

Sound Reception Analysis

Objectives

This case study is based on the research “The role of sound production in Atlantic cod spawning” which was conducted by Timothy Grabowski and Egill Guðmundsson in Iceland in July 2009.

Data from four DST-Sonic V8 recorders, manufactured by Star-Oddi, were used to collect data for the research.

The recorders were implanted into cod housed at a MRI experimental research station. The cod were placed in a 3-m diameter, 1-m deep tank. The tags were configured to measure every second. If the sound intensity was over a programmed threshold level within the programmed frequency range, a “1” was registered, else a “0”. These values were based upon a review of the pertinent literature. The tags were allowed to record data for 24 days and registered more than two million measurements each.

Definition of terms:

Detection: if sound intensity exceeded threshold level within the programmed frequency range => registered sound detection = “1”

This dataset represents the first part of a larger study to evaluate the role of sound production in cod reproductive and agonistic behavior

The objective of this particular study was to evaluate the performance of the DST Sonic V8 in its ability to distinguish between nearby sound, such as those from the cod it was implanted in and other individuals within the same tank (weaker sounds).

Questions that need to be answered are:

- How often do they all detect sound simultaneously?
- How often does only one detect sound?

Other combinations of simultaneous sound detections are also of interest.

Method

There are technical measurement timing issues to consider when comparing the signals second by second.

One timing issue is that when starting the recorders there is an uncertainty in the start-up procedure. If everything goes as it should, a minimum of 1-2sec uncertainty is to be expected, if for example the "OK" button is accidentally pushed before taking the recorder out of the box, another 2-5 sec can be expected.

The other timing problem is drift in the real-time clock that can in 24 days accumulate to 25sec.

So the timing uncertainty, though increasing with time, can be approximately 30sec.

Evidently we need to use averaging values in our comparison.

Other factors that influence the experiment are ambient sounds. These background sounds may be continuous, such as impeller and water noise from running pumps, or peaks, such as a door slamming shut in the facility.

We start by looking ratios of ones vs. zeroes.

Then we look at the number of registered sounds per minute, overlaying the data to get a feeling of how the recorders compare, and answer questions like can the data be compared over the whole time.

We select a comparable section and find the detection frequency and the duration times, for each recorder, and compare these values.

Creating a multiple file project (MFP)

A multiple file project, called S.MFP, was created. The project contains four SFPs, one for each cod, called Sonic22, Sonic23, Sonic24 and Sonic25.

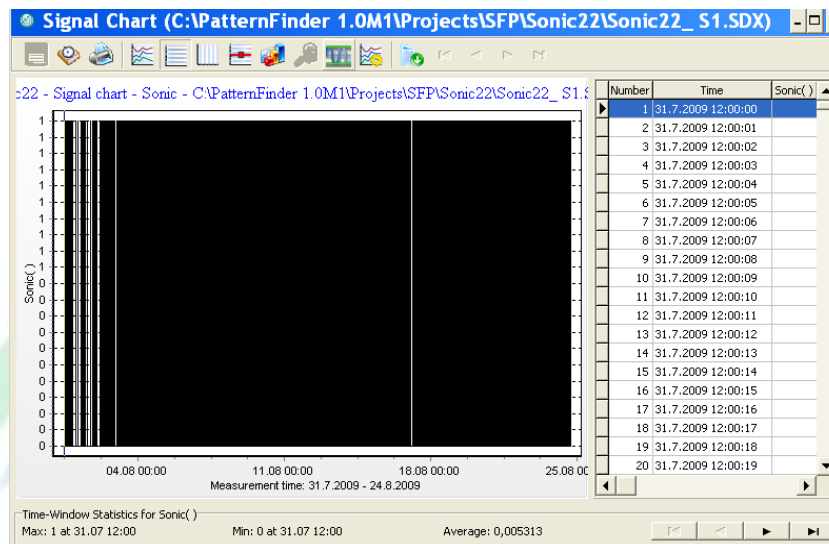


Figure M1. Measurements from Sonic22

Looking at the DAT file for Sonic22 (see figure M1) it seems that a lot of sounds have been registered. The histogram in figure M2 however tells a different story.

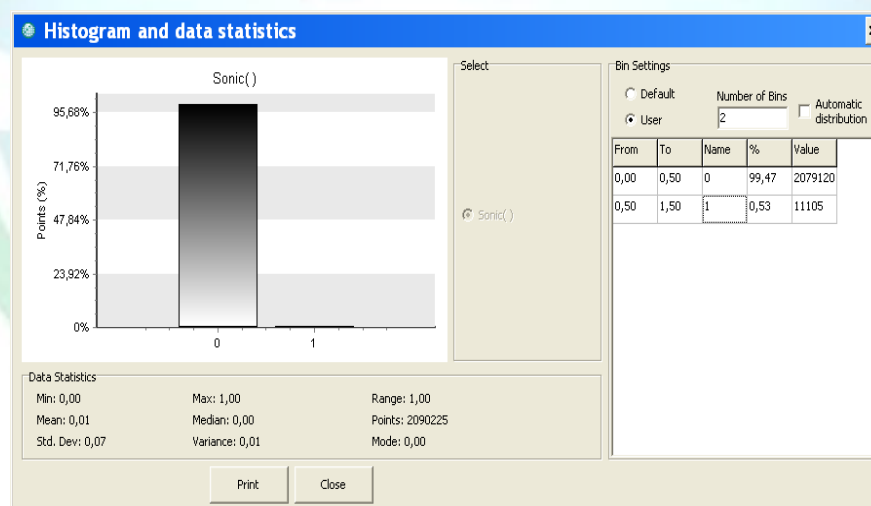


Figure M2. Histogram for Sonic22

Apparently there are only 11105 sound detections out of 2090225 measurements, i.e., ca. 0,53%. When looking at the DAT signals from the other recorders the following detection ratio is revealed:

SFP data:

SFP	Tag	Deployed	Days	Meas. Nr.	Detect. Nr	Detect. %
Sonic22	2100022	31-07-2009	24	2.090.225	11.105	0,5
Sonic23	500023	31-07-2009	24	2.090.225	9.078	0,4
Sonic24	400024	31-07-2009	24	2.090.225	398.488	18,6
Sonic25	500024	31-07-2009	24	2.090.225	34.157	1,6

Sonic22 and Sonic23 are similar in detection values, Sonic25 is somewhat higher, but Sonic24 stands out as suspiciously high.

1. Primary evaluation, detections per minute

Before we can compare the four cod signals we must first prepare them for evaluation. We want to see the number of detections per minute. This can be done in 4 steps for each SFP as described below. Sonic22 is used as an example. The last step in this primary evaluation is to compare the four detections per minute signals.

1.1 Extracting the sound signal from the DAT file

Select the DAT file and extract Sonic measurements 1-2090225.

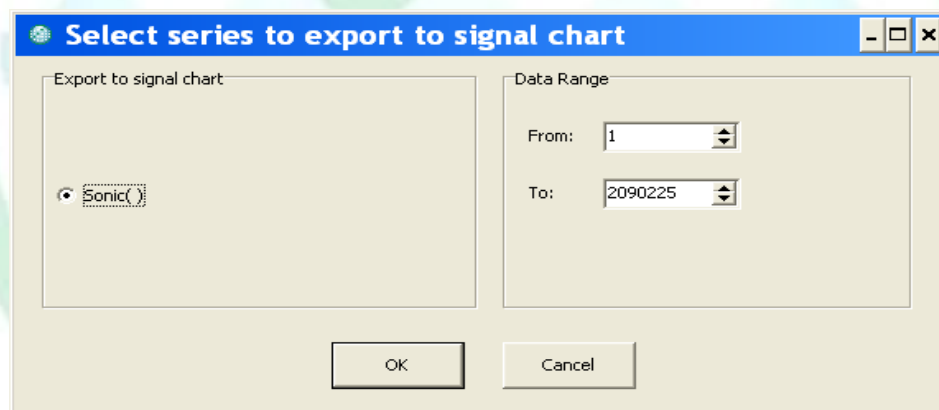


Figure 1.1 Extracting the Sonic signal from the DAT file.

The new file is saved as S22P. It is important to use descriptive alias names to avoid confusion.

1.2 Scale the data

As we are going to look at detections per minute we multiply the S22 by 60

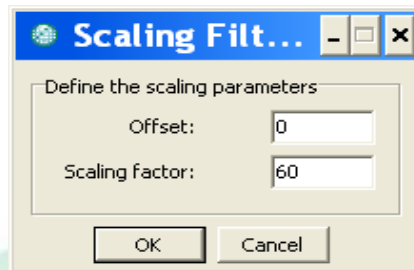


Figure 1.2.a: Defining a scaling signal

The new file is saved as S22P*60.

1.3 Periodic signal analysis

Having selected S22P*60 we activate the Periodic Signal Statistics Analysis function and define the time averaging period as one minute. As there is always a measurement on the period's margins and measurements are evenly distributed, the **Interpolate** and **Time weighing** options are not checked.

