Basic Course in Ornithology
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Lecture -14
Vocal Behaviour: Mechanisms (Part 1)

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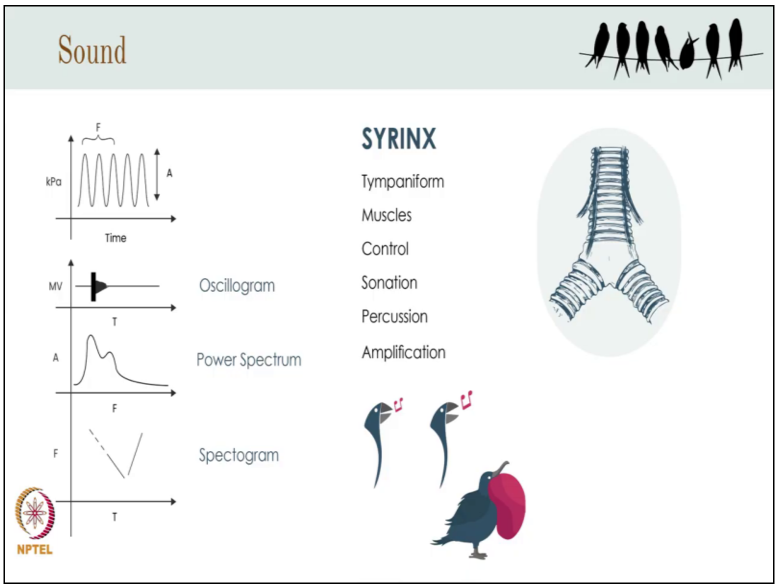

Hi everyone! So, today I am going to be talking to you in today's lecture about sound and the role that sound plays in a bird's life. So, song in particular and the calls that birds produce and Manjari and others are going to take this forward. Manjari starting at the second half of this lecture to explain what the role of sound is and what birds actually use it for and the way sound is controlled and propagated.

But I am going to talk about the business end, how sound is produced and how we measure sound. How we measure sound is intuitively easy to everyone. Before we talk about that let us talk about what sound is. Sound is a traveling pressure wave in air or in water or in many others.. any other substances. But for the purposes of birds and ornithology, we will talk about air because that is where most birds vocalize all right.

So, what is sound? Sound is a traveling pressure wave that in air travels at roughly 338 meters per second and it consists of alternating compressions and rarefactions. So, as I am speaking a pressure wave a compression originates here travels outwards behind it there is a region of low pressure and then another pressure wave and then another pressure wave and they ripple outwards.

Think of a ripple, a stone being dropped into water and ripples spreading outwards that is the kind of pressure wave we are looking at. If you assume that I am a point source of sound, I am not because then sound should radiate equally in all directions around me it doesn’t. Most of my sound is going forward towards you or rather towards the webcam that I am recording this on and it forms a beam within which these pressure waves travel.

And if you have an instrument that can pick up these pressure waves either your eardrum or the condenser membrane of your microphone that vibration is transduced into voltage either by our neural systems or by the microphone itself and that is what we measure as a sound. Now like any pressure wave if you were to look at sound here are these traveling pressure waves okay these are the traveling pressure waves of sound.

You can see pressure because I measured the pressure here and there are three important properties of sound that you should know. One being obviously time. Sounds can be short durations such as if I say ‘aa’ or long duration as if I say ‘aaaaa’ and that is reflected in the pressure waves that you see. The second thing to remember is how tall this wave is. This is the amplitude of sound or the loudness.

If I were to speak softly, you probably can't hear me but if I speak loudly, I am much more audible, because the amplitude or the pressure itself changes. The third thing to remember is how many of these cycles occur per second, that is the frequency. We perceive frequencies as differences in pitch. So, a sound that goes is ‘awwww’ lower in frequency than a sound that goes ‘aaaa’ which is higher frequency.

