Visualisation for bioacoustics and ecoacoustics

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2022-08-15

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About

Bioacoustics and ecoacoustics are rapidly advancing multi-disciplinary fields of study that focus on how organisms communicate using sound, and the overall sound of a landscape (the soundscape). Despite the focus on sound, much of the communication of ideas, and even sounds, between researchers is done using graphical representations.

This should not come as a surprise, the printing press came centuries before the radio as a means for long distance communication, and ink on paper has a permanence that sounds would not achieve for a long time after the invention of writing. The current flourishing of these disciplines is driven as much by the low cost and ease of use of products such as AudioMoth and the decreasing cost of digitial storage and processing as by novel ideas.

Visualizations of acoustic data however are not going away - we are a predominantly visual species, and as ways of summarising acoustic data - or making the ultrasound tangible, they are powerful tools in the hands of the acoustician.

Chapter 1

Introduction

> "...while we take it for granted that sounds may be described visually, the convention is recent, is by no means universal and, as I will show, is in many ways dangerous and inappropriate."
>
> — Schafer [1977]

While Murray Schafer's *Tuning of the World* [Schafer, 1977] inspired many soundscape scientists, this view is of an earlier time, where the concept of multiple simultaneous streams of acoustic data being processed by a single individual was still an idea beyond the horizon. Individual sounds could be isolated and studied (as today they still are by bioacousticians interested in the behaviour of individual species). The scale of many contemporary ecoacoustics projects precludes an individual from listening to every minute that is recorded, the task no longer delegated to students but networks of machines.

Additionally, it is now useful to distinguish between two concepts that Schafer bought together under the concept of *notation.* Schafer used this term to bring together what is more typically known as notation – phonetics and musical notation – alongside visual representations of the physical properties of acoustic waves (amplitude, frequency, etc).

Historically both musical notation and phonemes have been used to describe the songs of various animals, however these methods do not scale to the entirety of the biological soundscape. There is after all, a great deal of the soundscape that is beyond the limits of human hearing, the infrasound, the ultrasound, and the quiet. All manner of information is gathered and shared by other species beyond the limits of our perception, and visualisation is the main tool by which we are able to interpret the entire soundscape. For all species that share it.

Chapter 2

History

2.1 Descriptive acoustics

2.1.1 Phonemes and onomatopoeia

2.1.2 Musical notation

Typical musical notation shows broad similarities with a typical audio visualisation familiar to all bioacousticians and ecoacousticians - the frequency against time plot. Time proceeds in a strictly linear fashion from left to right, and frequency is represented rising from bottom to top.

2.2 Analytic acoustics

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2.2.1.3 Frequency vs Time

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Patterns of activity

Lots of organismal activities are tied to the cycles of the day, and particularly in temperate zones, cycles of the year. These cycles bring regular fluctuations in light levels, day lengths, temperatures, and a host of other influences. Often these cycles interact, with the dawn chorus peaking in the early daylight hours, and it's timing and intensity fluctuating on a yearly cycle. This chapter looks at visualising these cycles, and additionally the effects of lunar cycles.

These plots are created using the SonicScrewdriver package [Baker, 2021] which in turn uses the suncalc package [Thieurmel and Elmarhraoui, 2019] to perform the required sun and moon position calculations. The Plotrix package [Lemon, 2006] is used for creating the visualisation. These packages can be installed as shown below.

```
install.packages(c("plotrix", "sonicscrewdriver"))
```

The SonicScrewdriver package must be loaded before constructing a visual.

```
library(sonicscrewdriver)
```

7.1 Daily Cycles

The use of the term *diel* for daily cycles has been contested by Broughton [1963] as being an incorrectly formed unnecessary neologism, it sees greater use (according to the online Oxford English Dictionary) than his suggested *nycthemeral*.

The design for these plots came from a desire to compare the dawn chorus at various locations around the UK, although they also offer great potential for comparing locations with greater longitudinal and/or latitudinal separation. The plots show the times of day, night, twilight (7.1.1), sunrise, sunset, nadir and solar noon. The day part of the plot shows the altitude (angle of the sun above the horizon) throughout the day, with the maximum value representing the sun being directly overhead.

7.1.1 The Types of Twilight

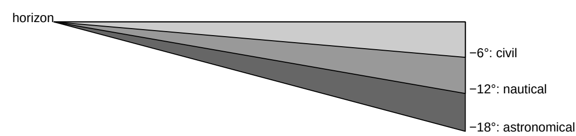


Figure 7.1: Different types of twilight as the sun sets below the horizon

7.1.1.1 Civil Twilight

Civil twilight occurs when the geometric centre of the sun (as seen from Earth) passes between 0° and 6° below the horizon. During this time it is normal for humans not to need the assistance of artifical light for everyday tasks.

