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Green Turtle Hearing Identification Based on Frequency Spectral Analysis

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Abstract

It is reported that fishing activities equipped with TED (Turtle Excluder Device) able to reduce the number of turtle by catch. This paper aimed to design a TED using sound technology. In order to dispel a turtle using sound, it is necessary to perform on turtle hearing ability. This study focuses on Green Turtle (*Chelonia Midas*) species. Three turtles have been measured. They have different age ie: 2, 5, and 9 years. A system known as Auditory Brainstem Responses (ABR) has been used on the green turtle detail analysis. The objective of this paper is to identify green turtle hearing ability by analyzing the ABR spectral. The measurement was taken at Turtle Management Centre Kg. Pantai Panjang Segari Perak Malaysia. The duration measurements were 3 days, December 30, 2008 – January 2, 2009. It was conducted out the turtle tank. From the data obtained can be seen that the 2-year old turtle has a hearing range narrower than 5 years old turtle while 9 years old turtle has the widest frequency range. As for the three types of turtle age, has a maximum power at the same frequency of 300 Hz.

Keywords: TED, *Chelonia Midas*, ABR, Stimulus

1. Introduction

Sea turtles are unfortunate bycatch in the longline fisheries, mainly because they share the same habitat as fish species targeted by this type of fishing activity. There are seven species of sea turtles around the world whereas five species of them are listed in the official list of endangered species from Brazil (MMA 2003). It is impacted by human activity and need conservation measures. (Parentel, et.al., 2006). The green turtle (*Chelonia mydas*), the loggerhead turtle (*Caretta caratta*), and the olive ridley turtle (*Lepidochelys olivacea*) are classified as endangered species, while the hawksbill-sea-turtle (*Eretmochelys imbricata*) and the leatherback-turtle (*Dermochelys) coriacea*) are classified as critically endangered (IUCN 2004).

Fishermen to catch fish and shrimp in accordance with the rules must be equipped with a TED (Turtle Excluder Device). TED that is equipped in the nets and trawls will be able to reduce the number of turtle bycatch. The inventor of TED is Sinkey Boone, a Georgia shrimper in 1969 (Marine Turtle newsletter). Since the TED was first introduced to the U.S. shrimp fishery in the late 1980's, research and development to improve TED performance has continued. Implementation of TED in net and trawl can be seen in Figure 1.

Although the hearing ranges of most species overlap to a large degree, considerable variation occurs in high and low frequency hearing as well as in absolute sensitivity (Heffner, 2007). Lenhardt (2002) suggest that continued exposure to existing high levels sound (noise) in vital sea turtle habitats and any increase in noise could affect sea turtle behavior and ecology. Thus, turtle repelling with sound is possible and can be made practical.

(Kuwada S, et.al, 2002) ABR signals have a waveform morphology which typically exhibits five waves (peaks) in the post-stimulus interval. The basic of the ABR signal can be seen in Figure 2. Auditory Evoked Potential (AEP) signals are transient electrical bio-signal produced by various regions of the human brain in response to auditory stimuli (such as a periodic repetition of "clicks"). These signals are traditionally categorized into: ABR which occurs during the first 11 ms after the stimulus, followed by a Mid-Latency cortical Response (MLR) which is typically confined to the next 70 ms, followed by a slow cortical response which starts at about 80 ms after the stimulus (Elvir, et.al, 2005). The first description of the human ABR was made by Jewett and Williston in 1971

