beginning of each simulation.

Open the RADIN_MovementTool.nlogo file. A window as in Figure 1 below should appear:

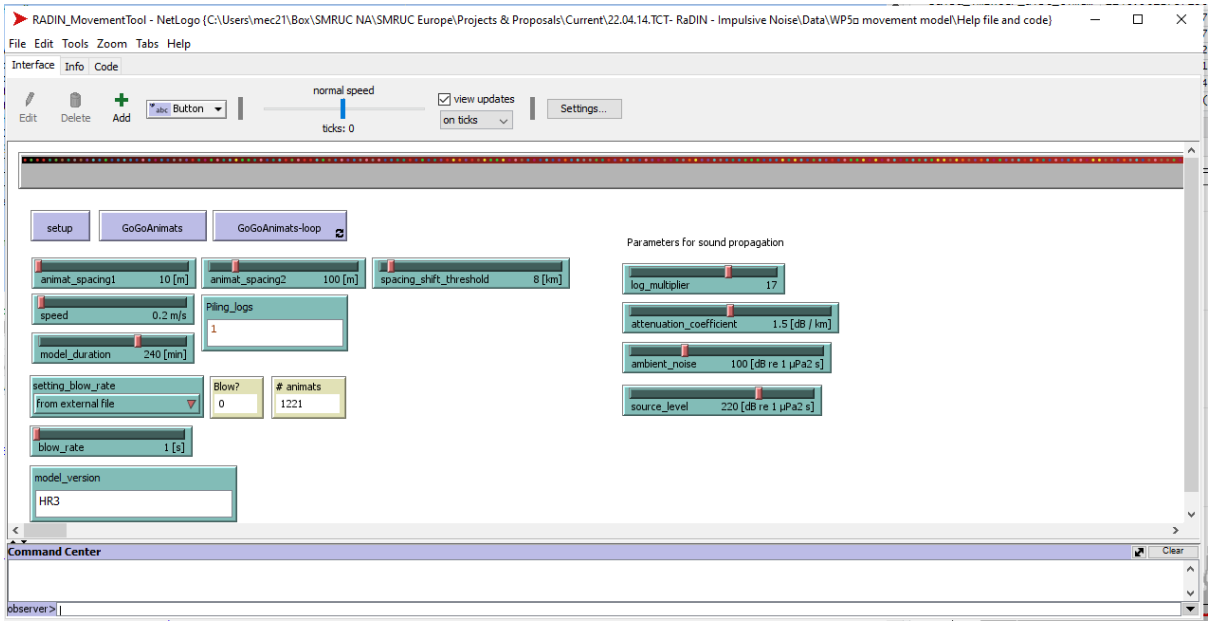


Figure 1. Software interface of the NetLogo RaDIN Movement Tool.

The model three primary tabs, which are highlighted in Figure 2**Error! Reference source not found.**: 'Info', 'Interface' (where user can define all input parameters), and 'Code'. **Do not change the Code section.**