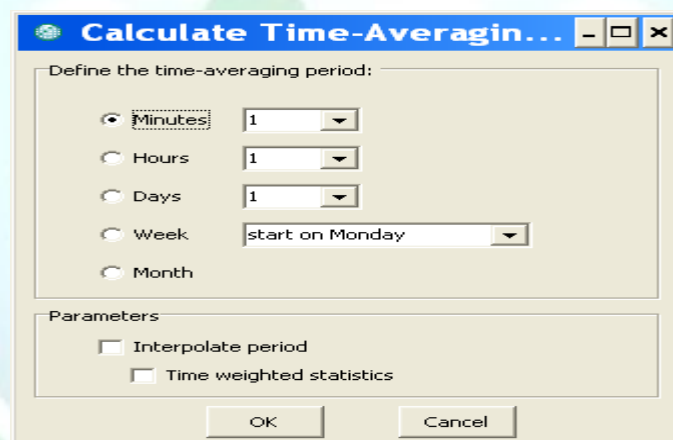


Figure 1.3.a: Defining a period

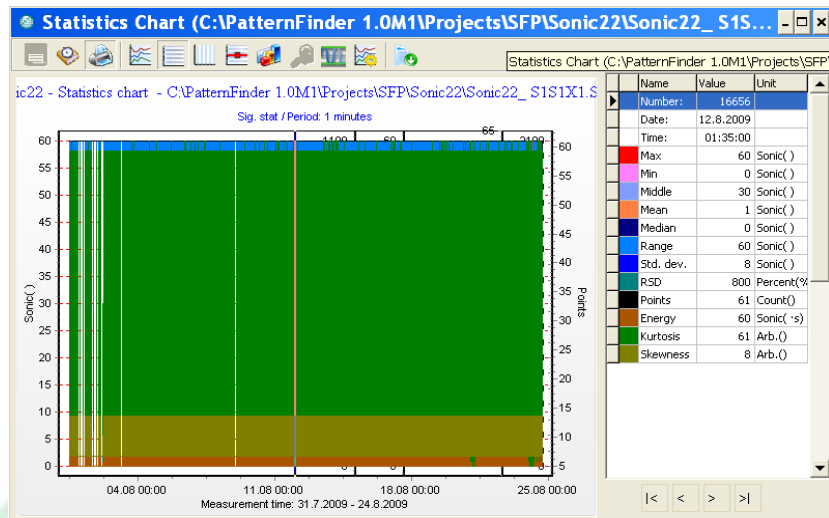


Figure 1.3.b Periodic Statistical Analysis

The statistics chart in figure 1.3.b is saved as S22P*60_Xmin.

1.4 Extract the detection numbers

We now extract the mean value from the statistics chart which represents the number of detections per minute.

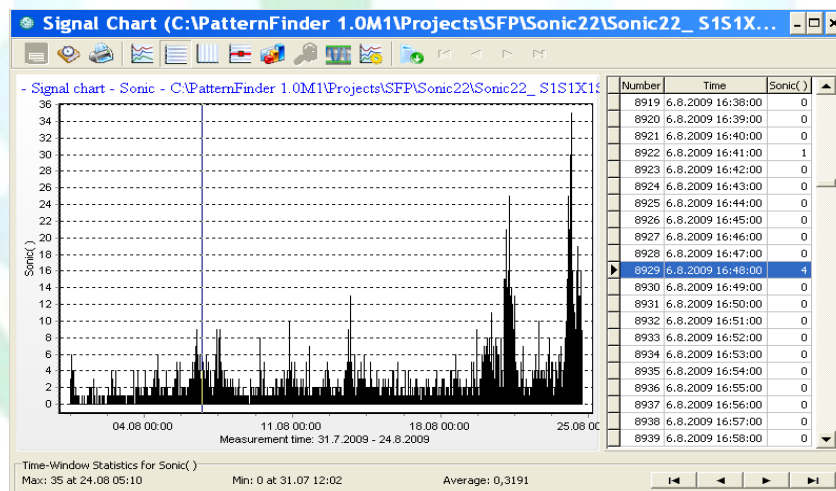


Figure 1.4 Extracted mean.

The signal chart in figure 1.4 is saved as S22Pmin.

1.5 Comparing the four, detections per minute, signals

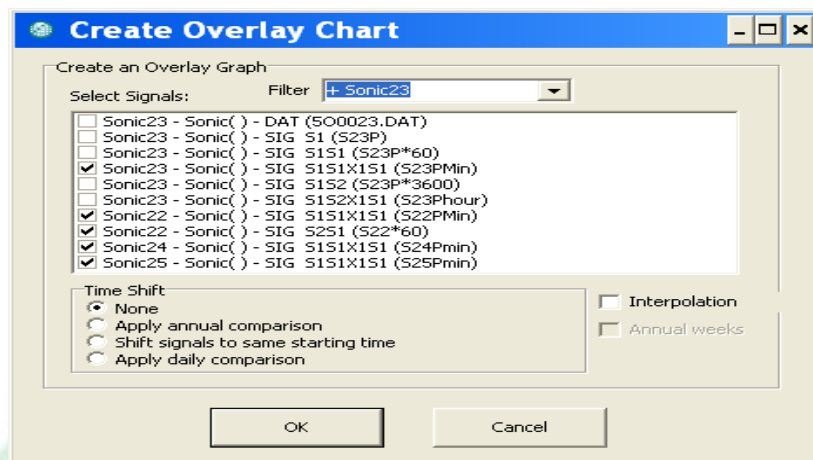


Figure 2.1.a: Selecting data for overlaying

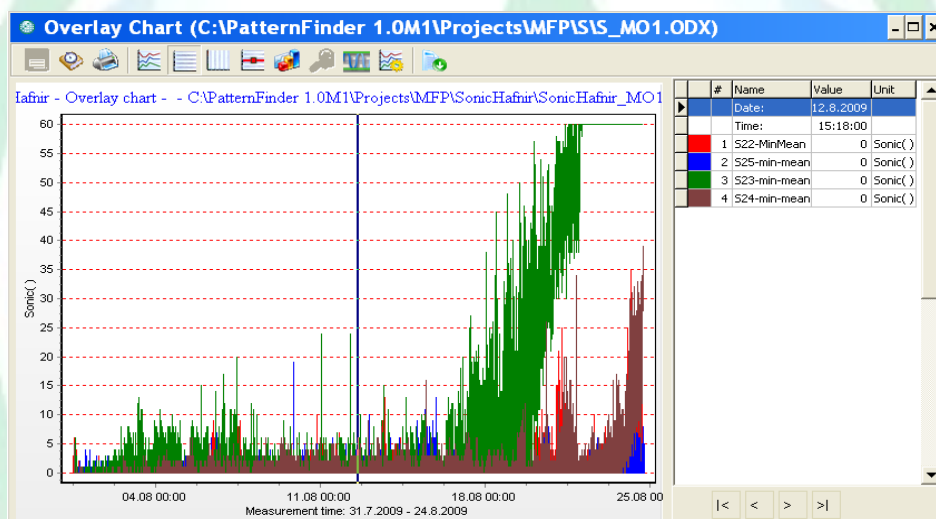


Figure 2.1.b: Detections per minute overlay

The overlay chart in figure 2.1.b is saved as SP_min.

2 Finding and comparing detections per hour

We execute the same procedures as in 1.2 – 1.5, except now the scaling factor is 3600 which gives us detections per hour.

The compared detections per hour are shown in the chart below.

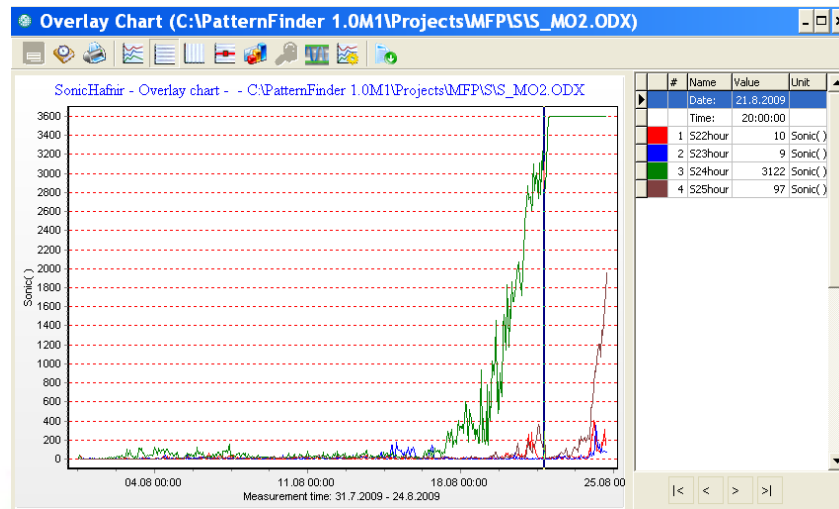


Figure 2.1.c: Detections per minute overlay

The overlay chart in figure 2.1.c is saved as SP_hour.

We now get a clearer view of the measurements. S24 is obviously too sensitive and has some malfunctions in the end. S25 shows some over sensitivity in the last two days.

3 Detection frequency and duration

We decide not to use S24 in our comparison.

As the signals do not have the same starting point and we want to dismiss the last two days in Sonic25, we now repeat the process described in 1.1 and adjust the start and end points of Sonic22, Sonic23 and Sonic25.

The resulting files are named S22, S23, S25.

The preliminary detections evaluation was not accurate enough as it did not take into account the duration of the sound signals thus a new method is deployed here. First we find sound detection events and then we find the number of occurrences per minute and per hour. To find the detection frequency (DF) and detection duration (DD) 4 steps are required for each recorder. We use Sonic22 as an example.

3.1 Ambient event analysis

Select S22 and choose the Event Analysis function. Define Ambient event and define/use a two level template L1 0-0,5 and L2 0,5-10 (see figure 3.1.a). All detections are defined as L2.