If we measure this and transduce this into voltage as a microphone does, you get a raw trace of sound that is this the voltage recorded on your microphone versus time on the x-axis. And you see the voltage fluctuates here. This is what we call an oscillogram or the raw voltage trace of your microphone. How can you identify the properties of a sound from there? Well, you can take a little slice of this sound and perform what's called a Fourier analysis on it.

Never mind the math of a Fourier analysis. Fourier analysis will basically give you the amplitude versus the frequency. So, you can see that this sound has high amplitudes at some frequencies but not at others and this representational sound is called a power spectrum/a Fourier power spectrum, it shows you how much power exists across all the frequencies. Now, let us take that power spectrum, take many of these for each window many different power spectra and put them all together.

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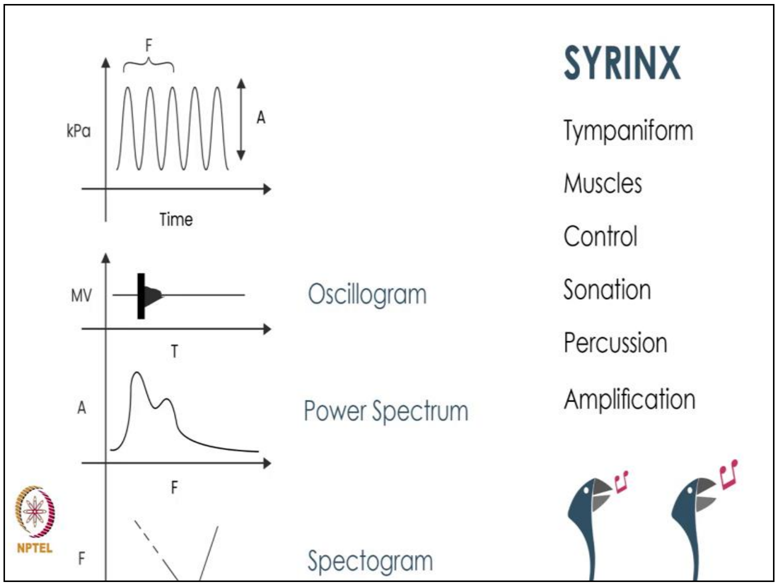

What you get is frequency on the y axis now, let us flip them this way, time on the x-axis and the louder or the higher more the more the darker the sound is represented here, the louder it is. So, you get frequency, time and amplitude all on one plot and this plot is referred to as a spectrogram. You will find these often-called sonograms in many places the term sonogram and spectrogram is used interchangeably. Sonogram refers specifically to a sound that is why you use them but the correct term (in engineering terms) is a spectrogram because any signal can be represented as a spectrogram not just a sound.

And the shape of a spectrogram will tell you a lot about the sound. If you look at this first note here that I have drawn frequency is decreasing with time, if it was a whistle, it would sound like

‘Phww’. This one goes up, it is ‘‘wwhht’. These are what you call frequency modulated or FM notes, the frequency is changing with time. Sometimes the frequency does not change with time like so, then you get a constant frequency note like ‘wwwww’ constant frequency notes.

Remember that if I were to ask you to interpret a spectrogram remember what the frequency is. Is it an FM note or a constant frequency note? Is it something more complex? Some notes can have inflections if these this can be one note it will it goes all as ‘Phwwhht’ one note. So, learn to interpret notes by staring at spectrograms and you can actually read what a sound looks like graphically. And this is the most common analytical method that most people use to study birdsong because from this you can calculate which frequency has the highest amplitude relatively speaking the ‘peak frequency’.

You can calculate what the highest frequency of a sound is and the lowest. You can calculate what the frequency is at the beginning and the frequency is at the end and thus each note has a unique set of parameters that can be used to describe it. You can also use the duration - the time parameters, you can use the time at which it reaches the peak frequency. You can in some cases use the interval between notes within a song.

