University of the Sunshine Coast

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Visualizing the soundscape of the calving grounds of the North Atlantic Right Whale

Abstract:

The key to this provocation is the spectrogram with its beautiful bands of colours. This image represents 44 days of recorded acoustic data which has been subject to false-colour imagery in the same way that satellite images are represented. The soundscape was captured to help ecologists understand the migration patterns of the endangered North Atlantic Right Whale. The spectrograms identify three dominant features of the ocean soundscape in the area of this sample (15 kilometres off the coast of Georgia in the centre of the whales' calving grounds): mechanical noise from passing ships; the night chorus of the black-drum fish (Pogonias cromis); and a mysterious third element, possibly caused by the cables that tether the hydrophone to the ocean floor strumming under the influence of strong tidal currents.

Biographical notes:

Dr Michael Towsey has held research positions at QUT since 1997. He graduated with a BScHons in biology (Auckland University, 1970) and completed a PhD in Computer Science (University of Queensland, 1997). Since then, the common thread in his research career has been to apply machine learning methods to solve biological problems. These have ranged from the sublime (analysis of bird song) to the ridiculous (analysis of milk yield in cow herds) with some bioinformatics in between! Since 2007, he has worked in the Ecoacoustics Research Group at QUT. He has worked on coding recognisers for iconic species such as the New Zealand Kiwi and the Australian Koala. More recently he has turned his attention to the problem of visualising and navigating long-duration recordings of the environment. The eye has a remarkable ability to synthesise large amounts of information at a glance, whereas the ear is limited by temporal constraints. Michael developed a technique to visualise long-duration recordings of the natural environment using false-colour spectrograms. THe technique can be used to visualise days, months, years of acoustic data with a surprising amount of detail. A surprising amount of detail can be seen in such images which span a day or more of recording. For example it is possible to identify the calls of individual bird and frog species even though the temporal resolution is only one spectrum per minute. The method can be used to visualise terrestrial, marine and fresh water recordings and for

continuous years-long recordings. When combined with automated acoustic analysis, these techniques promise a solution to the big-data deluge confronting eco-acoustics.

Leah Barclay is an Australian sound artist, composer and researcher working at the intersection of art, science and technology. She specialises in acoustic ecology, ecoacoustics and sound art through research projects that investigate environmental patterns and changes through sound. Her work has been commissioned, performed and exhibited to wide acclaim internationally by organisations including Smithsonian Museum, UNESCO, Ear to the Earth, Al Gore's Climate Reality and the IUCN. She composes complex sonic environments, immersive live performances and interactive installations that draw attention to changing climates and fragile ecosystems. Leah leads several large-scale research projects including Biosphere Soundscapes, an interdisciplinary venture exploring the changing soundscapes of UNESCO Biosphere Reserves and River Listening, which examines the future possibilities of freshwater ecoacoustics in collaboration with the Australian Rivers Institute. Leah is the president of the Australian Forum for Acoustic Ecology, the vice-president of the World Forum of Acoustic Ecology and serves on the board of a range of arts and environmental organisations. She is currently a research fellow at Griffith University in Australia where she is leading a portfolio of research in acoustic ecology and climate change.

Ginna Brock is a Lecturer in English and Creative Writing at the University of the Sunshine Coast (USC). Her PhD dissertation examined the extant Greek tragedies and proposed the philosophical concept that 'to be is to belong'. From this knowledge, Ginna explores the ramification of this belief both creatively and critically. She has developed a stage play which conflates the Ancient and modern worlds in an attempt to portray the universal and incessant need to belong and is currently compiling a poetic artefact that imagines present and future expressions of belonging.

Keywords:

Creative writing – North Atlantic Right Whale – Spectrogram – Anthropogenic noise – Soundscape – Ecoacoustics

Provocation

Michael Towsey

Context

The North Atlantic Right Whale (NARW, *Eubalaena glacialis*) is the most endangered of the large whales, with an estimated population around only 350 individuals. The main dangers are shipping strikes and entanglement in fish-nets. The species is typically monitored acoustically using ocean hydrophones to detect its calls. The recordings described here cover just 44 days in 2013 (towards the end of the calving season) and are part of a decade long study (Davis et al 2017). The recordings were made 15 kilometres off the coast of Georgia in the centre of the calving grounds, a region declared to be a "critical habitat" for the species. Far more audio is collected than can be listened to, so automated call recognition is essential. However, call recognisers give no indication of the larger marine soundscape in which whales are immersed.