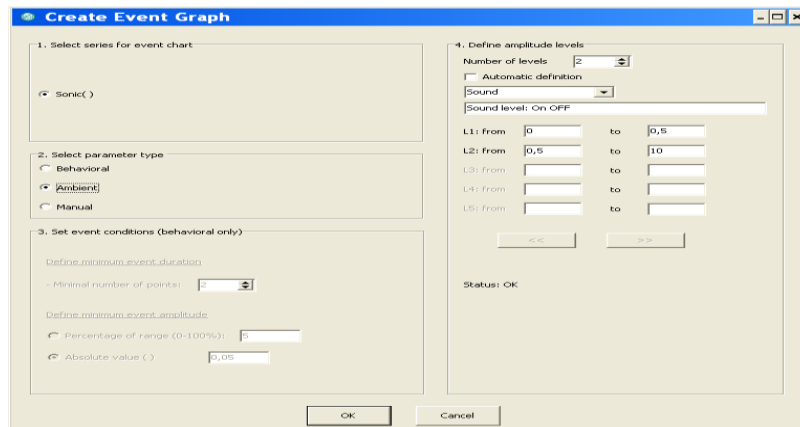


Figure 3.1.a Defining level Events

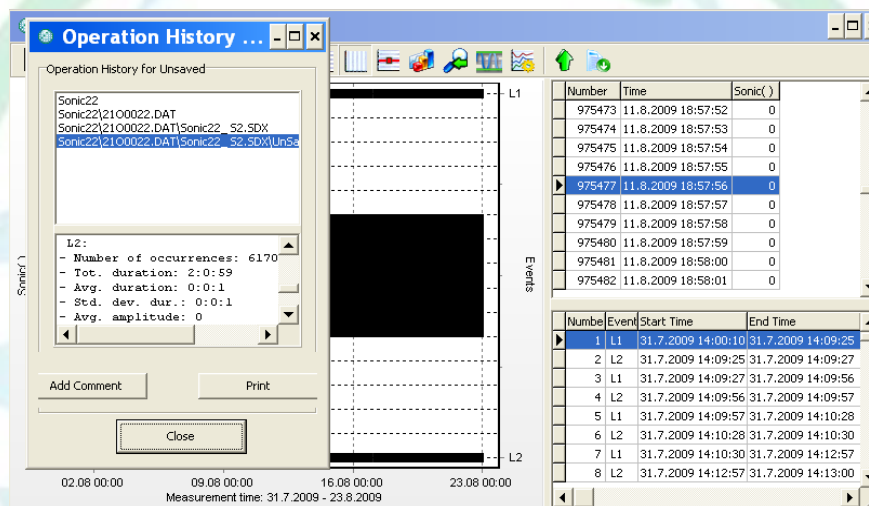


Figure 3.1.b Detection Events

The file is named S22_E.

Each event has a duration which defines the length of the sound signal.

You can see how the sound durations vary by selecting the histogram button and choosing the L2 event (3.1.c). In this case the duration varies between 1 and 10 sec.

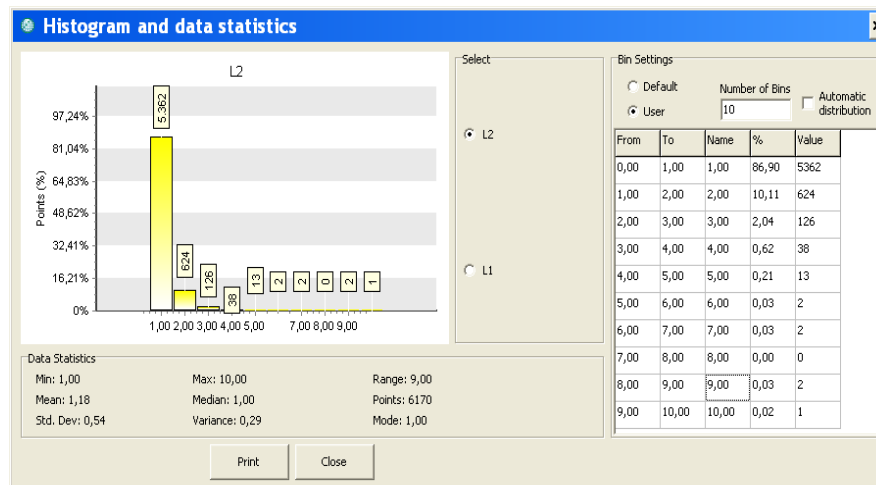


Figure 3.1.c Detections Event Histogram

These results along with the result data from Sonic23 and Sonic25 are listed in Table R1.

3.2 Detections per minute

Select S22_E and choose the Periodic Events Statistics operation. Choose the L2 event and define the time-averaging period as 1 minute. Disable **Events overlap periods**.

Create Event Statistics

Pick an event:

☐ Events overlap periods

Define the time-averaging period:

☒ Minutes:

☐ Hours:

☐ Days:

☐ Week:

☐ Month

OK Cancel

Figure 3.2.a: Event statistics selection dialog

After having defined the operation the following statistical event chart is presented.

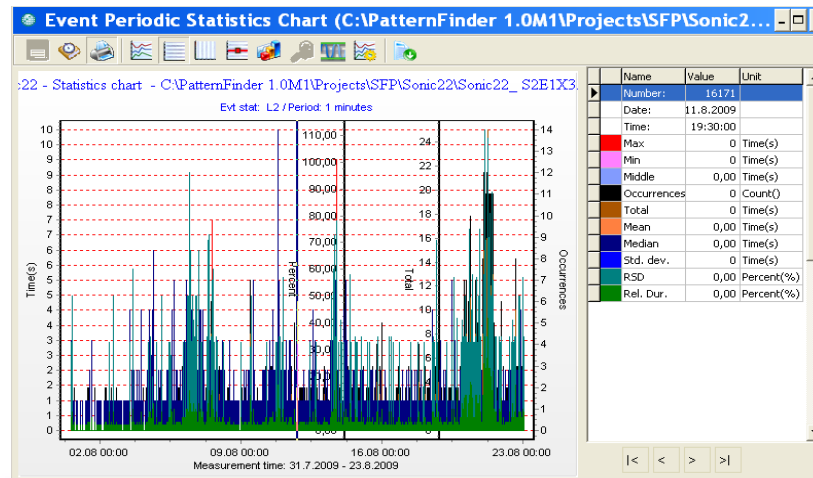


Figure 3.2.b Periodic Event Statistics: 1 minute

The event periodic statistics chart in figure 3.2.b is saved as S22_E_Xmin.

Extracting the **Occurrences** from S22_E_Xmin gives us detections per minute.

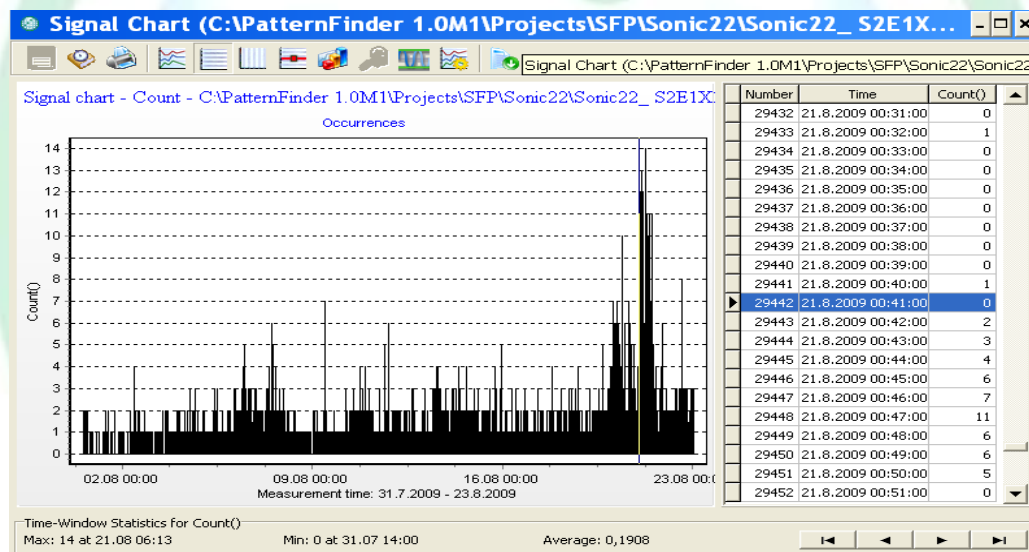


Figure 3.2.c: Detections per minute

The signal chart in figure 3.2.c is saved as S22_DFmin.

We can use these findings to compare the three recorders (see chapter 4).

3.3 Detections per hour

We use the same procedures as in chapter 3.2. Select S22_E and choose the Periodic Event Analysis function. Choose L2, but define the time-averaging period as 1 hour.

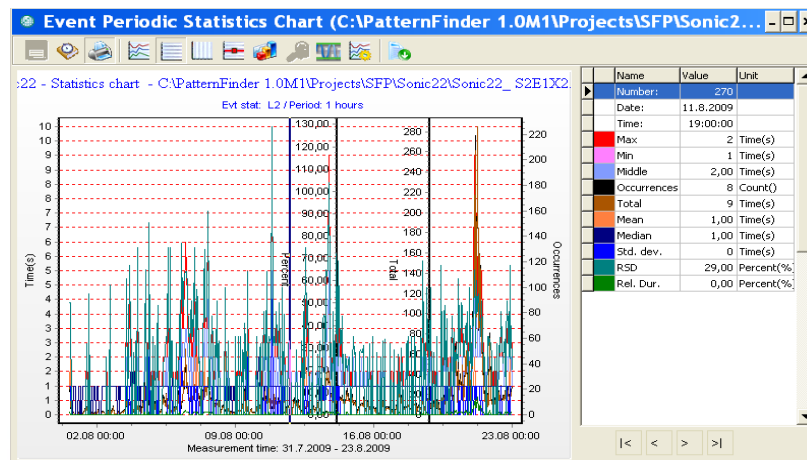


Figure 3.3.a: Periodic Event Statistics: 1 hour

The event periodic statistics chart in figure 3.3.a is saved as S22_E_XH.

Extracting the **Occurrences** from S22_E_XH gives us detections per hour.