The ABR responses are acquired from the animal subject in order to asses and determine the cranial auditory nerve function. In humans, similar techniques have been conducted to asses the viability of cochlear implantation, or the existence of any physical conditions that may prevent successful implantation (Intelligent Hearing Systems, 2007). The basic test of hearing consists of determining the ability of an animal to hear pure tones at intervals throughout its hearing range. The testing is done by training an animal to respond to a tone and then reducing the tone's intensity until the animal fails to respond. There is an overlap of those frequencies and the audible frequency range of sea turtles which perceive sounds from 60 to 1000 Hz (Parentel, et.al, 2006). (Sneary, et.al, 2007) have studied that provided a basis for understanding auditory hair cell frequency selectivity in the turtle (Lovell, et.al., 2004), the mechanism of sound reception and the hearing abilities of the prawn (Palaemon serratus) have been studied using a combination of anatomical, electron microscopic and *electrophysiological* approaches, revealing that P. Serratus is responsive to sounds ranging in frequency from 100 to 3000 Hz. ABR data have been analyzed for 10 turtles (juvenile and subadult *C. mydas* and juvenile *L. kempi*) and two of tuna (*Thunnus albacares*) using a correlation technique to identify the response to sound (Bartol and Ketten, 2006). The AEPs technique is a noninvasive and rapid method to measure the hearing range and temporal resolution of animals. It is a method that requires no training of the subject and is used also to asses hearing response in human infants (Hecox and Galambos R, 1974)

The collective knowledge of marine hearing and sound detection capabilities is very limited. Fisheries, which has jurisdiction over most marine mammals and all sea turtles in the region, has not set any standard measurement for safe sound levels. This reason is because limited knowledge of true hearing thresholds of such animals and their sensitivity to various sound levels, frequencies and durations (Peter Howorth, 2003). Amount of 12 hatchling through sub-adult turtles (Lepidochelys kempi, Chelonia mydas, Caretta caretta) show juvenile green turtles have a slightly broader hearing range (100-800 Hz; best sensitivity 600-700 Hz) than sub-adults (range 100-500 Hz). Kemp's Ridleys had a more restricted range (100-500 Hz) with most sensitive hearing at 100-200 Hz (Ketten, et.al, 2005).

Works describing techniques for extracting the ABR from the EEG are given in Elvir, et.al, (2005). A new algorithm of adaptive filtering in the time-frequency domain using a specific Wavelet Transform and compare it to traditional ABR extraction in the form of compare it to traditional ABR extraction in the form of bandpass filtering followed by averaging as well as adaptive filtering in the Fourier domain proposed by Elvir, et.al.(2005). One of methods to measure the temporal resolution of the auditory system is to estimate the modulation rate transfer function (MRTF) using AEP. Popper, (2000), have used ABR to measure hearing capabilities of several other clupeid species in order to ascertain whether ultrasonic hearing is found in all Clupeiformes, or whether it is only found in a limited number of species. A typical MRTF is low pas in shape, and the corner frequency of that MRTF can be inferred as the temporal resolution of the subject (Supin AY, et.al, 2001).

The extraction of ABR from an EEG signal did by Jacquin et.al. It is based on adaptive filtering of signals in the wavelet domain, where the transform used is a nearly shift-invariant Complex Wavelet Transform (CWT). They compare the algorithm to two existing methods: the first simply consists of band-pass filtering the input EEG signal followed by linear averaging. The second method uses signal-adaptive filtering in the Fourier domain based on phase variance computed at each spectral component of the FFT. Davey, et.al. (2007) classified ABR models by generated using time, frequency and cross-correlation measures. Classification employed both artificial neural networks (NNs) and the C5.0 decision tree algorithm. Moneey Aran, et.al., 2006, using FFT to quantitatively determine the Envelope Following Response (EFR) magnitude. Singleton and Poulter, (2007) the signal analyzed, peaks in the estimated spectrum were observed at each integer multiple of the fundamental frequency. The smoothed spectrum is used as an estimate of the power spectral density function.

2. Materials and method

2.1 Subject and facility

The measurement was taken at Turtle Management Centre Kg. Pantai Panjang Segari Perak Malaysia. The duration times were 3 days, December 30, 2008 – January 2, 2009. It was conducted outside the turtle tank as shown in Figure 3.

The species of the turtle is Green Turtle. The measured Green turtles have different age as shown in table 1. The SmartEP software setting is shown in Table 2.

2.2 ABR Recording and measurement

The ABR measurement last for 1 hour (Figure 4). Click stimulus is used in this measurement. The frequency range of ABR analyzer is between 0 to 5 kHz. The species were equipped with ABR system and been hold in stable position. The species was made relaxed in that resting position. The recorded ABR signals saved in rpt format. Later the measured data have been analyzed using SmartEp software.