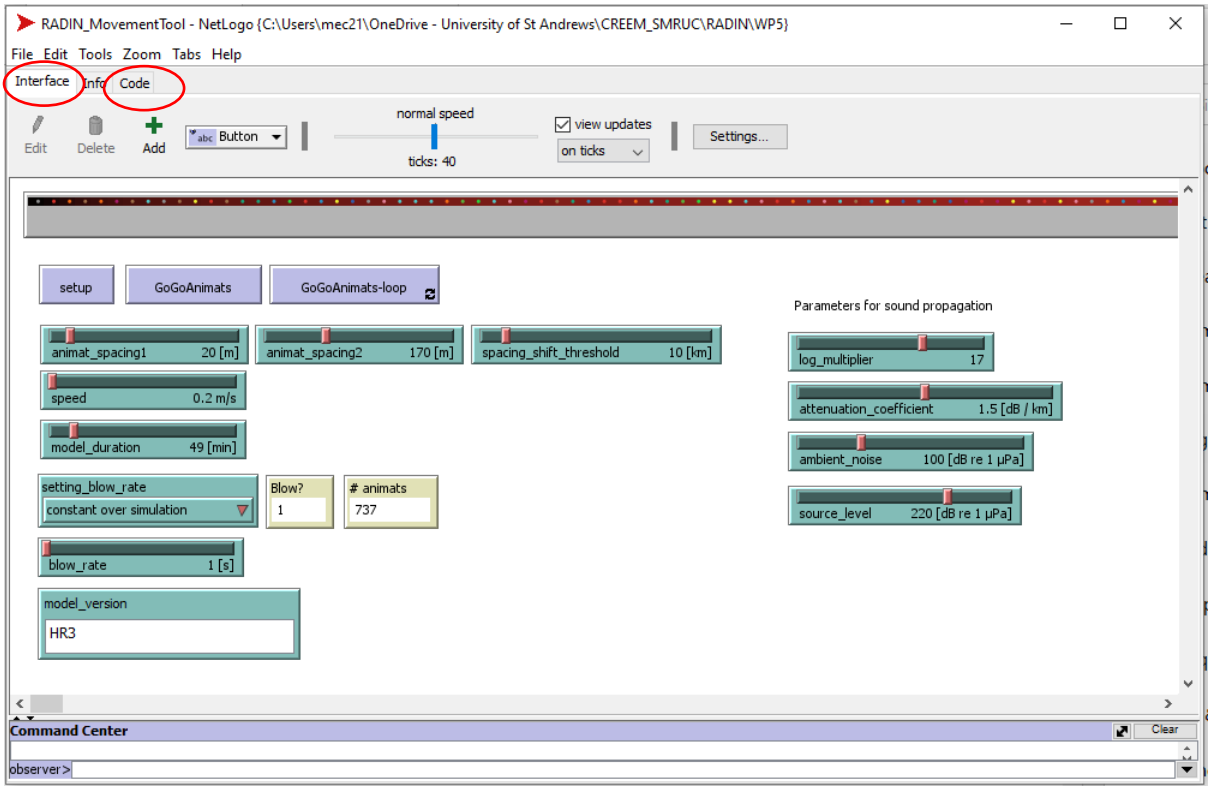


Figure 2. Software interface of the NetLogo RaDIN Movement Tool with the 'Interface' and 'Code' tabs highlighted.

1.2.1.1 Setting up the parameters for sound propagation

This has to be done only once, before the model run. Any changes in the parameters after the start of simulation will not be implemented.

Move the sliders to your desired values of the four parameters framed in the red box in Figure 3**Error! Reference source not found.** below. The parameters are described in Equation 1.

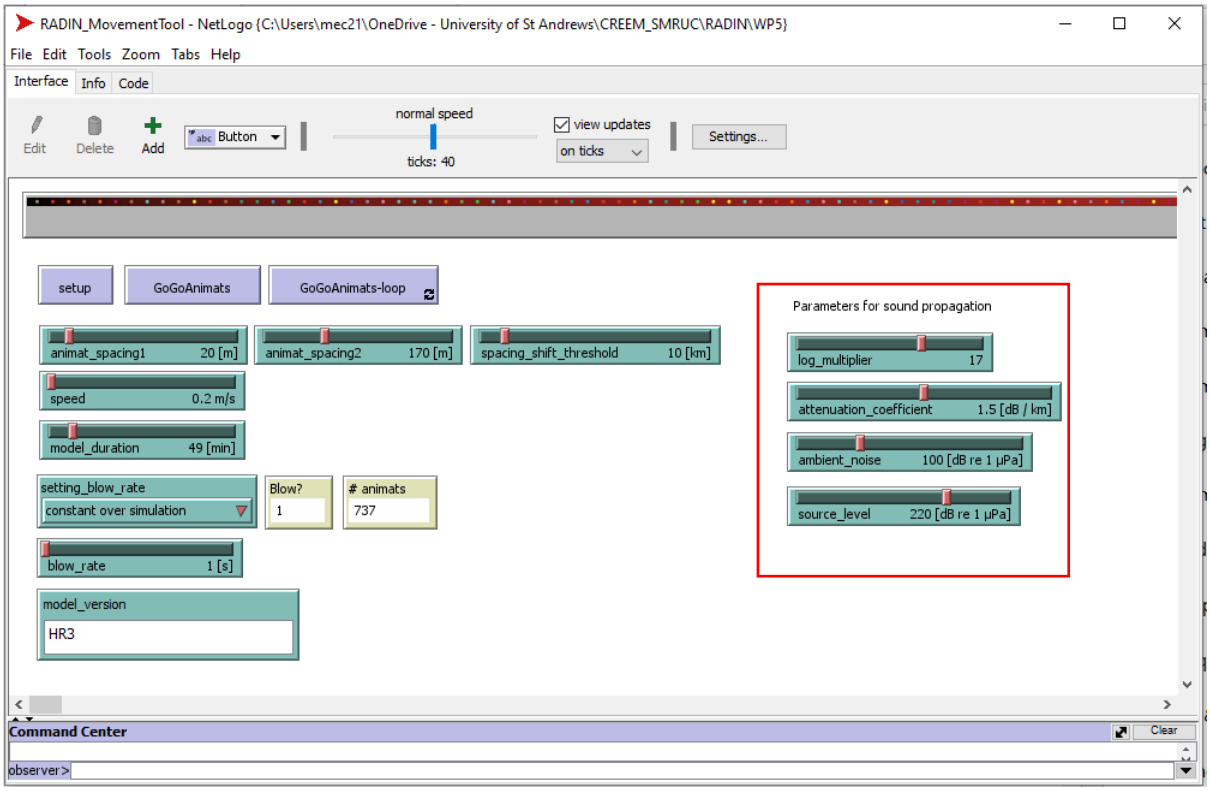


Figure 3. Software interface of the NetLogo RaDIN Movement Tool with the section for soundscape propagation parameters highlighted.

1.2.1.2 Setting up the initial animat distribution

You can define the initial distribution of the animats which determines the number of simulated individuals (see Figure 4). *animat_spacing1* defines how far apart [m] are animats from each other until *spacing_shift_threshold* [km]. After that threshold animals are distributed at *animat_spacing2.*

In this way you can define the number of simulated animals by increasing or decreasing the spacing between them. The number of simulated individuals is proportional to the length of each simulation and the size of the output file.