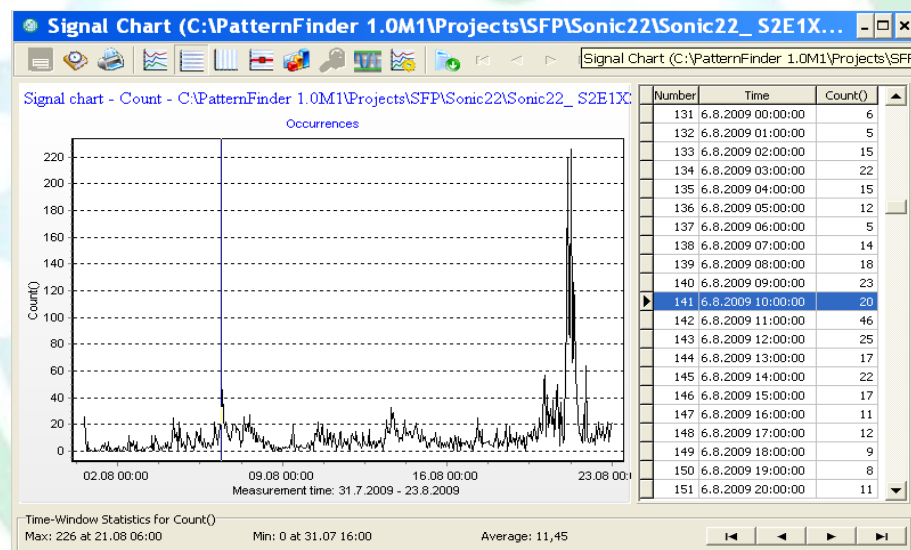


Figure 3.3 Detections per hour

The signal chart in figure 3.3 is saved as S22_DFh.

Comparison of the hourly detections frequency for the three recorders can be seen in chapter 4.

3.4 Detections duration per hour

Select S22_E_XH and extract the **Total duration**

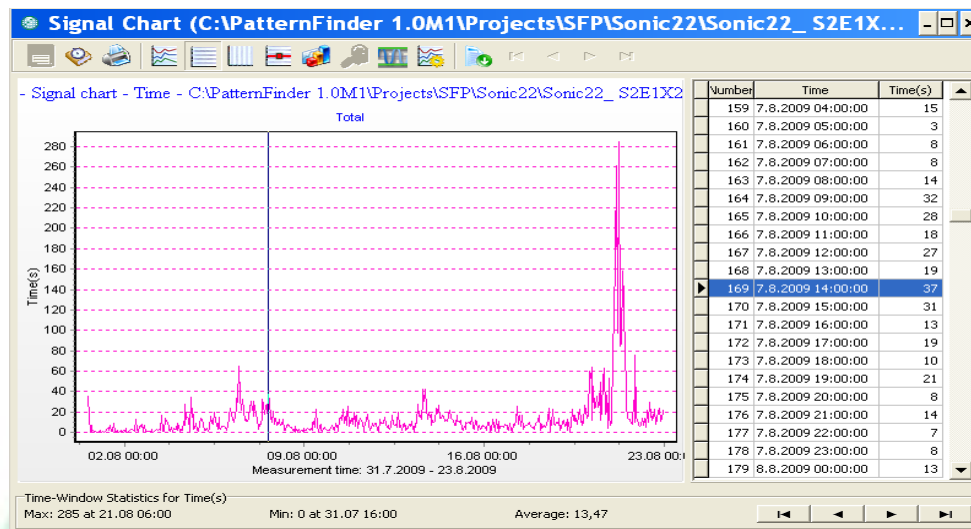


Figure 3.3 Detections duration per hour

The signal chart in figure 3.3 is saved as S22_DDh.

Detections frequency comparison is in chapter 4 and detections duration comparison for the three recorders is in chapter 5.

4 Detection frequency comparison

4.1 Detection frequency per minute comparison

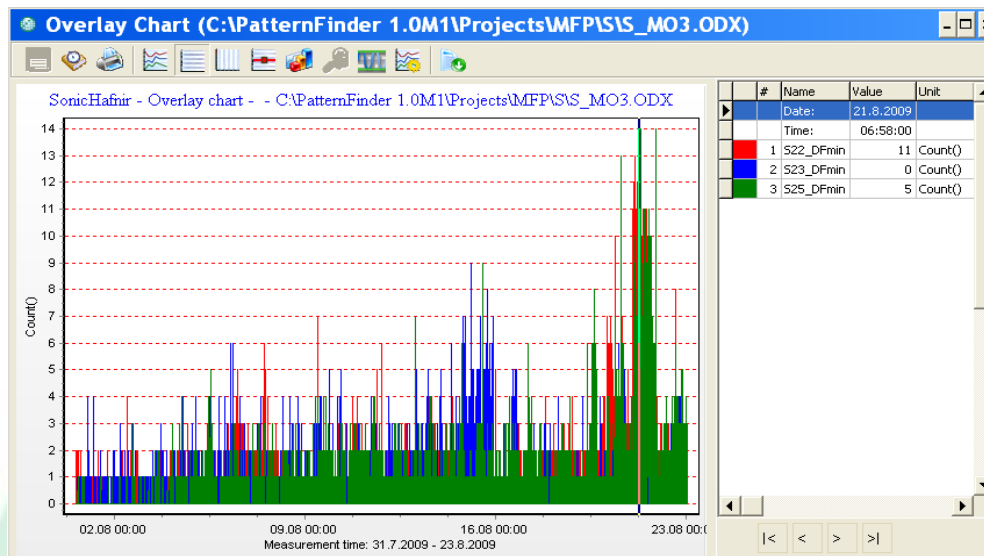


Figure 4.1.a Overlay detection frequency per minute

The overlay chart in figure 4.1.a is saved as S_ODFmin

We now perform an Overlay statistics analysis. The results can be seen in the chart below.

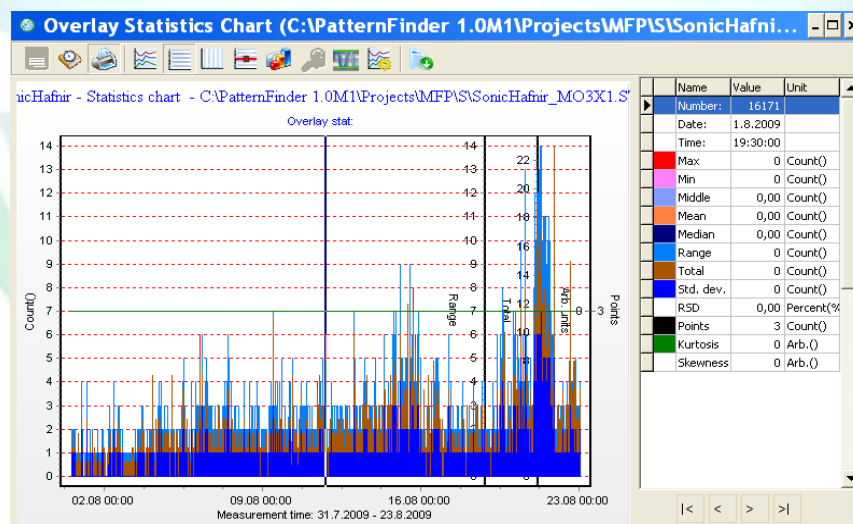


Figure 4.1.b: Overlay statistical analysis

The overlay statistics chart in figure 4.1.b is saved as S_ODFmin_X.

We extract the **mean value**.

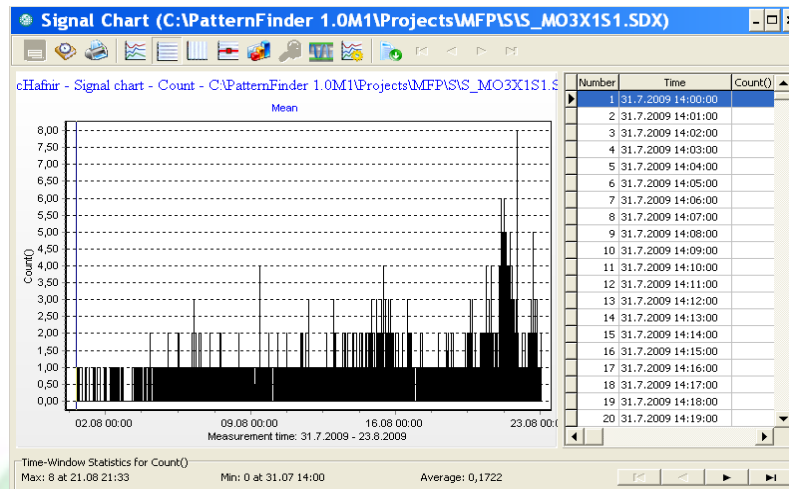


Figure 4.1.c Average detections per minute

The signal chart in figure 4.1.c is saved as S_DFmin

4.2 Detection frequency per hour comparison

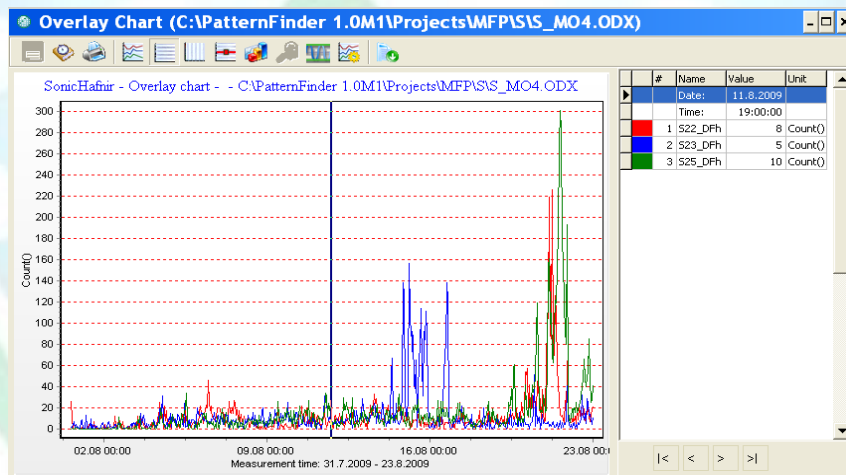


Figure 4.2.a Overlay detection frequency per hour

The overlay chart in figure 4.2.a is saved as S_ODFh.