7.1.1.2 Nautical Twilight

Nautical twilight occurs when the sun is between 6° and 12° below the horizon. During this time there is sufficient light to distinguish the horizon even without illumination from the moon (allowing determination of position at sea through star sightings).

7.1.1.3 Astronomical Twilight

When the sun is between 12° and 18° below the horizon many astronomical observations are possible even though some light from the sun is visible through the atmosphere. In urban areas with light pollution this is often considered to be a dark sky.

7.1.2 Diel Plots

As the times of the solar day are dependent both on the date and location these must be passed to the `dielPlot()` function.

```
dielPlot("2022-08-08", lat=53, lon=0.1)
```

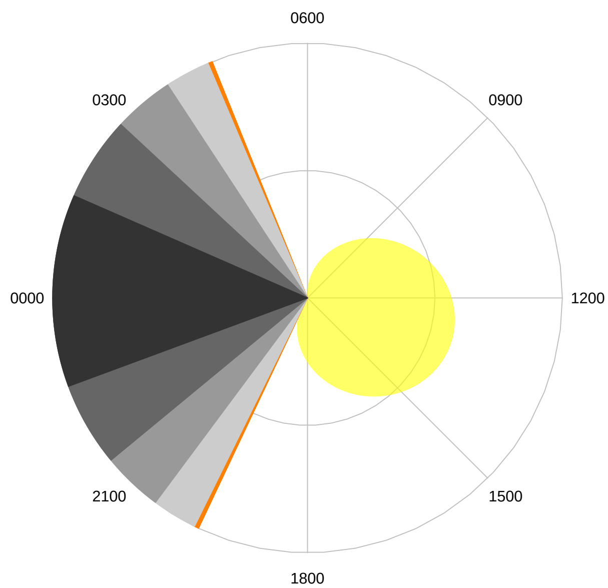


Figure 7.2: Example of a diel plot

7.1.2.1 Customising a `dielPlot()`

In addition to the `date`, `lat` and `lon` parameters to `dielPlot()` it is possible to make additional customisations to how the information is presented.

Legend

A legend can be added to the plot by setting `legend=TRUE`.

```
dielPlot("2022-08-08", lat=53, lon=0.1, legend=TRUE)
```

Plotting Components

The components that can be plotted are listed below. By default all are plotted except for `Solar Noon` and `Nadir`.

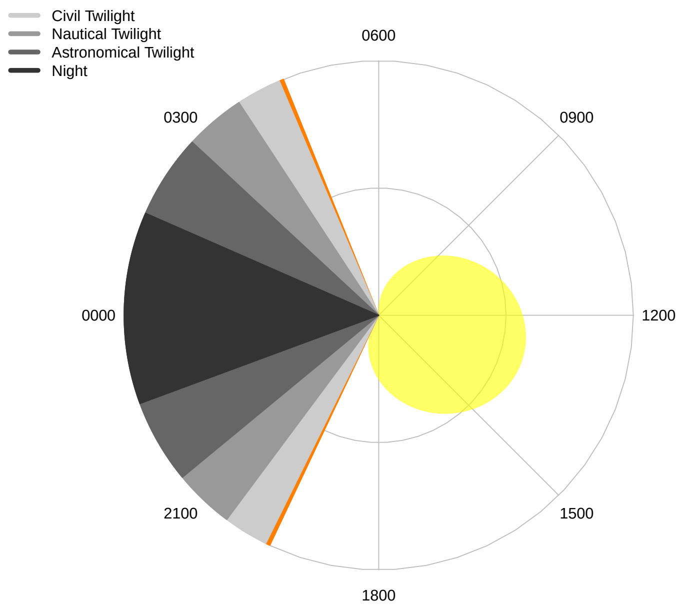
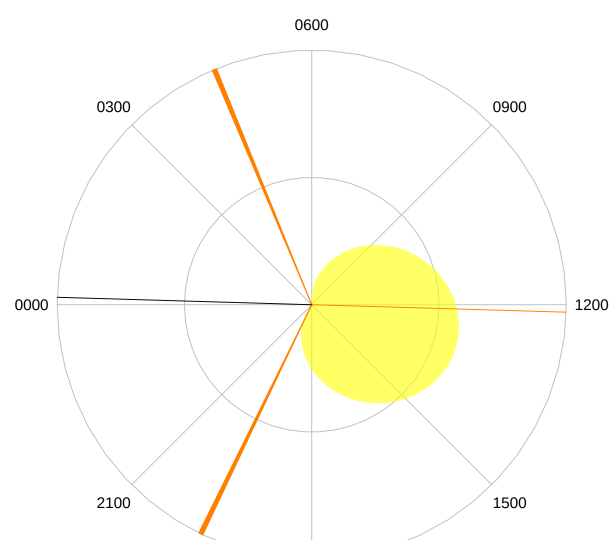