And these are things that you are going to hear about a lot more in subsequent lectures. So, now you should have a functional understanding of how to read sound from a pressure wave all the way up to a spectrogram that tells you how a sound is structured. But that is not all that is relevant to studies of sound or what you call bioacoustics. The physics principles that underlie bioacoustics go a little further. You have to think how is sound produced? How do we produce sound?

Air moves over our vocal cords, the vocal cords vibrate, they set the surrounding air in vibration and that is how you get sound, that vibration travels out. Sounds pretty simple. But birds do not have vocal cord. Our vocal cord is in our larynx it is up here. Birds actually have their voice box a lot lower down. The bird voice box is called the syrinx. And the syrinx is something that is present a lot lower down.

In many species, such as ducks and geese and others, it is present here you can see this blue thing. If you see the blue thing over here this is the trachea, the wind pipe which bifurcates into bronchi that goes to each lung. Now some birds have the syrinx in the trachea, there are other birds that have the syrinx in the bronchi. Now note, if you have your syrinx in the trachea you have only one vibrating structure but if you have your syrinx in the bronchi you have two and they can be controlled independently of each other that is an important thing to remember here.

Most songbirds and you are going to hear a lot about songbirds going forward have what is called the in red here the tracheobronchial syrinx.

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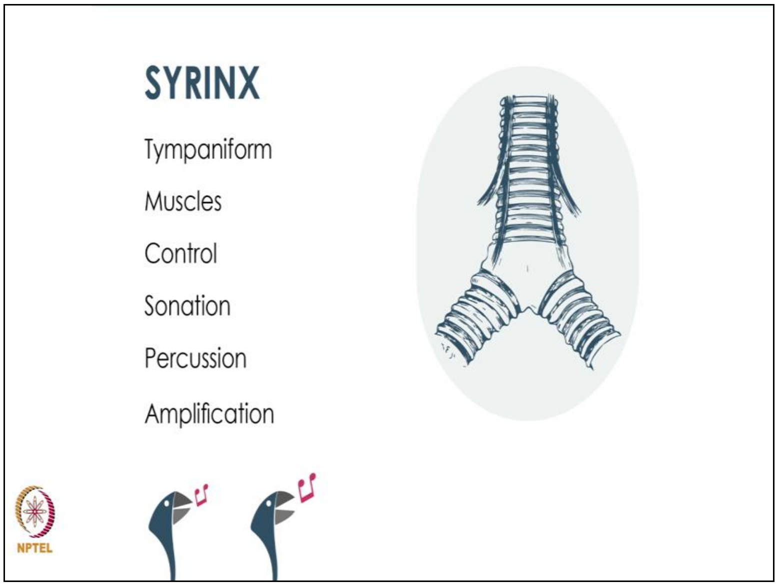

This entire area is highly modified to contain a bunch of valves and a bunch of membranes that they can set into vibration when air pressure forces them to. So, whenever air pressure builds up, they pop open and shut and force membranes into vibration and that is how you produce sound. The trachea or bronchial syrinx can also have both sides controlled independently. How do they do this? To do that let us talk about the anatomy of the syrinx a little bit.

Syrinx consist of what is called a tympaniform membrane, that is the vibrating structure. The tympaniforms are what sets the air in motion. The faster they vibrate the faster the air goes into vibration the higher frequency your sound is. All right. For them to vibrate faster think of a guitar string if you want to get our string to vibrate faster it has to be a really high tension, all right, what puts them in this tension? what causes the membrane to go into this tension?

You have muscles that pull things apart and pull valves in place and force the membrane to buckle. So, the muscles/the syringeal muscles which are heavily modified muscles that are attached and found only in birds cause the membrane to buckle into the path of the air in response to high pressure or in response to a command from the brain and this air sets the membrane in vibration.

The bird song production is controlled by the midbrain. The midbrain sends a command to the syringeal muscles which contract cause the membrane to buckle into the path of the airflow the membrane vibrates and the bird produces sound. The song control system is a very complex, one aspects of this are learnt other aspects are innate to the bird it does not learn them. You will hear more about this in subsequent lectures.