Final number of animats will be displayed in *# animats* after pressing *setup.*

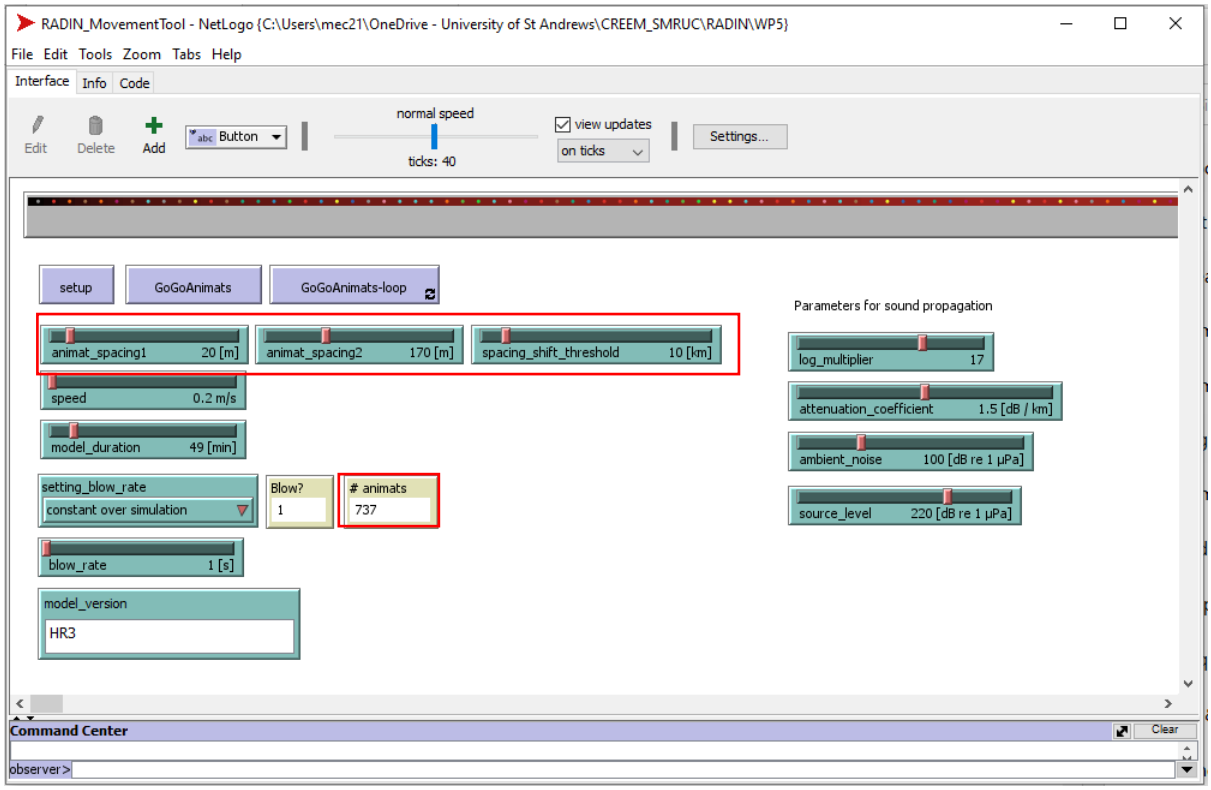


Figure 4. Software interface of the NetLogo RaDIN Movement Tool with the sections for animal spacing and the number of animats highlighted.

1.2.1.3 Setting up the piling hammer blow rate

Although blow rate does not affect the behaviour of the simulated animats or the soundscape, it is necessary for further analysis using the movement analysis tool. The movement tool allows you either to set a constant blow rate (*blow_rate*) or read a sequence of blows from a file. For a constant blow rate, set *setting_blow_rate* to *constant over simulation* by pressing the small red arrow next to *setting_blow_rate*, and then set your desired blow rate by using the *blow_rate* slider.

To load blow rate from a file, choose *from external file* in *setting_blow_rate* (see Figure 5). The input file has to be stored in 'Input' folder as 'blow_seq1.csv', where each row represents 1s and indicates presence ('1') or absence ('0') of a blow in this 1s (see Figure 6 for an example). The file should, therefore, have as many rows as the *model_duration* * 60 and have no header. The *model_*duration will be automatically set to the length of the blow rate input file so you must not change the *model_duration* if your blow rate is read from the external file. An example is presented below.