Figure 7.3: Example adding a legend to a diel plot

Name	Notes
Astronomical Twilight	
Nautical Twilight	
Civil Twilight	
Sunrise	
Solar Noon	The time when the sun is highest in the sky
Sunset	
Nadir	

The components that are plotted can be specified using the `plot` parameter.

```
components <- c("Sunrise", "Sunset", "Solar Noon", "Nadir")
dielPlot("2022-08-08", lat=53, lon=0.1, plot=components)
```



7.2 Yearly Cycles

7.3 Lunar Cycles

7.4 Core and ring plots

These visualisations for cyclical data plot their information onto a circle with radius of two units. It is possible to limit the plot either to the centre of the circle (a 'core' plot) or to the edge (a 'ring plot'). These alternative forms may be more useful when these plots are used to visualise addition variables (7.5).

```
dielPlot("2022-08-08", lat=53, lon=0.1, limits=c(0,1))
```

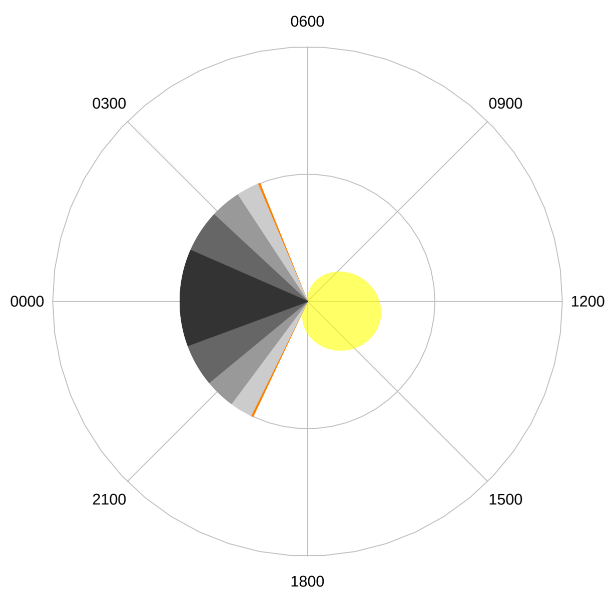


Figure 7.5: A 'core' diel plot.

```
dielPlot("2022-08-08", lat=53, lon=0.1, limits=c(1,2))
```

7.5 Adding data to the visualisation

7.6 Interactive Plots

These plots can be used to create Shiny apps

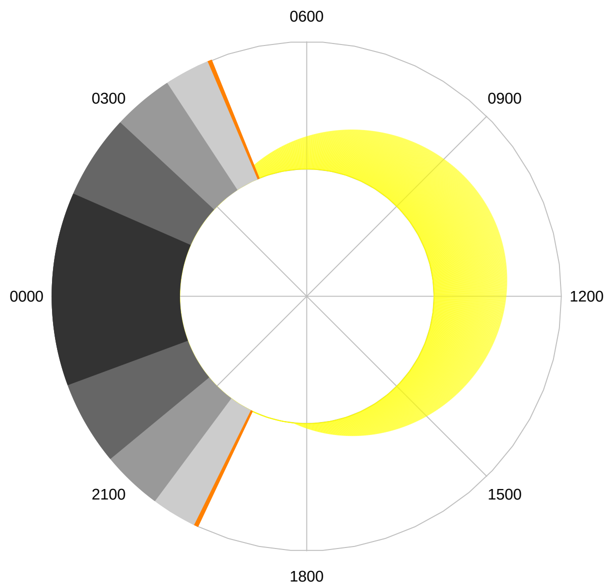


Figure 7.6: A 'ring' diel plot.

- shiny-diel is an example that shows diel plots for a number of locations, and can be animated using the play button under the date slider.

Chapter 8

Displaying annotations

Chapter 9

Shiny: Interactive Web Apps

Chapter 10

The Future

Chapter 11

Acknowledgements

For discussions around visualisation as part of the Urban Nature Project: Chris Raper, John Tweddle.

Bibliography

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