Case study

Perform an Overlay statistics analysis, the results can be seen in the chart below.

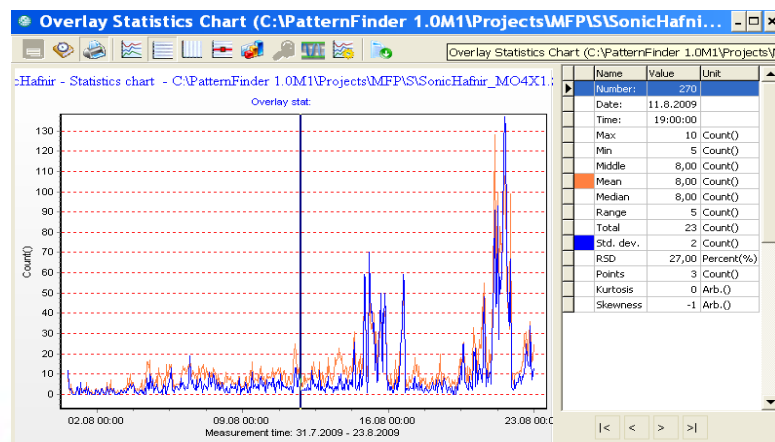


Figure 4.1.b: Overlay statistical analysis

The overlay statistics chart is saved as S_ODFh_X.

We extract the **mean value**.

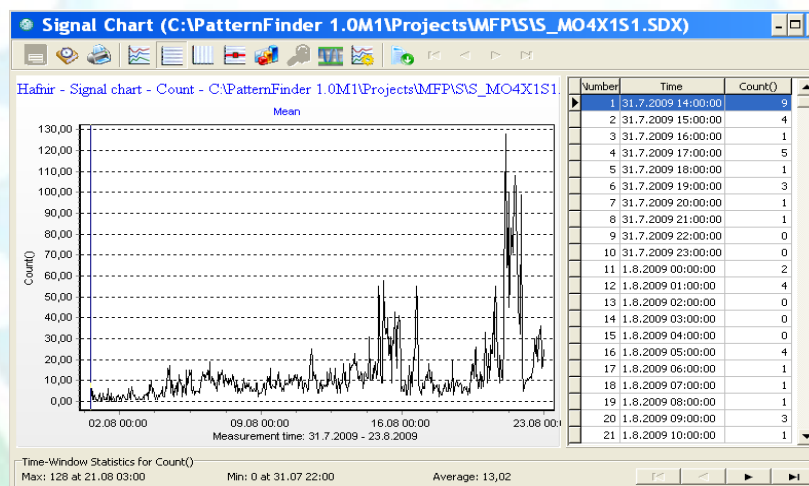


Figure 4.1.c Average detections per hour

The signal chart in figure 4.1.c is saved as S_DFh.

5 Detections duration comparison

5.1 Detections duration per minute comparison

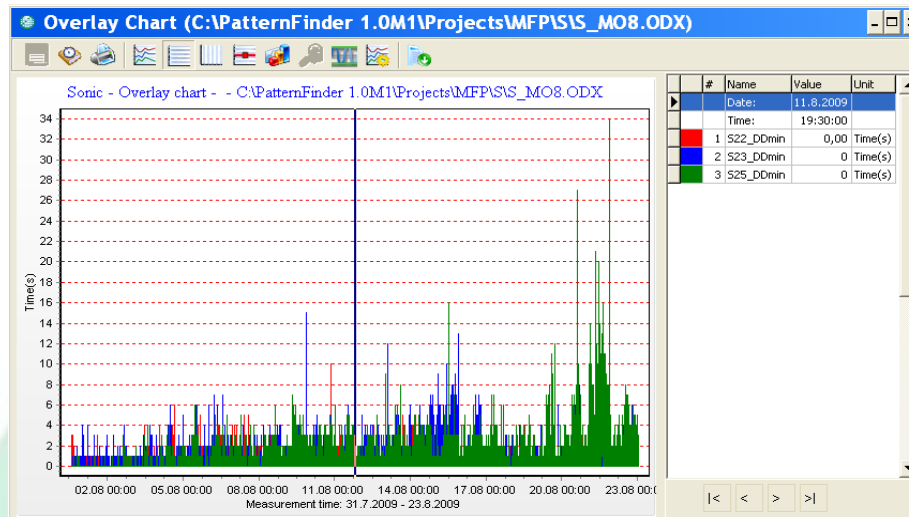


Figure 5.1.a Overlay detections duration per minute

The overlay chart in figure 5.1.a is saved as S_ODDmin.

Perform an Overlay statistics analysis, the results can be seen in the chart below.

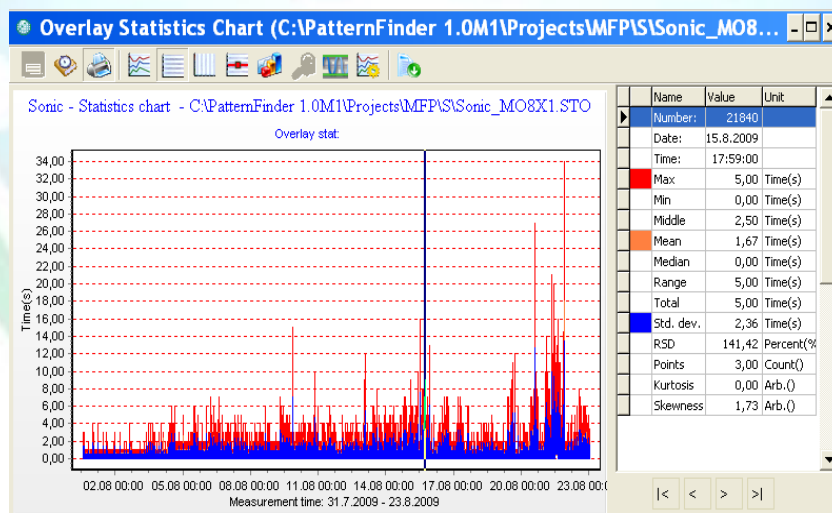


Figure 5.1.b Overlay statistical analysis

The overlay statistics chart in figure 5.1.b is saved as S_ODDmin_X.

Extract the mean value.

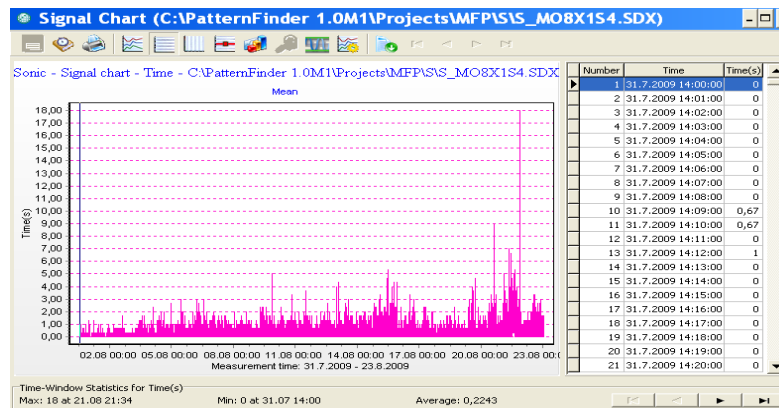


Figure 5.1.c Average detections duration per minute

The signal chart in figure 5.1.c is saved as S_DDmin_mean.

5.2 Detections duration per hour comparison

As can be seen in chapter 4, the variations are more visible when performing a statistical comparison on an hourly basis. We will therefore use the hourly comparison in the duration comparison as well.

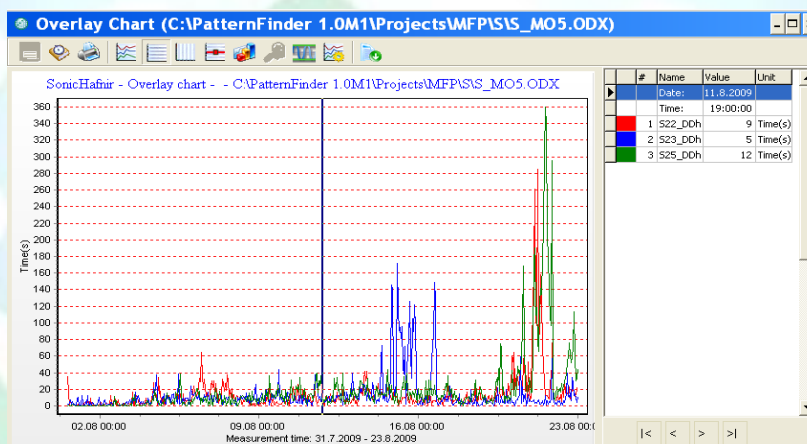


Figure 5.2.a Overlay detections duration per hour

The overlay chart in figure 5.2.a is saved as S_ODDh.

Case study

Perform an Overlay statistics analysis, results are shown in the chart below.

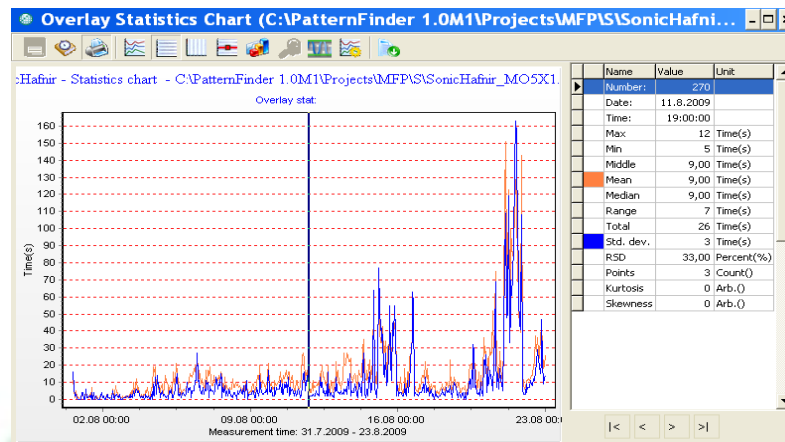


Figure 5.2.b Overlay statistical analysis

The overlay statistics chart in figure 5.2.b is saved as S_ODDh_X.