The click stimulus records were divided into 25 durations. The durations were set from 100 μs up to 2500 μs. The recorded data saved into three modes that are time domain, ASCII code, and data reported (rpt). Furthermore, the data were analyzed in frequency domain using FFT (Fast Fourier Transform) method that included in SmartEP software.

3. Results and discussions

Green Turtle were equipped with ear electrode (earphones). The earphone delivers the stimulus to the turtle's ear. Four earphones were used to measured turtle hearing threshold. The collected data collected indicates the response of the turtle.

The click stimulus was emitted started in 100 μs duration time. The ABR response signal was obtained in the time domain signal as shown in Figure 5. Later, it was transformed into frequency domain with SmartEp. Frequency spectral was obtained with a stimulus duration 100 μs has maximum power at frequency 300 Hz (Figure 6). The frequency spectral has the harmonic at a frequency of 900 Hz. Later the measurement was repeated until 2,500 μs with 100 μs interval. The frequency spectral is shown in table 4, table 5, Table 6 for 2, 5, 9 years turtles, respectively.

4. Conclusion

The frequencies spectral of green turtles have been analyzed in frequency domain. Green Turtles hearing ability can be obtained that the 2-year old turtle has a hearing range narrower than 5 years old turtle while 9 years old turtle has the widest frequency range. As for the three types of turtle age, has a maximum power at the same frequency of 300 Hz.

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Table 1. Green Turtle species for the ABR Measurement

No	**Age (year)**	**TL (cm)**	**NH (cm)**	**Wide (cm)**	**Weight (Kg)**
1.	2	43	12	28	20
2.	5	80	18	56	30
3.	9	96	17	76	66

TL: total length, NH: length of neck – head.

Table 2. ABR setting for turtle hearing ability measurement

File was saved	IHS 3845-20091203
Object	Green Turtle 2, 5, 9 years
Type of stimulus	click
Duration time of stimulus	25 µs.
Rate	70.00/s
Intensity	58 dB nHL
Number of Sweep	1000
Time Scale	25.0 µs (12.8 time scale)
Gain	5.0 K
line filter Status	On
Ear	Right
Rejection Time	1.0 – 10.0 ms
Rej. Artefact	31,00 µV
Type of Filter	Blackman

Software set for IHS system ABR signal analyzer.

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Table 3. Hearing Ranges of Fish

Common Name	Scientific Name	Hearing Range in Hz
Atlantic Salmon	*Salmo salar*, (Lin. 1758)	40 to 350
Bonito/Tuna	Euthynnus affinis, (Can. 1849)	100 to 900
Red Piranha	*Pygocentrus natereri*, (Kner. 1858)	80 to 1,500
Goldfish	*Carasius auratus*, (Lin. 1758)	40 to 3,200
Brown Bullhead	*Amereius nebulosus*, (Lesueur 1819)	100 to 4,000
Stone Moroko	*Pseudorasbora parva*, (T & S. 1846)	100 to 8,000
Atlantic Cod	*Gadus morhua*, Lin. 1758	20 to 38,000
American Shad	*Alosa sapidissima,* (Wilson 1811)	200 to 180,000
Gulf Menhaden	*Brevoortia patronus*, Goode 1878	200 to 1,800

The hearing ranges of fish is published by http://www.earthlife.net/fish/hearing.html)

Table 4. Recorded ABR signal of 2 years turtle

Sample Number	Stimulus Duration (μs)	Peak power in freq Spectral (Hz)	Range freq. Spectral (Hz)
1.	100	300	10-1300
2.	200	300	5-1600
3.	300	300	0-1300
4.	400	300	5-1200
5.	500	NA	NA
6.	600	300	0-900
7.	700	300	75-900
8.	800	300	75-900
9.	900	300	0-1200
10.	1000	300	0-800
11.	1100	300	0-1100
12.	1200	300	75-700
13.	1300	300	0-1600
14.	1400	300	0-1000
15.	1500	300	0-1200
16.	1600	300	0-1000
17.	1700	NA	NA
18.	1800	NA	NA
19.	1900	300	0-940
20.	2000	300	0-1000
21.	2100	300	0-1000
22.	2200	300	0-1000
23.	2300	300	0-800
24.	2400	300	0-800
25.	2500	300	0-630