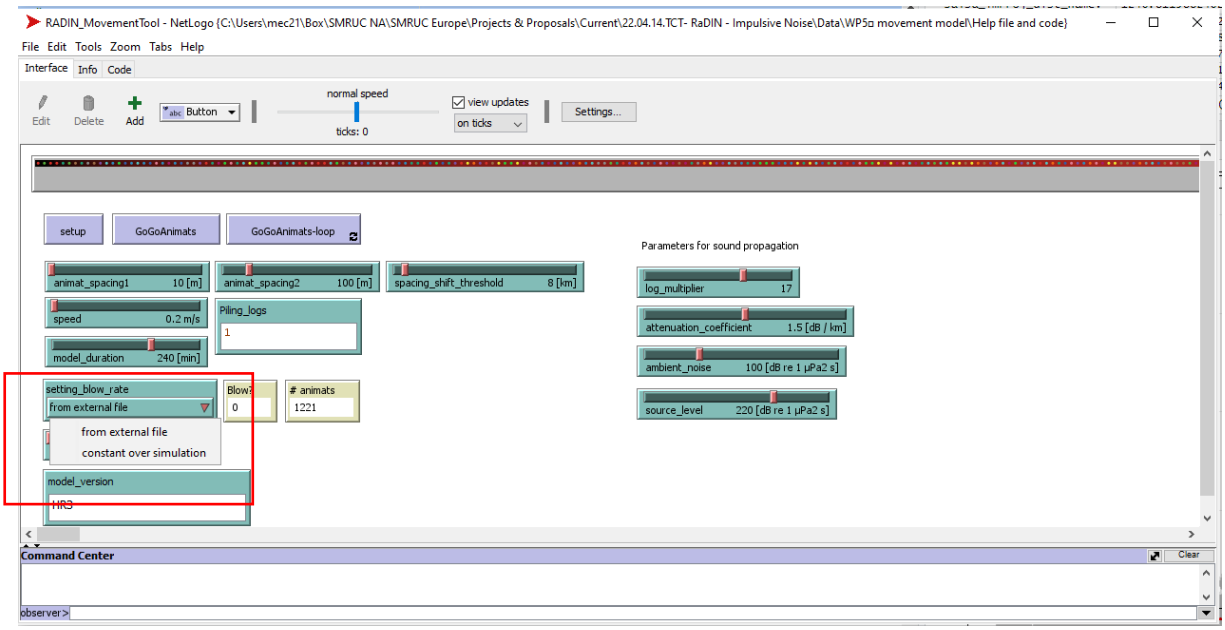


Figure 5. Software interface of the NetLogo RaDIN Movement Tool with the sections for setting the hammer blow rate highlighted.

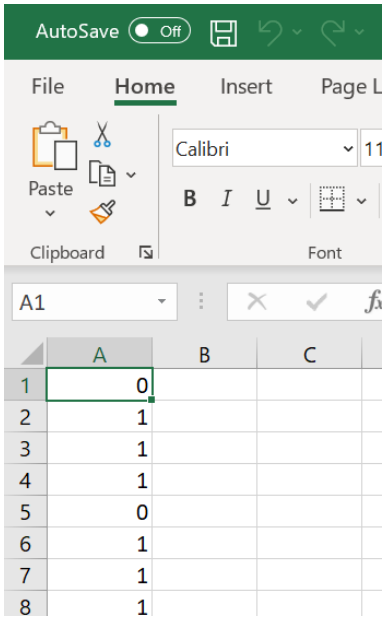


Figure 6. Example of a .csv file (displayed using Microsoft Excel) which can be loaded into the NetLogo RaDIN Movement Tool to set up a custom blow rate.

1.2.1.4 Setting up the remaining parameters

Use the sliders to set up animat *speed,* and *model_duration* (see Figure 7). If using a sequence of blows from an external file, make sure the model duration and the number of rows in the file correspond. The minimum allowed *speed* is 0.1 m/s and maximum is 5 m/s. The maximum *model_duration* is set to 6h. Use *model_version* to set up a name you want to include in your output file. Do not use "_" in the *model_version* you specify. Use *model_*version to specify, for example, the date of your simulation, the project name or the simulated windfarm. It is important that each output file has a unique name,

otherwise NetLogo may merge files together or overwrite them. Currently the name of the output is set to:

'Radin_output_" model_version "_sp_" speed "_br_" blow_rate "_sl_" source_level "_tl_" log_multiplier".csv'

This way, all the major parameters are saved in the output name.