But fundamentally, in the from the physics point of view you have just got to set a membrane vibrating at the frequencies that you want and the muscles adjust how much this is able to vibrate to produce complex sounds. Important point to remember, the muscles on either side can be controlled independently. So, birds can not only breathe with one syrinx while singing with the other they can also control their syringes

so fast that they can take mini-breaths in between notes, that is one of the reasons birds are able to sing for so long and finally birds can do something else that is really cool. They can produce combinations of notes with each of the two syringes and that is how you sometimes get two notes that overlap in space. Now, most bird songs and indeed most biological songs are what you call harmonic. So, if you see a sound like this, it will have a second band usually at 2x at 3x and 4x where x is the frequency of the sound and those are called harmonics.

Harmonic sounds are in an inherent property of biological sounds because they are produced by vibrating membranes. The way they produce all biological sounds will have these harmonics. But if you see a sound overlapping this one that is not at 2x that is at a different frequency that is not a harmonic it was probably produced by the other syrinx. Sometimes the same note can be produced half by one syrinx and half by the other.

Cardinals have a note that looks like this but actually half of it is produced by one syrinx and half by the other. If you block the left syrinx this disappears, if you block the right syrinx this disappears. I might have the exact terminology wrong but the principle remains the same. One syrinx control one half of the note and the other syrinx seamlessly integrates to produce what looks like a smooth note but is actually a very complex note produced by both the syringes and that is something that can only arise if you have independent control.

And that is a feature of bird syringes and bird sounds that almost no other organism possesses. We certainly do not, we have one vocal cord most other animals also have one vocal cord. The bird vocal anatomy has undergone massive specializations that allow it to do this and to actually carry out these functions. But birds do not just produce sounds with their bills. Birds can do a number of cool things to produce sounds.

One of the most common other ways in which birds make sound is something called sonation. Sonation is a phenomenon where some parts of the bird particularly the feathers clack together and produce sounds. Sonation can be as common as the beating of a pigeon's wings - pigeons clap their wings when they are taking off and when they are in displays. The whirring sounds of certain birds’ wings when they take flight.

They make little ‘whrrr’ sounds when they take flight which are also an example of sonation and they can get to as exaggerated and extreme as the rattling noise of the Lesser Florican when it jumps. Every time a Lesser Florican does its famous jumping display it makes a rattling noise that is because of its feathers striking together at high speeds. The most extreme example of this is a bird called the Club Winged Manakin in South America. It raises its wings behind its head and vibrates them as many as several hundred times a second against each other and these are special modified feathers.

So, when they vibrate, they make a noise that goes like ‘kee kee’ (you can find this on YouTube if you are interested). But that is an extreme example of what birds are capable of with sonation. Other birds make clicks, snaps, buzzing noises, all without using their syrinx. The other kind of noise that is very common among birds is percussion. Percussion is what happens when one surface strikes another like I am about to do right now that is a percussive noise (by knocking on the board) drum drum… birds are capable of this too.
Stork for example do not have a syrinx, they cannot actually make vocal noises but they clatter their bills this is a percussive noise. The other kind of famous percussive noise can be used done using an external object. So, Palm cockatoos will find a stick and a hollow log and they will go ‘dhak dhak dhak dhak dhak’ with that, the sound can carry a great distance and that is a percussive noise. You are probably familiar with the drumming noises that woodpeckers make on trees that is also a percussive noise.

And woodpeckers actually select trees that amplify these drumming noises. Just like a drummer does selecting the kind of drum he or she wants to make the kind of sound they want to make. One of my favorite woodpeckers is the Northern Flicker which has a tendency to land on tin or metal roofs and go ‘darank’ because nothing is more percussive than the sound of something hitting metal at high speed and that noise can carry a great distance.

So, birds are capable of very interesting processes when they make percussive sounds. Now production of sound is just one step, if you have a thin membrane vibrating in the air that in itself is not going to produce the kind of sounds that are going to carry all the way to say a webcam or hundreds of meters is in the case of several birds. So, after producing a sound you need to amplify it and birds have many ways in which to do that.