For this study, we used an imaging technique known as long-duration, false-colour spectrograms to visualise, rather than listen to the audio (Towsey et al 2014; Phillips Towsey & Roe, 2018). This allows biologists to visualise long duration marine audio at multiple temporal scales, from hours, days, months, even to years. (The x-axis of a spectrogram is time and the y-axis is frequency. A spectrogram reveals the changes in the frequency composition of the marine soundscape over time.)

The Science

Our technique calculates acoustic indices (statistics that describe different features of the marine soundscape) at 30-second resolution and then combines the indices into spectrogram images, in a manner similar to false-colour satellite imagery. This technique reveals far more acoustic information than does a call recogniser searching for just a single whale species.

In order to visualise many days of recordings, we converted each of the 44 one-day spectrograms to a ribbon, 2880 pixels wide (two pixels per minute) and just 32 pixels high. By stacking the day length ribbons one on top of the other, marine biologists can see changes in the soundscape from hour to hour and from day to day (Figure 1). To help you orient within this soundscape, each ribbon starts at midnight on the left, passes though midday in the centre and finishes at midnight on the right. This makes it easy to identify the same time of day over the 44 days.

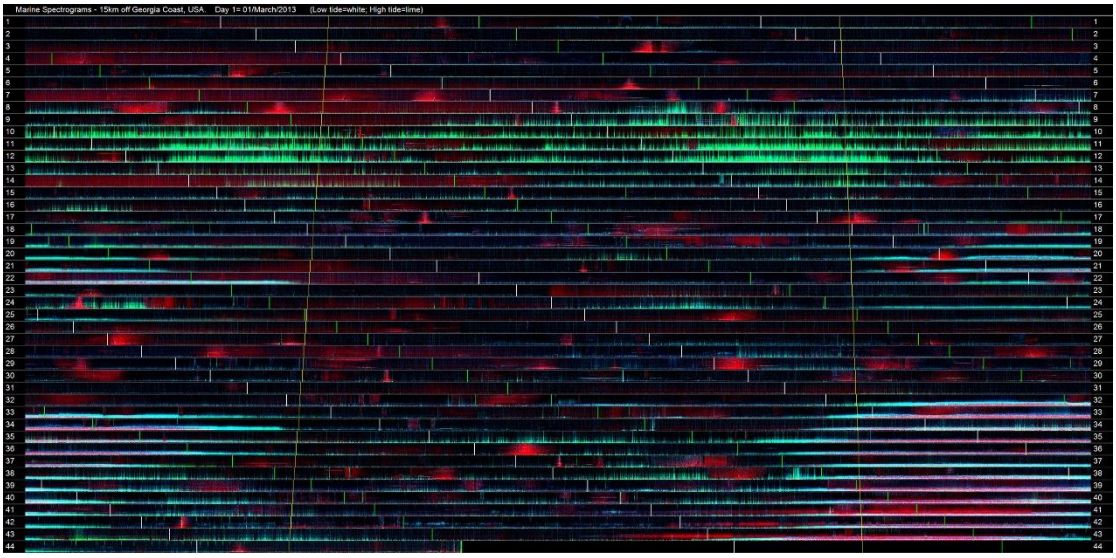

Figure 1: The Spectograph[i]

Interpretation

Three visual features dominate this image. Most striking are the pyramids of red, each one of which indicates the passing of a ship. Each ship has a distinct acoustic signature which facilitates its identification. Engine noises travel large distances in the ocean, and these whale calving grounds happen to sit within a busy shipping lane. A baby whale born in this part of the world is exposed to harsh, almost continuous mechanical noise from the moment it is born. This image vividly illustrates the reality of marine "noise pollution" (Brown 2015). Just like humans, whales suffer physiological stress when exposed to unrelenting noise.

A second dominant feature in this image (shown as pale blue stripes at bottom-left and right of the image) represents the night-time chorusing of the black-drum fish (*Pogonias cromis*). With appropriate adjustments to your listening software, black-drum chorusing sounds like a symphony of kettledrums. People lying in bed at night on the Georgia coast can listen to this symphony because the sounds travels through the water, under the beach and up the foundations of beach-side houses!