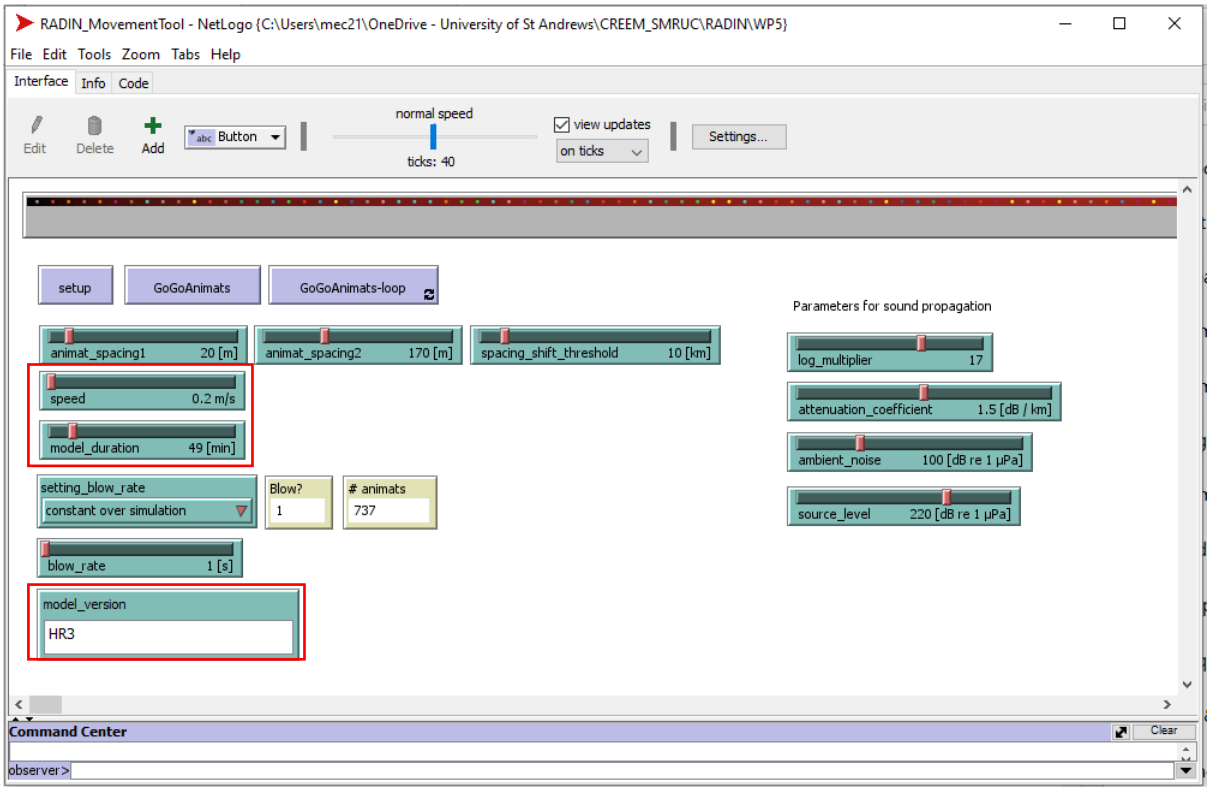


Figure 7. Software interface of the NetLogo RaDIN Movement Tool with the sections for setting the animal swimming speed and model duration along with model version highlighted.

1.2.1.5 Running simulations and a description of the output

To start simulation, press *setup* (see Figure 8). This will create your animats, colour code the soundscape by noise level and calculate the number of simulated individuals (*# animats*). Press *GoGoAnimats_loop*. The *ticks* should update every time step. Each time step *Blow?* will update to show whether there is ('1') or is not ('0') a blow and how many animats are left in the simulations. Individuals which reach the edge of the soundscape (50 km from the source) are removed from the simulation, hence *# animats* is decreasing with time. Simulation stops when *ticks* stops updating. To speed up simulations, untick *view updates.*

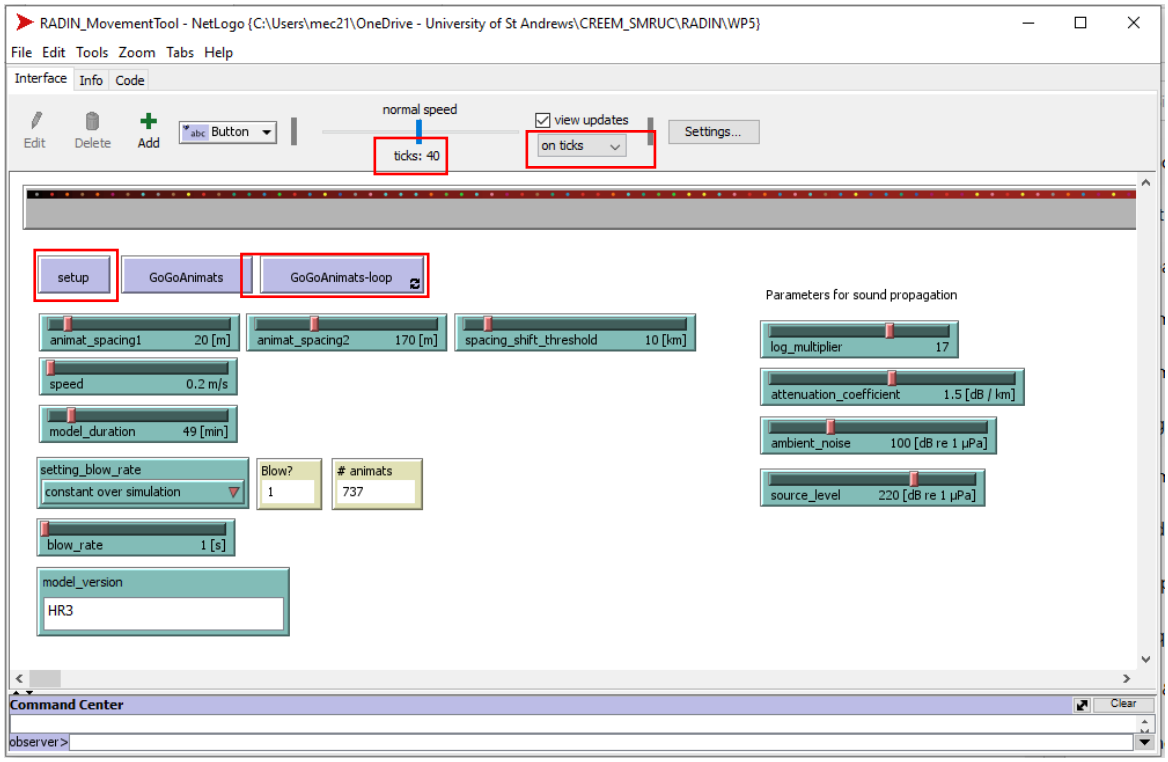
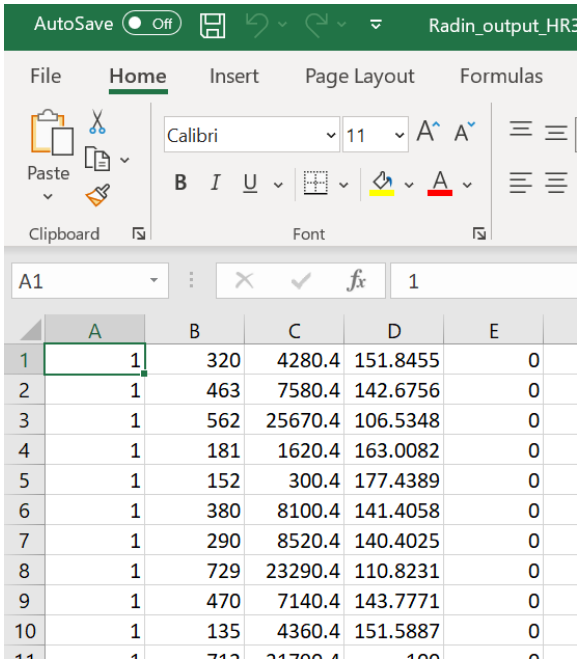