The most important physics phenomenon here to understand is resonance. The bird's vocal tract has a certain resonant property at a certain frequency it will vibrate with a much larger amplitude and the sound booms out. So, because these birds vocal tracts have different resonant properties and these resonant properties impact, how the sound is produced, birds have a number of adaptations that can actually change and amplify the emitted sound.

So, that's what we are going to talk about on an evolutionary time scale. You can evolve fixed ways of resonating and amplifying a sound that works really well at producing loud sounds but it doesn't work so well when it comes to being able to change your sound on the fly. So, ducks etc have a big swelling on the side of their syrinx called the bulla, bulla which resonates and amplifies the sound.

Other birds increase the length of their trachea because as you know the resonant frequency is related to the length of the column that it is resonating in. So, some birds do that. The other way evolutionarily to change the sound that you produce is to change your size because that also changes the resonant properties of the vocal column and therefore the properties of the emitted sound. But these like I said are fixed they do not give the bird a lot of flexibility.

There are other ways to change the resonant properties of your vocal tract. One is to open your mouth and sing wider that allows you to change the resonant frequency of your vocal tract and birds that do this often sing at higher frequencies. So, if you look at this bird when it opens its bill wider the higher frequencies come out stronger and when it opens its bill less, the lower frequencies come out stronger.

The other way to do this of course is to have a vocal sac. This is a magnificent Frigatebird, a bird that makes these courtship sounds by inflating an air sac and then making this 'thaar thaar thaar' noise that resonates because of the vocal sac. Barbet and many other birds also use vocal sacs to amplify the sounds that they produce and poop them out into the world. Perhaps the most extreme example of this is the Kakapo, a flightless parrot in New Zealand.

It inflates itself up with air, sits in a shallow bowl in the ground and then rushes all the air out at once in this boom and this boom also booms out so it is not just the air sac that acts as a resonator

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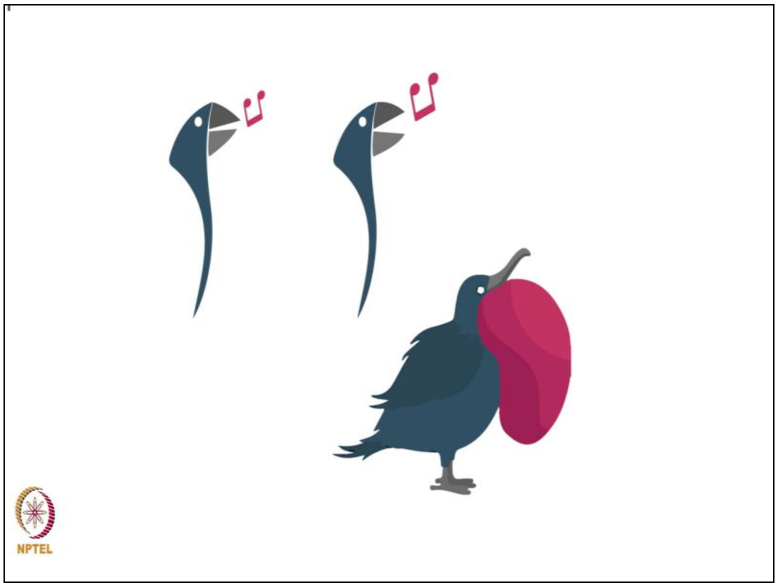

but the bowl structure that it does it in also acts as a resonator and amplifies its sound such that it carries more than a mile. So, using a number of strategies both evolutionarily and behaviorally, birds are able to amplify and change the properties of the sound that they produce. But what happens once this sound leaves the bird? What functions does it serve? What is its ecological role? How are these songs actually learned? This is something that you are going to do in subsequent lectures. And with that I will end my part of this lecture on sound. Thank you.