It remains uncertain what the third dominant feature is in this image (the green stripes through days 10, 11 and 12). Most likely it is of non-biological origin, possibly the cables that tether the hydrophone to the ocean floor, strumming under the influence of strong tidal currents. A useful feature of images such as this one, is that it can be overlaid with other information of interest. The curved yellow lines represent sunrise and sunset. The white and green ticks represent high and low tide. It becomes apparent that the “green noise” is dominant in between low and high tide when ocean currents and strumming effects are likely to be at a maximum. This is a useful reminder that sometimes, even with a “passive acoustic monitoring” technique, the act of observation changes that which is being observed.

In conclusion, the visualisation of soundscapes, whether terrestrial, marine or freshwater, is a very useful technique to understand the acoustic world in which animals live. It should be noted that a custom written NARW call recogniser did not find a single whale call in this 44-day portion of recording, presumably because it was late in the

season and the whales had started their migration northwards. If all you have is a whale-call recogniser and there are no whales, you are left with only darkness and silence. These visualisations are a great way to understand the oceanic sound world of the NARW.

Works cited

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Creative Responses

Creative Response 1

Soundscape Composition and Reflection

Leah Barclay

This image was amongst the first that attracted me to the incredible work of Michael Towsey and his false colour spectrogram techniques for long-duration field recordings. This image represents 44 days of ocean recording 15 km off the coast of Georgia, USA, in the calving grounds of the North Atlantic Right whale. Michael describes each horizontal ribbon as one day of recording, midnight to midnight. The yellow lines represent sunrise and sunset and the vertical tics represent low and high tide. The image does not display the individual whale calls at this scale, but it provides access to the overall acoustic world in which whales live. Each red swell in the image is a passing ship which immediately demonstrates the impact of anthropogenic noise in this environment. The image shows how sounds shift and change with tidal currents, such as the pale blue colour representing chorusing black-drum fish. What I love about this image is that we are looking at 44 days of complex scientific data, but it is immediately accessible and visually beautiful. It is a work of art in itself. I also love that I can show this to young children and they understand what is happening – they make comments about how loud the ships must be for the singing whales and wonder if they can hear each other as the ships pass by.

The ocean is a complex acoustic environment, where marine life is reliant on sound to communicate and survive. Sound is felt, reflected and absorbed in aquatic ecosystems. It propagates underwater at different speeds and is affected by temperature, pressure and salinity. The impacts of climate change are often very visible in terrestrial environments, yet dramatic changes in marine ecosystems are going unnoticed simply due to visibility. Increased anthropogenic noise and rising temperatures continue to cause unfathomable ecological disruptions that are dramatically transforming the acoustic ecologies of our oceans.

This image - a visualisation of scientific data - provides access to this world. It would not be possible to listen continuously to 44 days of recordings to understand the magnitude of ocean noise pollution, yet the red swells permeating through the 44 ribbons of sound make the impact extremely clear. Marine life live in a world of sound and vibration which is sometimes difficult to comprehend.

My creative response to Michael's image is an intuitive soundscape composition, inspired by the world of sound the image evokes[ii]. The piece draws on my personal hydrophone recordings from marine environments in Australia and the USA in locations that are major transitory points for whale migrations. The soundscape does not sonify the data or map specific time codes, rather it is an intuitive and artistic response. The piece draws particular inspiration from the red swells throughout the image and explores how anthropogenic noise is dramatically transforming the acoustic ecologies of our oceans.

Creative Response 2

'Paradise Disturbed'

Ginna Brock

I've always sensed you, underneath it all –
A lingering presence, a beckoning call.
Your vibrations thrum through the vast expanse
A low, deep cadence like a rhythmic dance,
Which twirls and plays, swirls and sways together –
Tidal undulations on a dove's feather.

The tenuousness of your subtle breath
Stills. And like a soldier facing death,
You ready yourself to persist, to stand
Against the onslaught of a sharp, quick hand,
Which seeks to squelch Eirene's eternal torch
And extinguish your light, only to scorch
Itself instead – dirtied, sullied, and stained.

You are silenced. Your calm voice drowned and strained.
You do not protest and always remain
Steadfast in your course. Machines mar your gift,
Undermine your presence and seek a rift;
    Turning virtue to vice,
Turning calm to clamour,
    Turning purity to pitch,
    Turning tranquillity to tumult.
These destructive machines, that thrive on noise
Intent on striking fear and chaos – poised
On the precipice of extinction,
Slip past the point of distinction.

And like that Ancient Mariner of lore,
We ‘have done a hellish thing’. Seeking more
Glory, more comfort only to ignore
The truth that lies at the incessant core.
And with your loss;
Tranquillity is lost,
Hope is drowned,
Despair abounds,
Chaos descends.