Extract the mean value.

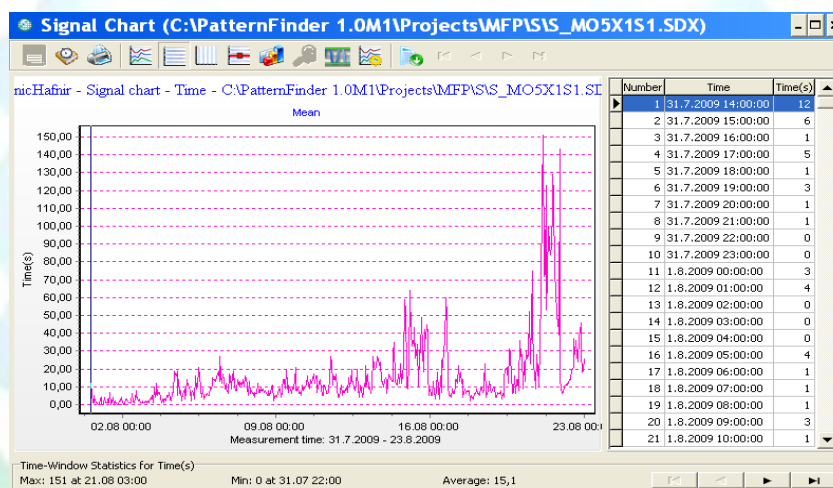


Figure 5.2.c Average detections duration per hour

The signal chart in figure 5.2.c is saved as S_DDh.

6 Sound reception selectiveness

We need answers to the following questions:

- How often do all the recorders detect sound simultaneously?
- How often does only one recorder detect sound?
- How often do only two recorders detect sound?

The detection duration is a good parameter to use as it allows us to visualize the duration as can be seen in figure 6.0.

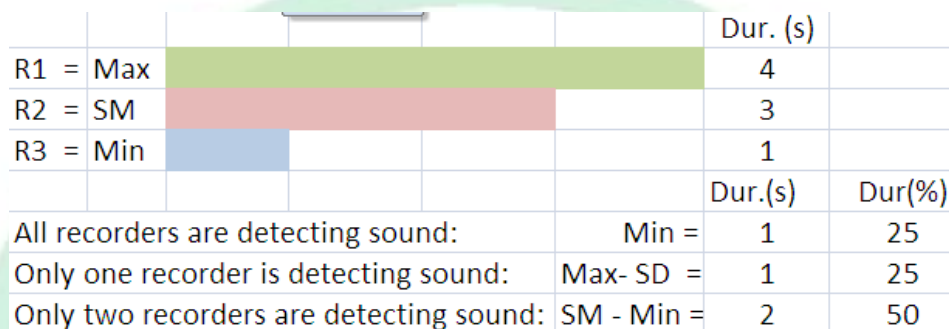


Figure 6.0. An example of how selectiveness can be estimated

All the statistical values are available in the overlay statistical chart, max, min and as there are only three signals the SM is represented by the median value.

6.1 Extracting the Max, Min and Median values.

As the detections duration overlay statistical chart, S_ODDmin_X, is already available, we start by selecting it and then extract the Max, Min and Median values as shown in figure 6.1

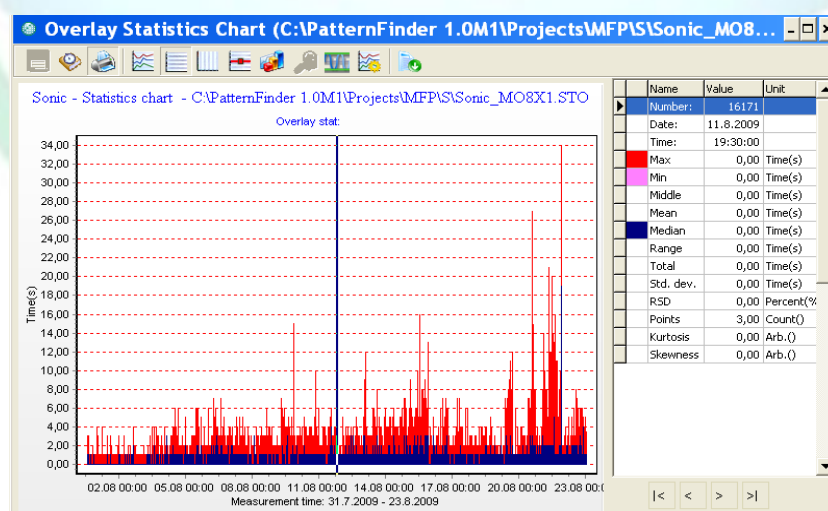


Figure 6.1. Max, Min and Median detection duration values.

The files are named S_DDmin_max, S_DDmin_All, S_DDmin_med.

The file S_DDmin_All will show us how often all the recorders detect sound simultaneously.

6.2 Find the “Only one” and “Only two” duration signals.

In both cases we subtract one signal from the other.

6.2.1 Find the “Only one”

First select S_DDmin_max and then select S_DDmin_med to subtract.

The result is shown in figure 6.2.1

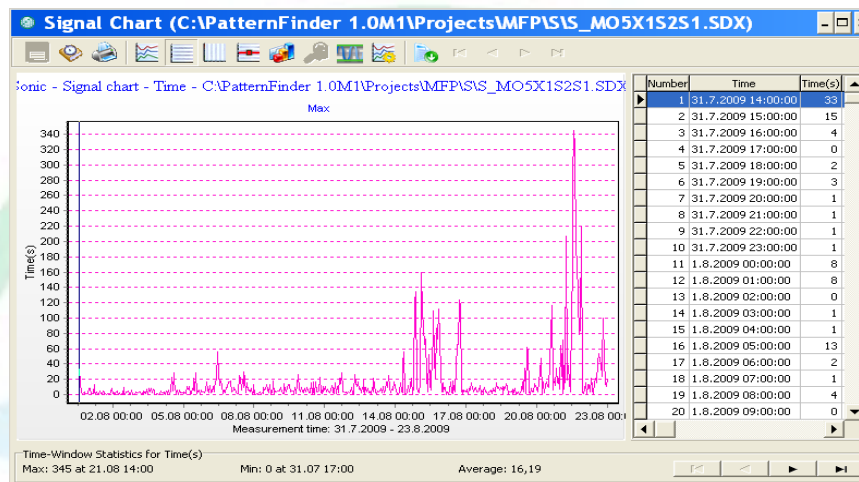


Figure 6.2.1. “Only one” detections duration

The signal chart in figure 6.2.1 is saved as S_DD_One.

6.2.2 Find the “Only two”

First select S_DDmin_med and then select S_DDmin_one to subtract.

The result is shown in figure 6.2.2.

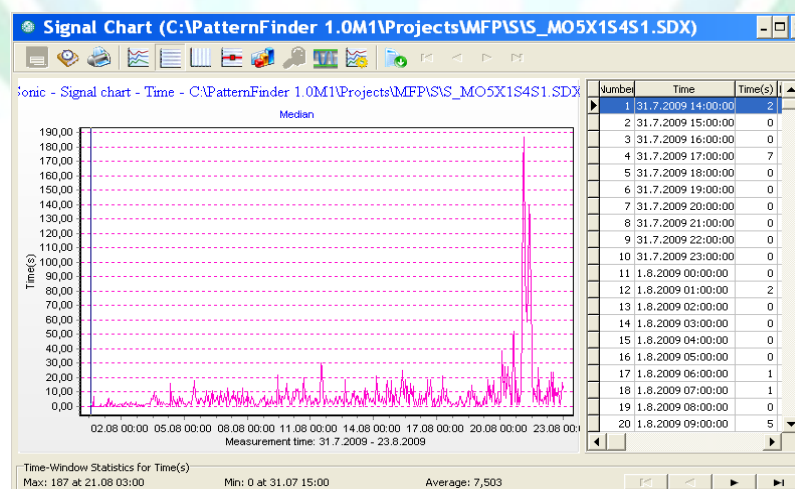


Figure 6.2.2. “Only two” detections duration

The signal chart in figure 6.2.2 is saved as S_DDmin_two.

6.3 Summarize “All”, “Only one” and “Only two” duration signals.

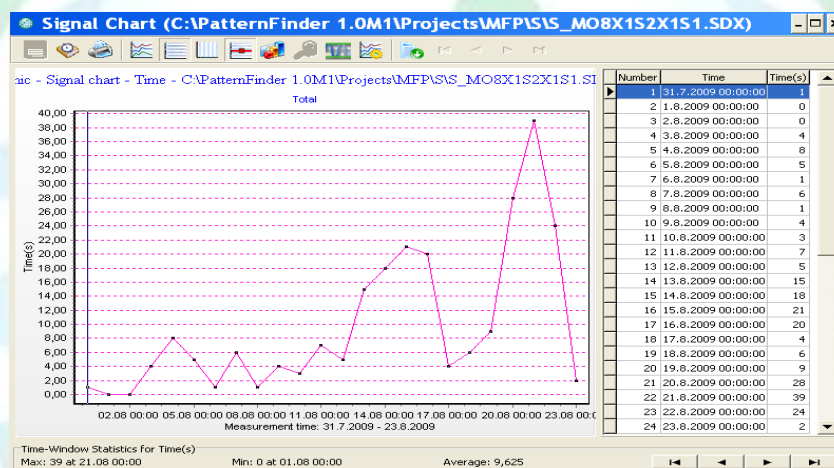
We have now found “all”, “only one” and “only two” duration values per minute. As we have seen previously, it is difficult to view signals on a minute interval and even on an hourly interval. We will therefore transfer the results to a daily interval.