Figure 8. Software interface of the NetLogo RaDIN Movement Tool with the sections for setting up the simulation or iterative simulations highlighted.

All the outputs are saved in the 'Output' folder and are a headerless .csv file, as shown in Figure 9 below:



	A	B	C	D	E
1	1	320	4280.4	151.8455	0
2	1	463	7580.4	142.6756	0
3	1	562	25670.4	106.5348	0
4	1	181	1620.4	163.0082	0
5	1	152	300.4	177.4389	0
6	1	380	8100.4	141.4058	0
7	1	290	8520.4	140.4025	0
8	1	729	23290.4	110.8231	0
9	1	470	7140.4	143.7771	0
10	1	135	4360.4	151.5887	0

Figure 9. Example of a .csv file (displayed using Microsoft Excel) produced by the NetLogo RaDIN Movement Tool at the end of a simulation.

Column A is time step at 1s intervals, column B is a unique id of each simulated animat, columns C is distance [m] from the source, column D is SEL_{ss} at this distance, and column E is whether there is ('1') or there is not ('0') a blow in a given second.

1.2.1.6 Running multiple simulations

Multiple simulations for parameters from the interface

NetLogo is specifically designed for agent-based models and offers a variety of tools for testing multiple scenarios. 'BehaviorSpace' allows you to test scenarios where user defined parameters can vary between simulations. This option can be used, if, for example you would like to make simulations with a range of speeds or blow rates. 'BehaviorSpace' can only be used to vary the parameters listed on the 'Interface' and controlled by the sliders. It cannot be used to vary input parameters like user defined blow sequence.

To use it, open 'BehaviorSpace' from the *Tools* dropdown menu (see Figure 10). There is already an example set called 'experiment_example_speed'.

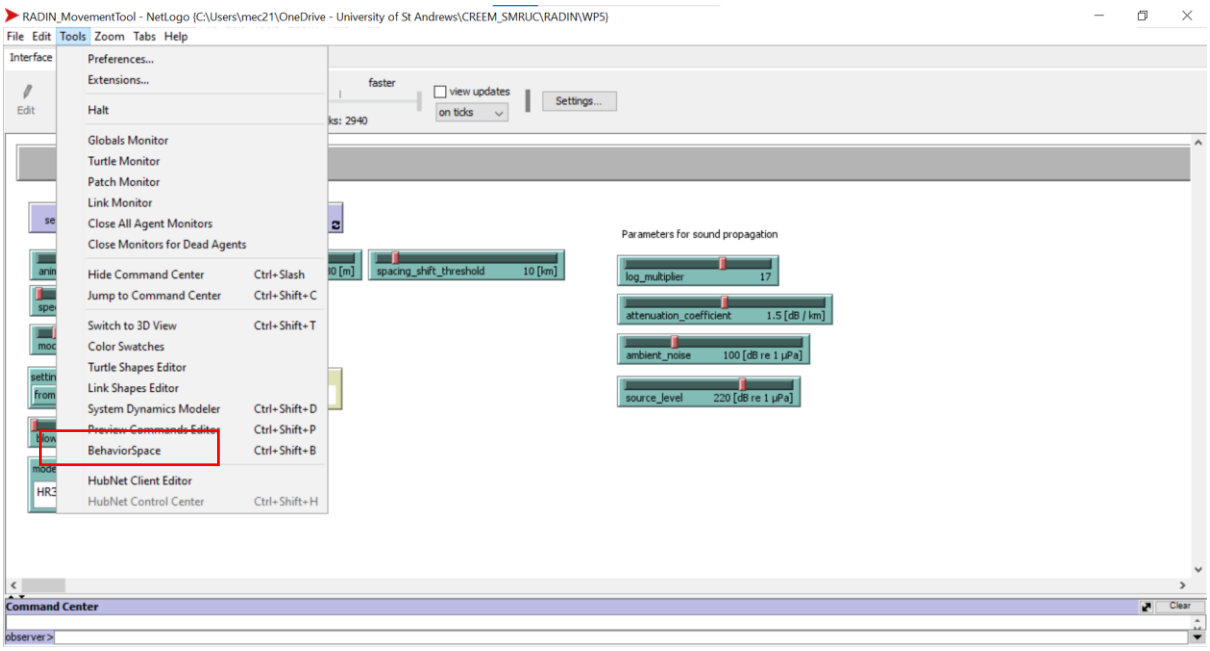


Figure 10. Software interface of the NetLogo RaDIN Movement Tool with the 'BehaviorSpace' tool highlighted.

