UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias Biológicas y Ambientales

Evolution in song patterns of humpback whales (*Megaptera novaeangliae*) during the breeding season 2012, 2013, and 2015 off the coast of Esmeraldas, Ecuador.

Proyecto de Investigación

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Evolution in song patterns of humpback whales (*Megaptera novaeangliae*) during the breeding season 2012, 2013, and 2015 off the coast of Esmeraldas, Ecuador.

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Resumen:

Durante la época de reproducción las ballenas jorobadas machos (*Megaptera novaeangliae*) producen una demostración vocal sexual repetitiva o canto. El canto está en constante estado de cambio, y definitivamente hay un componente social , ya que las ballenas copian de otras ballenas y hay un cambio cultural dinámico ocurriendo a través de múltiples poblaciones. Esta investigación describe los cambios culturales que se produjeron en la temporada de reproducción 2012, 2013 y 2015 frente a las costas de Esmeraldas, Ecuador. Las canciones se agruparon en base a la similitud cualitativa de sus temas y a cada tipo de canción se le asigno un color representativo para su identificación. Tres diferentes tipos de canciones se registraron en la región en el 2012, 2013 y 2015. Esta investigación tiene como objetivo demostrar la utilidad y el valor del uso de patrones vocales como una forma de entender la evolución del canto que existe en la población del Pacifico Tropical Este.

Palabras Claves: Canción, Ballena Jorobada, Demostración vocal sexual, cambio cultural dinámico, unidades , frases , temas

Abstract:

During the breeding season southern male humpbacks whales (*Megaptera Novaeangliae*) emit a highly stereotyped, repetitive and progressively evolving sexual display called, "song". The song is in constant state of change and represents a social component as whales are exchanging with one another. This exchange is seen as a repeated, dynamic cultural change occurring across multiple populations at large geographic scales. This investigation describes the cultural changes that occurred in the breeding season 2012, 2013 and 2015 off the coast of Esmeraldas, Ecuador. Songs were grouped together based on qualitative similarity of themes into song types that were assigned color name as arbitrary labels. Three different song types were recorded in the region in 2012, 2013 and 2015. This research aims to demonstrate the usefulness and value of using vocal patterns as a way of understanding the evolution of the song that exist in the Tropical East Pacific population of Humpback Whales.

Key Words: Song, Sexual display, dynamic cultural change, units, phrases, themes.

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1 Introduction:

Southern Humpback whales, undertake yearly migrations from summer feeding grounds in polar waters, to tropical winter breeding and calving grounds (Garland et al., 2011; Helweg et al., 1998; Dunlop et al., 2009; Winn et al., 1981). During the winter breeding season, male humpback whale, produce a highly stereotyped, repetitive and progressively evolving vocal sexual display, called "song" (Garland et al., 2011, 2012, 2013; Mercado et al., 2005; Payne et al., 1983; Smith et al., 2008). The song consists of repeating patterns, hierarchically organized, ranging from individual sounds (units), through phrases and themes (Payne & McVay, 1971). Singing occurs during the breeding season but also during migrations to the breeding area and at summer feeding grounds (Payne & McVay, 1971, Winn and Winn, 1978; Parsons et al., 2008).

Singers are mainly lone adult whales. Males sing in a continuous session without stopping and a single song can last from 5 to 20 min or more (Payne & McVay, 1971; Tyack, 1981). The song has a hierarchical structure; short sounds or "units" are organized into recognizable patterns to form "phrases", an unbroken series of similar phrases forms a theme, and the combination of multiple distinctive themes, comprise a song (Garland et al., 2011; Helweg et al., 1998; Dunlop et al., 2009; Payne & McVay, 1971). Different versions of the display are called "song types" and all singers adhere to this hierarchal arrangement (Garland et al., 2011, 2012, 2013; Whitlow et al., 2006).