We summarize the max minute duration signal as well and use it as the comparison basis in 6.4.

The four signals are processed in the same way. We use “All” to illustrate.

Select the S_DDmin_all signal and perform a Periodic statistics analysis. Select 1 day as the time-averaging period. The statistical chart is saved as S_DDmin_all_Xday.

Extract the total signal. The result is shown in figure 6.3.



Figur 6.3. “All” total detections duration per day

The signal chart in figure 6.3 is saved as S_DDmin_all_Day.

The other files are saved as S_DDmin_one_Day, S_DDmin_two_Day and S_DDmin_max_Day.

6.4 Convert duration signals to ratios of max duration.

We want to convert the values from “all”, “only one” and “only two” to proportional percentage values of the maximum detection duration.

We use the **Compare** option. Although its main function is to compare two signals against a level and give a true/false (1/0) result, it can also be used to find the ratio signal.

The three signals are processed in the same way. We use “All” to illustrate.

Select S_DDmin_all_Day and choose the **Compare** operation. Select the S_DD_max_Day signal to compare.

Select **Ratio** in the **Compare** pane and check “Larger values defines denominator”. The level options are irrelevant.

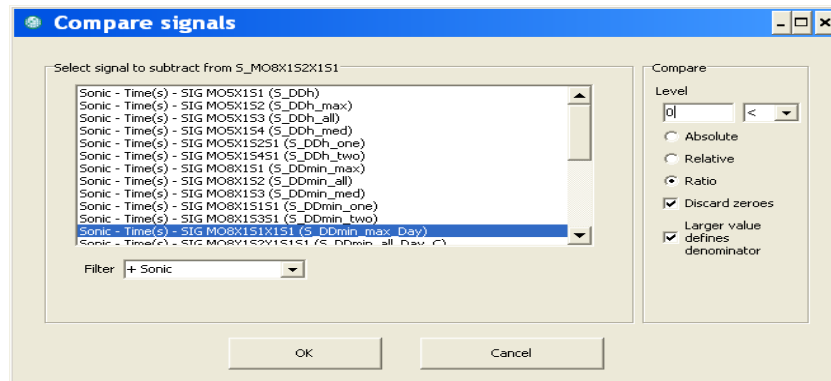


Figure 6.4.1.a Compare options

The result chart is saved as S_DDMin_all_Day_C.

Extract the **difference** signal from S_DDmin_all_Day_C.

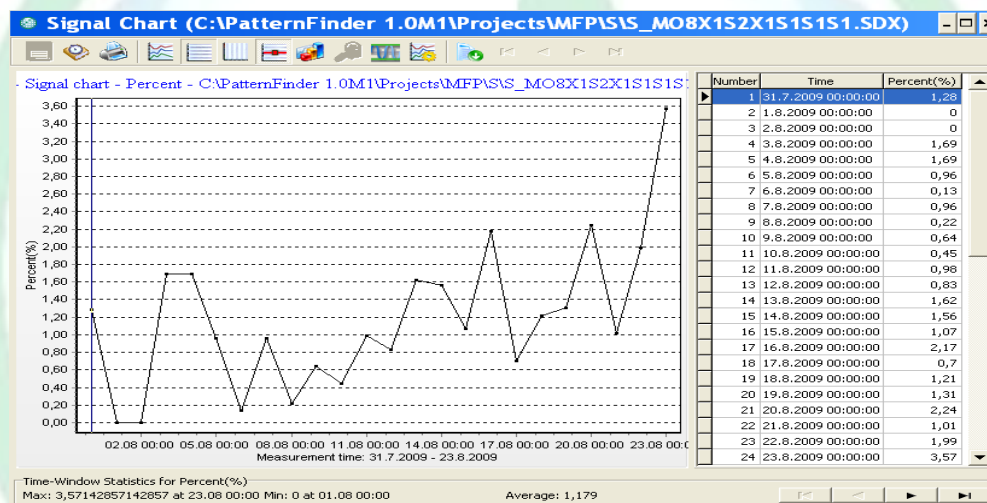


Figure 6.4.1. "All are detecting" duration ratio.

The signal chart in figure 6.4.1 is saved as S_DDmin_all_Day_%.

The other files are named in a similar fashion.

Results:

Detections Duration distribution

Name	Total	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s	11s	12s	13s
S22	6170	5362	624	126	38	13	2	2	0	2	1	0	0	0
S23	6221	5806	343	56	10	2	0	1	1	1	0	0	0	1
S25	8682	7391	958	251	56	22	2	1	1	1	0	0	0	0

Table R.1. Detection duration statistics

Detections Frequency and Duration

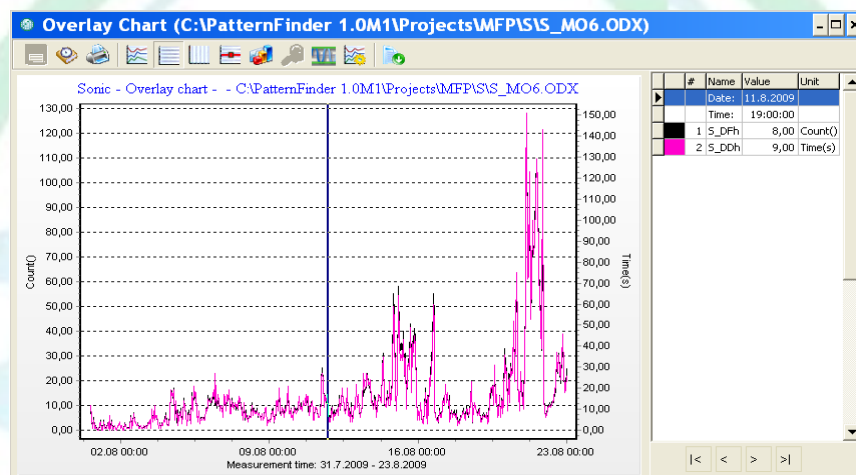


Figure R.2 Average detection frequency and duration per hour

The overlay chart in figure R.2 is saved as S_ODF&DD.

Evidently the detection frequency and duration go hand in hand as was to be expected.

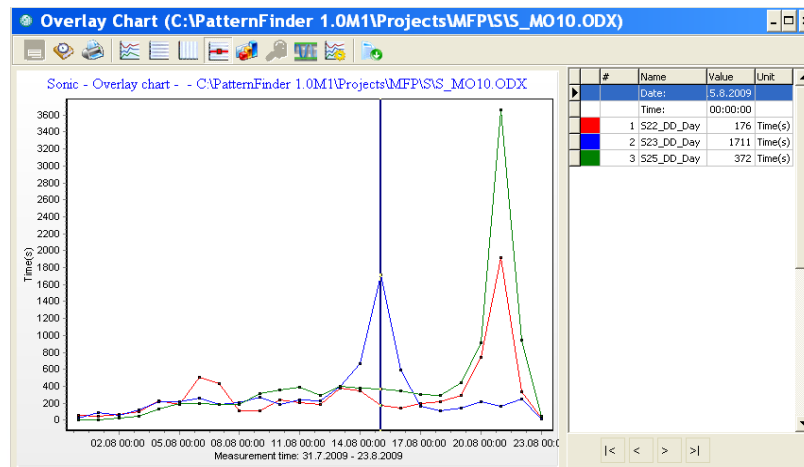


Figure R.3. Overlay of total duration per day, for S22, S23 and S25

The overlay chart in figure R.3 is saved as S_ODDDay.

Most of the time the duration is similar, but S25 peaks (3 days) while the other two are similar. 3 days later S22 and S23 peak (3 days) while S25 is “calm”.

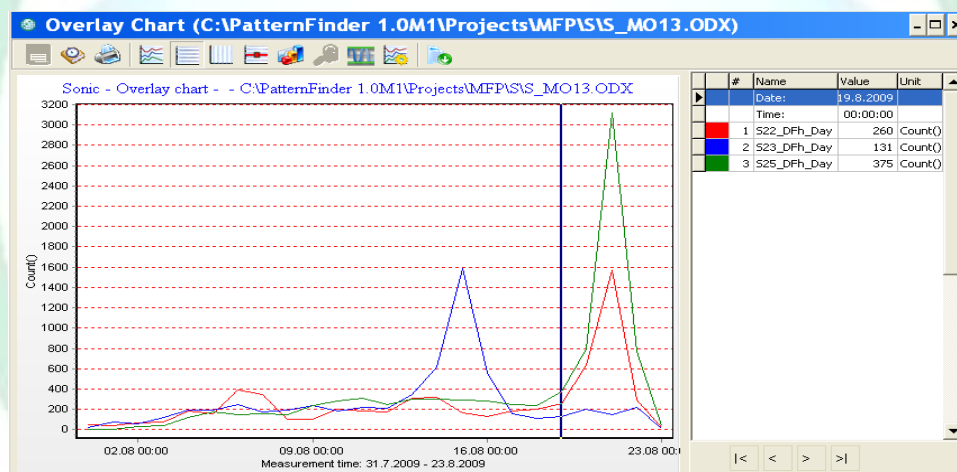


Figure R.4. Overlay of total detections per day, for S22, S23 and S25

The overlay chart in figure R.4 is saved as S_DFh_Day_O.