The results of frequency spectral obtained from frequency domain, age 2 years

Table 5. Recorded ABR signal of 5 years turtle

Sample Number	Stimulus Duration (μs)	Peak power in freq Spectral (Hz)	Range freq. Spectral (Hz)
1.	100	290	10-940
2.	200	NA	NA
3.	300	290	10-600
4.	400	290	10-600
5.	500	300	10-1100
6.	600	300	10-600
7.	700	50	10-900
8.	800	75	10-900
9.	900	300	10-1200
10.	1000	75	5-900
11.	1100	75	10-800
12.	1200	300	5-1125
13.	1300	400	10-1600
14.	1400	450	5-1900
15.	1500	300	10-1600
16.	1600	900	10-1050
17.	1700	900	5-1100
18.	1800	900	5-1100
19.	1900	900	5-1500
20.	2000	900	5-1200
21.	2100	300	5-900
22.	2200	800	5-1100
23.	2300	900	5-1200
24.	2400	NA	NA
25.	2500	NA	Na

The results of frequency spectral obtained from frequency domain, age 5 years

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Table 6. Recorded ABR signal of 9 years turtle

Sample Number	**Stimulus Duration (μs)**	**Peak power in freq Spectral (Hz)**	**Range freq. Spectral (Hz)**
1.	100	300	5-1400
2.	200	300	5-1400
3.	300	300	50-1300
4.	400	300	10-1500
5.	500	310	25-800
6.	600	900	10-1200
7.	700	300	15-1300
8.	800	300	5-1250
9.	900	300	5-930
10.	1000	300	10-1500
11.	1100	300	10-1600
12.	1200	300	20-1600
13.	1300	300	25-1600
14.	1400	300	75-1500
15.	1500	300	100-1500
16.	1600	300	100-2600
17.	1700	300	100-2600
18.	1800	300	100-3000
19.	1900	300	150-2700
20.	2000	300	100-2800
21.	2100	300	200-2800
22.	2200	300	100-2700
23.	2300	300	100-2600
24.	2400	300	200-2700
25.	2500	300	200-2500

The results of frequency spectral obtained from frequency domain, age 9 years

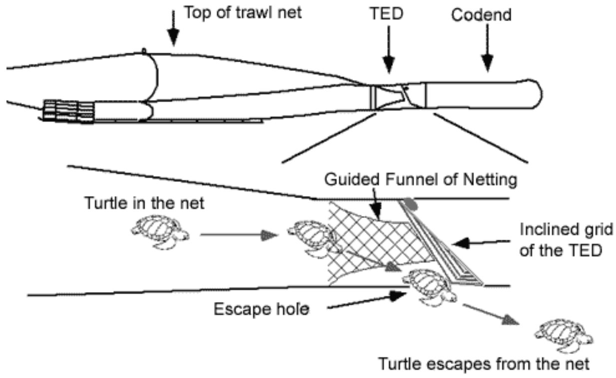

Figure 1. Diagrammatic representation of a Turtle Excluder Device fitted to a trawl net
http://www2.dpi.qld.gov.au/fishweb/10559.html