The most unique characteristic of the song is that it changes gradually during the breeding season; basic units change in frequency, position and the ways they are organized to make phrases (Payne & McVay, 1971; Winn and Winn 1978; Oviedo et al., 2008; Garland et al., 2011; Darling et al., 2006). Phrases change in the number and types of units they contain and in their rhythmic patterning and at higher level, insertion or omission of entire themes. Evolution of song type can occur through a number of types of changes at all levels within the song (Winn & Winn, 1978; Payne *et al*., 1983; Payne & Payne, 1985; Cato, 1991).

Song variants or song types are culturally transmitted among individuals and populations within an ocean basin (Garland et al., 2011, 2012, 2013; Darling et al., 2006; Dunlop et al., 2009; Payne & Payne, 1985). The conformity to a single song type within a population is thought to occur via social learning from surrounding males. When song transmission is examined at the ocean basin scale, is considered one of the best examples of horizontal cultural transmission in a non-human animal (Garland et al., 2011, 2012, 2013; Eriksen et al., 2005; Murray et al., 2009).

Little is known about behavior, ecology and seasonal variations of songs structure of the Southeastern Pacific humpback whales. Whether innovating or copying, humpback whale song has artistic elements that are used in their communication, reproduction and social learning among conspecifics. The uniqueness and creativity of the song should be studied to improve our understanding of the continuous evolution humpback whale songs undergo and to create a good strategy for the conservation of this songs from the rapid human caused changes that occur every year in the winter breeding grounds of the coast of Esmeraldas Ecuador.

This research aims to explore the acoustic features of the song of male humpback whales in breeding areas off the coast of Esmeraldas, Ecuador.

2 Justification:

During recent years there is growing concern that sound introduced into the sea by human activities has detrimental effects on marine mammals. There is now strong evidence that noise pollution can affect significantly the distribution and bioacoustics behavior of highly vocal animals like the Humpback whales (Scheidat et al., 2004).

Coding and identifying the songs structure of humpback whales during the breeding seasons of 2012, 2013 and 2015 off the coast of Esmeraldas will help to provide a baseline to understand the impact of sound contamination on cetaceans.

3 Research Question, Hypothesis and Objectives:

3.1 Research Question:

¿The acoustic structure of humpback whales songs off northern of Ecuador varies within the breeding seasons 2012, 2013 and 2015?

3.2 Hypothesis:

The acoustic structure of humpback whale songs will change within breeding seasons 2012, 2013 and 2015.

3.3 Objectives:

1. Describe the content of phrases and themes for all song types recorded in the north of Esmeraldas in 2012, 2013, 2015,
2. Compare song content within seasons 2012, 2013, and 2015.

4 Methodology:

4.1 Study Area:

Ilustración 1: Recordings 2012, 2013 and 2015 Esmeraldas - Manabí

From July to October Humpback whales breed all along the coast of Ecuador with breeding hotspots in Salinas, Machalilla National Park, Bahía de Caráquez, Pedernales and off the coast of Esmeraldas (Rubianes, 2015). Our research was conducted in 2012, 2015 in the northernmost extension of the breeding area from the Esmeraldas River (N 0°59′54,1″;W 79°38′37,7″) to the Muisne River (N

0°37′3,9″;W 80°02′01,9″), and in 2013 recordings were made in the southernmost part, in deep waters of the coast of Manabí (S 0°52′14,23″; W 82°37′01,25″) from a sailing boat called Frangipani.

In this breeding hot spots sea surface temperatures range within 24 to 26 C° throughout the year. The seabed structure of the coast of Esmeraldas is composed of areas with hard substrate, mixed bottoms formed of sand and rock, wall with rocks and soft bottoms with muddy channels, with depths ranging from 10 to 200 m (Denkinger et al., 2006).

4.2 Data Collection:

Humpback whale surveys were conducted from June to August of 2012, 2013 and 2015 from a small outboard powered 8m fiberglass fishing boat. Recording equipment consisted of H2a-XLR omnidirectional hydrophone, a digital recorded (Tascam DR-40) and a pair of headphones.