After opening an experiment, the window shown in Figure 11 below will pop up:

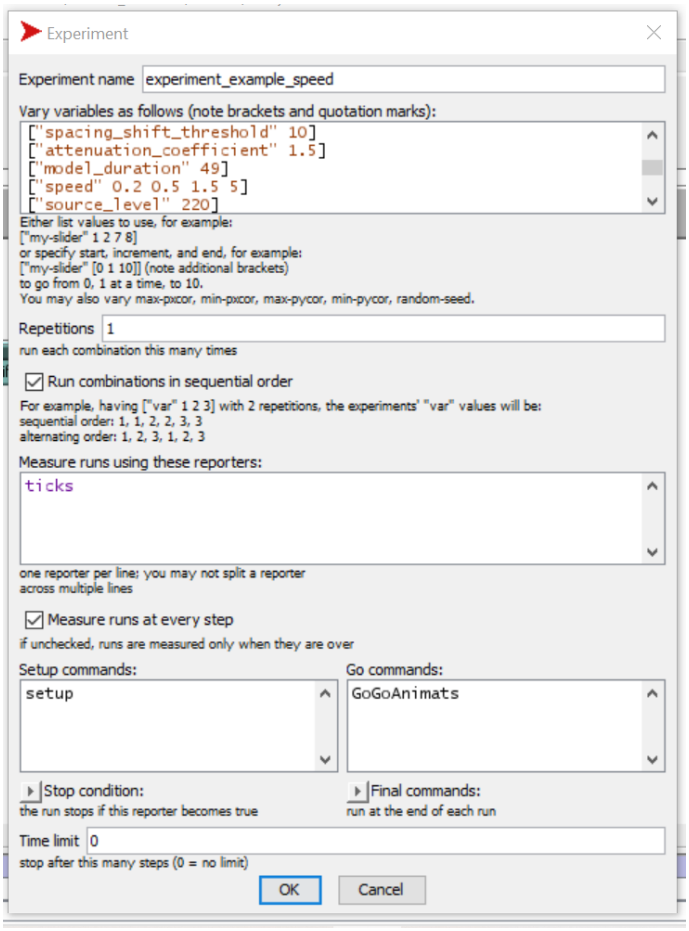


Figure 11. NetLogo software window of an experiment which is part of the 'BehaviorSpace' tool.

In the 'Vary variables as follows' window all the parameters from the 'Interface' are listed together with their default values. Default values are the values set in last time you saved the. nlogo file. If you want to run simulations when one or more parameters is varied at a time, list all the values you want to include as in the example for *speed.* In the example, the tested values of speed will be 0.2, 0.5, 1.5, and 5 m/s. If you do similar for another parameter, for example *source_level* and set it to 200 and 220, the 'BehaviorSpace' will run all eight combinations of the chosen *speed* and *source_level.*

Press OK and then Run. Do not tick any of the boxes in the run options dialogue box (see Figure 12) and set 'Simulations run in parallel' to your desired number. The default is 8 but if you run simulations on a machine with less than 8 cores or you perform many other analyses on the machine at the same time, reduce the number to 2 or 4. If any error appears, it is most likely related to setting too many simulations to run in parallel. Reduce the number and start again to see if the error disappears.

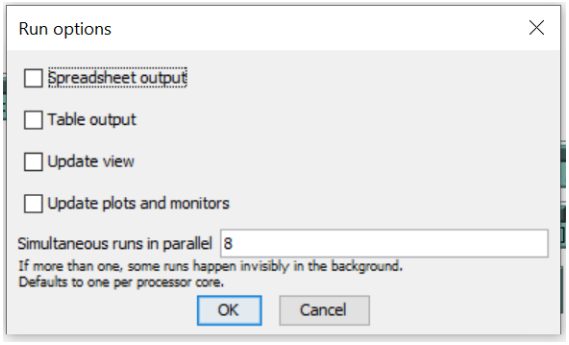


Figure 12. NetLogo software dialogue box which is part of an experiment of the 'BehaviorSpace' tool.

A window with the running progress will appear (see Figure 13). When this window closes, the simulations are done and you can check the Output folder for the results. To get an understanding which output refers to which simulation, check the output name: a different speed should be listed for each output if you use the settings in the example.