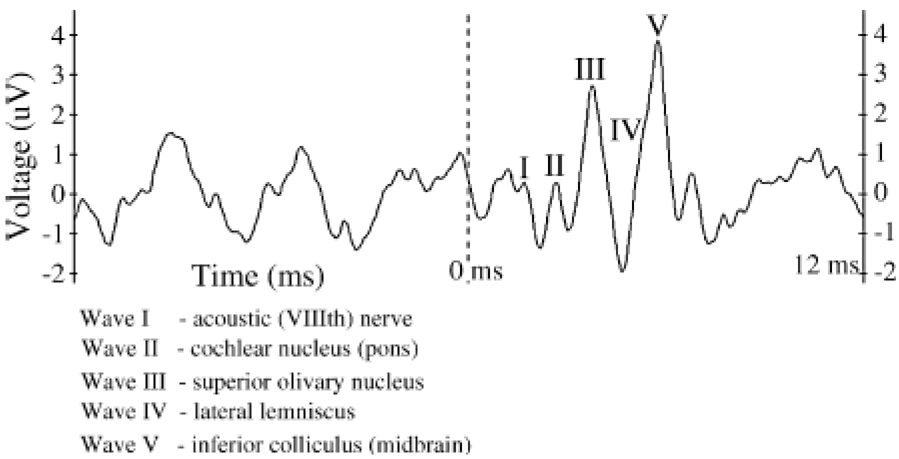

Figure 2. Template ABR (elvir, et.al, 2005)

Figure 3. Study area

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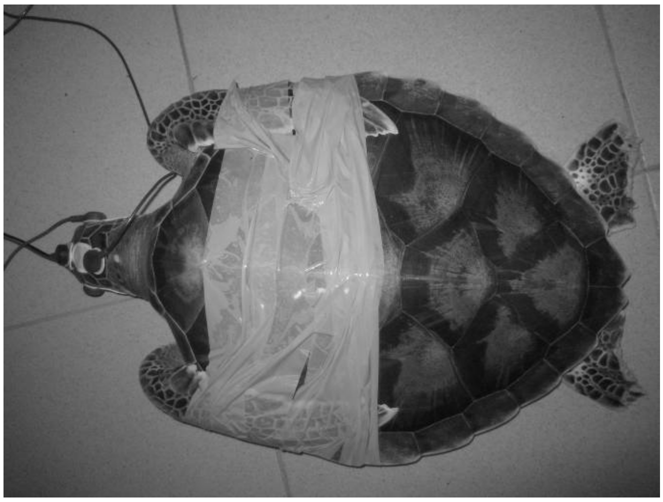

Figure 4. Chelonia Midas during Measurement activities

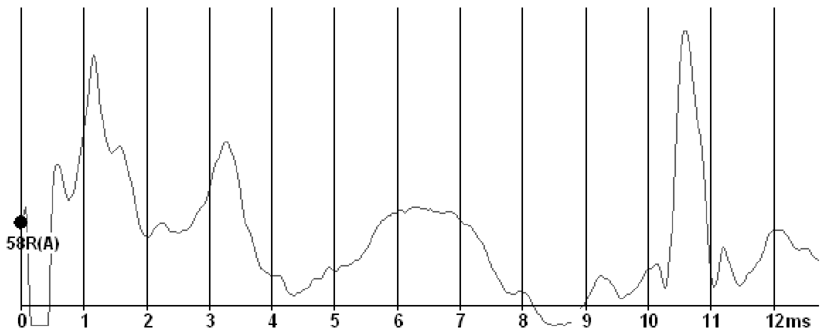

Figure 5. Green Turtle ABR in time domain

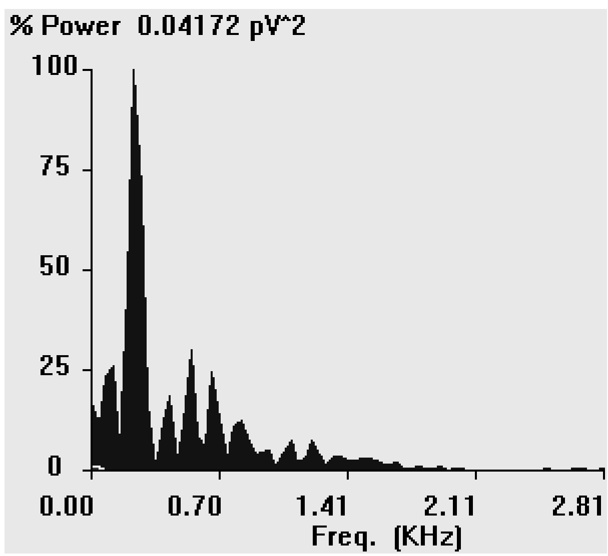

Figure 6. Green Turtle ABR in frequency domain