For a while cacophony prevails,
Discordance reigns and dissonance derails
Harmony. Unity denied and soiled.
It jars,
It crashes,
It clangs,
It roars.
In the wake of our anger it boiled
Over and coiled intertwined with greed,
Perfectly in sync with our toxic deeds.

Yet for all our folly, you persisted
Rippling through the currents of our twisted
Intentions – fluttering through the stillness,
Providing a pathway for tranquilness –
A serene surging, like an opened seed,
Urging our selfishness to recede.
A momentary treaty,
An attempted arrival,
A conscious effort,
A trembling hope.

And then you return, when the roar subsides
The jarring fades and your calm resides
Once more, echoing through the pervasive
Caverns. You settle, weary and pensive.
We've come to understand how extensive
Your depths and how great the need to stabilise
Your existence. We claim that we are wise.
Little did we know, you did not return whole,
A little fractured,
A little hesitant,
A little wary,
A little forlorn.
And we vowed to make it right, to undo
The damage and pain that we have brought you.

And for a time, all is calm, all is bright,
Your presence again brings a soothing light.
And we rest for now in your deep embrace
The thoughts of your absence we try to erase.
The undulations return. You now soar
Differently through the vibrations off shore.

Exegesis

Michael Towsey

Response to Leah's soundscape and her written commentary:

I listened to Leah's soundscape before reading her commentary so that I would have no preconceptions. I only knew that it was a response to false-colour spectrogram images that I had produced from 44 days of marine recordings taken at a depth of some 15m, 15 kilometres off the coast of Georgia, USA. The recordings were originally made as part of a research program to monitor the North Atlantic Great Right whale. No one can listen to 44 days of recording, hence the value of being able to produce a visual summary.

There is growing concern about the amount of noise pollution in the oceans of the world, and my images of the marine soundscape off the coast of Georgia help to illustrate just how noisy the world is into which a young whale calf is born. It sets one's nerves on edge.

Perhaps it is no coincidence therefore that Leah's soundscape begins in silence and ends in silence. Within a few seconds however, one is bathed in the relaxing world of gentle swirling currents and water bubbles. The world that some lucky children experience snorkelling in rocky pools.

And then the first whale calls and the soundscape immediately becomes vast and deep. But it is still a paradise of sound.

By the end of the second minute of Leah's soundscape, one senses that something is not quite right. A deeper ominous sound, subterranean, that is growing gradually in strength. The occasional whale call can still be heard but other scratchy sounds are intruding. One holds one's breath and eventually the leviathan passes. Quiet is gradually restored but it is not the same kind of gentle peace that one remembers from the beginning. More like the sounds of a deep exhaustion.

The message in Leah's soundscape is clear. No need for words.

Response to Ginna's poem, 'Paradise Disturbed':

On my first reading of Ginna's poem, I felt parallels to Leah's soundscape. First there is peace (represented by Eirene, the Greek goddess of peace) and the profound stillness of the deep ocean. Then there is disturbance created by the passing of many ships ("destructive machines, that thrive on noise") which rend the marine soundscape. And eventually a kind of peace returns, but it is a peace which is a "little fractured", hesitant, wary and forlorn".

The title of the poem is an obvious reference to Milton's "Paradise Lost" and it offers us further insight into Ginna's poem. Just as Milton tells us that the woes of humanity are brought about by disobedience to the word of God, Ginna tells us that the destruction of nature is the result of humanity chasing "glory" and "comfort", while ignoring "the truth that lies at the incessant core" of the natural world (the paradise) in which we live.

One thought that occurred to me, however, towards the end of Ginna's poem, is that humanity is not trapped eternally in original sin. The fact that so many scientists have devoted their lives to fathoming the secret lives of whales and that so many artists, poets and musicians (such as Ginna and Leah) have communicated the emotional depth of this story, tells me, at least, that humanity can escape from original sin. But it will require us to listen to the sound of the cosmos and the depths of the ocean.

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[i] View a larger file of the spectograph (<IMAGE.png>) by copying and pasting the following link into your web browser: https://drive.google.com/drive/folders/0BzcDaJjOMWNgbjhadEJoZllRVUk

[ii] Please listen to the ecoacoustic recording (<SOUND.wav>) at the following link, by copying and pasting the following link into your web browser:
https://drive.google.com/drive/folders/0BzcDaJjOMWNgbjhadEJoZllRVUk