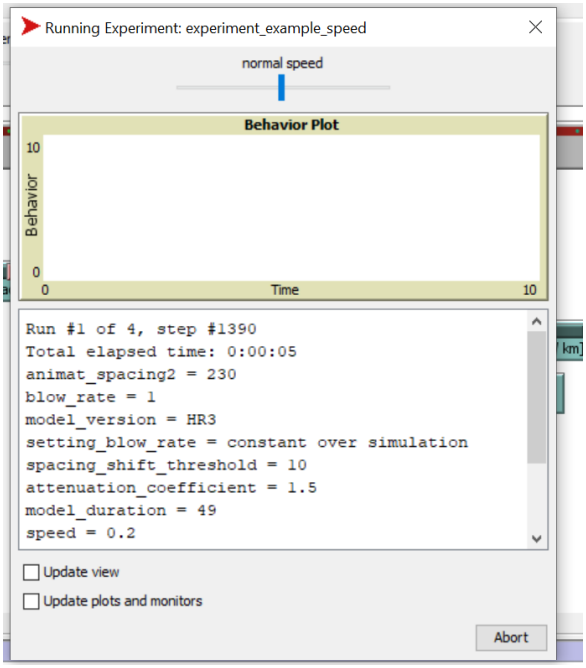


Figure 13. NetLogo software window which is part of an experiment of the 'BehaviorSpace' tool.

Simulations for multiple blow rate scenarios read from external files

Place all your blow rates sequences in the format described in section 2.2.3 in the Input folder. Name files blow_seqX.csv where X are consecutive numbers from 1 to number of files you want to simulate.

In BehaviorSpace set ["Piling_logs" [3 1 20]] so the range you desire. The example ["Piling_logs" [3 1 20]] means that you want to run files from 3 to 20 in 1 increment.

1.3 The movement analysis tool

1.3.1.1 Setting up the tool

Depending on the number of simulated animats and the length of the simulated piling, the output files from the Movement tool can be very large files containing several million rows. Processing such large files is very computationally intensive and the analysis tool is, therefore, designed to optimise the processing time. However, if running simulations for a large number of animats over long duration and/or processing the outcomes of multiple simulations, processing time could be several hours.

The analysis tool is designed to process all of the output files in 'Output' folder at once. The tool uses parallel computation meaning that several cores of your machine will be used at the same time.

1. Open the 'Movement_analysis_tool.R' code.

There are 8 packages that the code requires, and they will be installed automatically if you don't have them installed already:

- `ggplot2`
- `dplyr`
- `tidyr`
- `stingr`
- `parallel`
- `doParallel`
- `data.table`
- `here`

2. Set the working directory to the 'Output' folder.
3. Define the number of cores you want to use in your simulation. The `parallel::detectCores()` function can tell you how many cores your computer has. We recommend leaving at least two cores for the background processes.
4. Make a list of all the files you want to process using `fls <- list.files(getwd(),"csv")`
5. Choose the hearing group you want to analyse.
6. There are four hearing groups which can be analysed: VHF- very high frequency, HF - high frequency, LF - low frequency, PCW - phocids in water. Use `groups <- c("LF", "VHF", "LF", "PCW")` to define the one of interest to you. As default all four groups are chosen.
7. Define the transition thresholds between impulsive and non-impulsive sound.
8. Five different thresholds must be specified. The default values are 1, 2, 3, 7 and 10 km. The change from impulsive to non-impulsive sound is currently modelled as a step function.

9. Define the SEL correction for each hearing group, TTS, and PTS thresholds as well as growth rates of cumulative SEL depending on the impulsiveness of the soundscape. You can use the default values shown in **Error! Reference source not found.**.

1.3.1.2 Running the analysis and description of the output

1. Mark the lines 73 – 356 and

press

2. The progress of the analysis is indicated in the Console. Each file is analysed for each hearing group separately. If `"Group: LF of file: 1"` shows up in the Console, it means that LF group of file 1 has finished analysing. Do not stop the analysis until the  sign is gone.

3. The results are also stored in the 'Output' folder as a .csv file and each output file from the Movement Tool results in one output from the Movement Analysis Tool. The name of the result file contains all the information on the settings used in the Movement tool. The file has the following name:

`"pts_max_dist_BlowRate_A__Speed_B_sl_C_TL_D.csv"`

, where 'A', 'B', 'C' and 'D' are values of blow rate, speed, source level and transmission loss log multi plier

respectively used in the simulation.

An example of an output file is shown in Figure 14 below:

	A	B	C	D	E	F	G	H	I	J
1	h_group	max_tr1	max_tr2	max_tr3	max_tr4	max_tr5	br	sp	sl	tl
2	LF	990.4	1830.4	1860.4	1860.4	1860.4	1	0.2	220	17
3	VHF	870.4	900.4	900.4	900.4	900.4	1	0.2	220	17
4	LF	990.4	1830.4	1860.4	1860.4	1860.4	1	0.2	220	17
5	PCW	240.4	240.4	240.4	240.4	240.4	1	0.2	220	17
6										

Figure 14. Example of .csv file (displayed using Microsoft Excel) produced by the R RaDIN Movement Analysis Tool.

The '*h_group*' column lists the chosen hearing groups, *max_tr1* to *max_tr5* columns show the maximum distance [m] at which animats have to be at the beginning of the simulation in order to experience PTS for each of the five chosen impulsiveness to non-impulsiveness thresholds. The last four columns repeat the settings used for the simulation: *br* blow rate, *sp* speed, *sl* source level, and *tl* transmission loss log multiplier.