Detection selectiveness

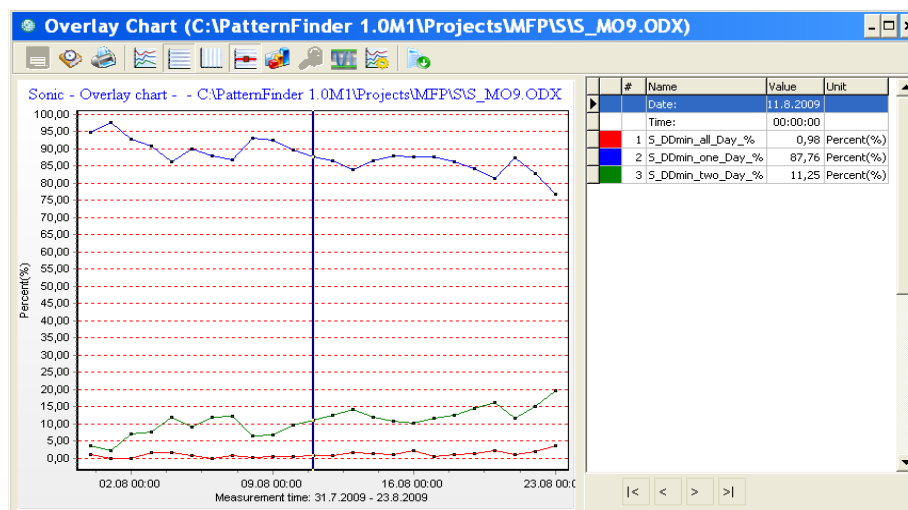


Figure R.5. Overlay of detection duration selectiveness between “All”, “Only one” and “Only two”

The overlay chart in figure R.5 is saved as S_DDmin_Day_OOneTwoAll%.

The selectiveness is apparent as “Only one” detecting sound is between 77-98%, “Only two” detecting simultaneously is 2-20% and “All” detecting at the same time is 0-4%.

By performing an overlay statistics analysis we see that the **Total** parameter lies between 99,99-100,01%.

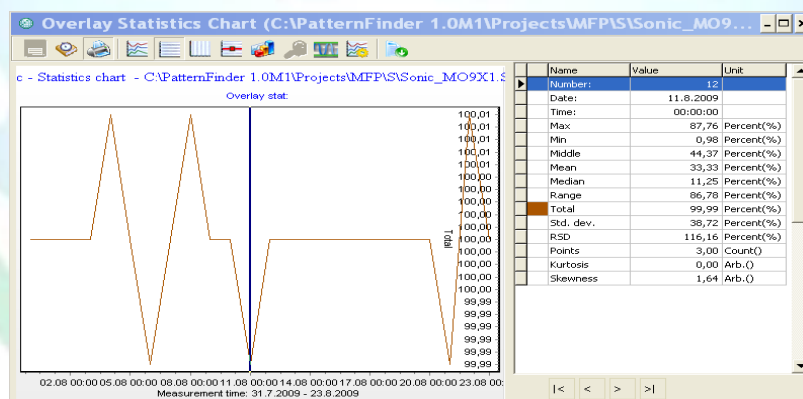


Figure R.6. Overlay statistics of S_DDmin_Day_OOneTwoAll%

The overlay statistics chart in figure R.6 is saved as S_DDmin_Day_OOneTwoAll%_X.

Case study

Daily detection frequency

Select S_DFh and overlay it with the “Daily” option.

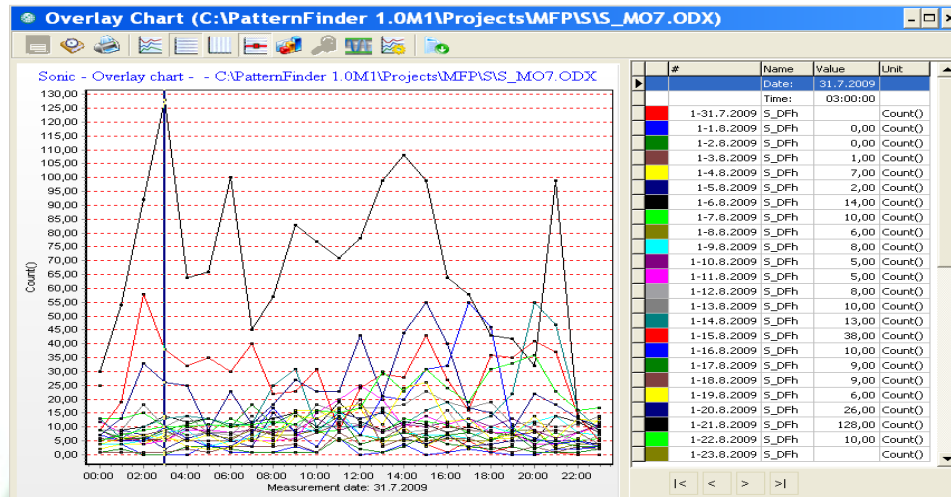


Figure R.7 Daily comparison of average detection frequency (per hour)

The overlay chart in figure R.7 is saved as S_ODF_Daily.

Perform an overlay statistics analysis.

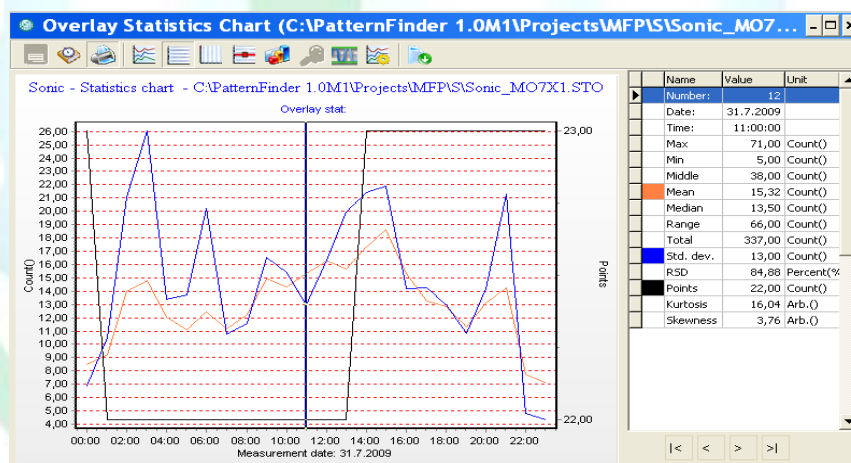


Figure R.8. Statistical daily overlay

The overlay statistics chart in figure R.8 is saved as S_ODF_Daily_X.

Extract the average value. The results can be seen in figure R.9.

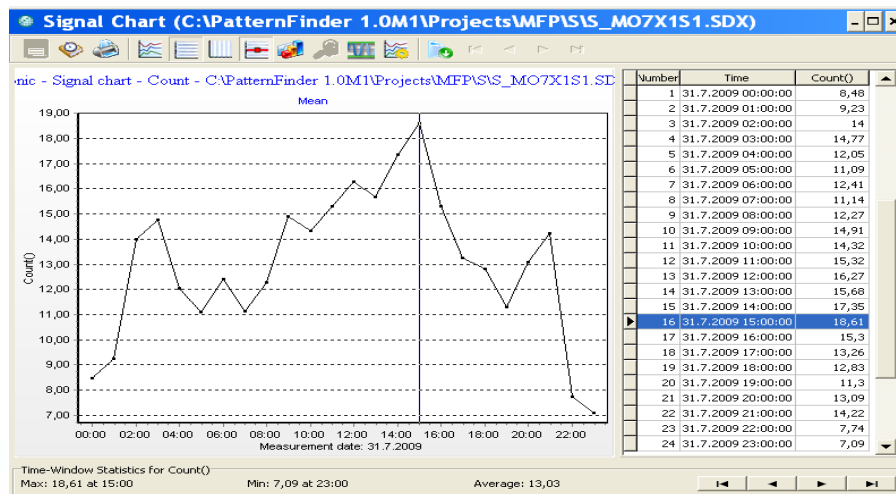


Figure R.9. Daily average detection frequency, detections per hour

The signal chart in figure R.9 is saved as S_DF_Daily_mean.

Discussion:

The accuracy of the method used to analyse the selectiveness is of concern.
Will the method work if applied over a larger period than a minute?

Finding the total detection duration over a 1 day period and then finding “all”, “only one” and “only two” using the same method yields the following results.

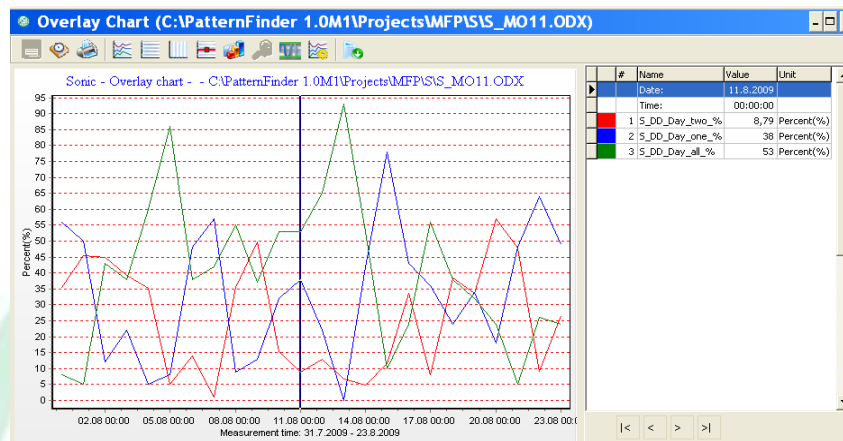


Figure D.1 Overlay of detection duration selectiveness based on a “from scratch” 1 Day comparison

Obviously there is little coherence between the “Day” comparison and the “Minute” comparison. It can be argued that this is normal as stretching the period will obscure the “at the same time” comparison.

References:

This case study is based on the research “[The role of sound production in Atlantic cod spawning](#)” which was conducted by:

Egill Guðmundsson, BSc Marine Biology

Timothy B. Grabowski, Ph.D.