If a single whale or a group of whales was sighted, the boat approached the group, the engine was turned off and the hydrophone was lowered 10 m below the surface to initiate underwater recording. At each recording, date, time, geographic position, file number (TASCAM 001), number of individuals, their distance, and their behavior and the direction of the group in relation to the boat was recorded. This process was carried out every 25 to 30 minutes. The songs were recorded for 30 minutes or more, when good singers were present, or from 5 to 15 minutes when songs were of average quality. Acoustic samples were recorded on a Tascam DR-40 digital recorder, set for recording (WAV files, 16 bit, 44.1 kHz sample rate); files were converted to digital format using Adobe Audition CC 2014.

4.3 Song Transcription

Songs were viewed as spectrographs in Adobe Audition CC 2014 to allow each unit to be viewed clearly. Song was transcribed based on the visual and aural qualities of the sound. Each unit sound type was assigned a name, which was descriptive and allowed the fast recognition of a unit (moan, whoop). All units were coded and the repetitive nature of song allowed phrases and themes to be identified. (Garland et al., 2011, 2012, 2013).

A phrase was defined as a series of units sung in a particular order that was repeated more than once (Payne & McVay 1971). A theme was defined as the repetition of a phrase with similar content (Payne & McVay 1971).

Songs were grouped together based on qualitative similarity of themes into song types that were assigned color names as arbitrary labels (see Garland et al., 2013). Song types were grouped together into song lineages if the song was observed to evolve (through changes of units or addition of units to existing phrases, or the addition or deletion of themes) from one song to another (Example: Blue song to Light blue song). If a new, song appeared, it was given a completely new color name (Green Song). Three different song types were recorded in the region in 2012,2013 and 2015.

5 Results:

There were 3 different song types present off the Coast of Esmeraldas in 2012,2013 and 2015.

Table 1: Song types in 2012, 2013 and 2015

	2012	2013	2015
Blue Song			
Light Blue Song			
Green Song			

5.1 The Blue Song (2012):

The Blue Song had 10 themes (Table 1, Appendix). Theme 1 had a purr /groan/purr followed by a moan. Theme two started with a long groan, followed by a purr/whoop. Theme 3 contained a purr/groan, followed by a purr. Theme 4 started with a purr/ whoop, followed by a whoop and again a purr /whoop. Theme five had two descending moan followed by five purrs. Theme six started with an ascending cry, followed by a moan, and tree ascending cry and a modulated ascending whistle. Theme seven started with modulated moan and a descending moan, followed by five n. shaped moans then continued with a n. shaped moan followed by groan/modulated moan, and a moan followed by a groan /modulated moan and finally a descending moan, the last part of these theme was a groan/n. shaped moan followed by a n. shaped moan. Theme eight started with a long groan

followed by a moan. Theme nine had a moan followed by a groan. Theme ten with was present only in the second singer started with a long moan followed by a moan.

5.2 The Light Blue song (2013):

The Light Blue song had five themes (Table 2, Appendix). Theme one started with a descending shriek followed by a purr/whoop. Theme two started with a whoop followed by a purr/whoop, this theme was similar to theme 4 in the blue song, but it has it slightly variations in the way the units were organized. Theme tree started with a long ascending moan followed by a short ascending moan, followed by two descending cry, a modulated whistle and again a descending cry, this theme was similar to theme 6 in the blue song, but instead of descending cries and ascending moans, theme 6 had ascending cries and moans. Theme four started with groan followed by a descending moan, this theme was similar to theme eight in the blue song, but instead of a descending moan, theme eight had a moan. Theme five started with a groan followed by a descending moan/groan.

5.3 The Green song (2015):

The Green song had six themes (Table 3, Appendix). Theme one started with tree ascending moans followed by a modulated ascending moan, and tree or four short ascending moans and a modulated ascending moan. Theme two started with a long purr followed by a modulated ascending moan. Theme tree started with a whoop followed by an ascending moan. Theme four started with a purr/whoop, followed by a squeak and an ascending shriek, this theme was similar to theme one of the green song, but instead of an ascending shriek, this theme had a descending shriek and was lacking the squeak that the theme four of the orange song had. Theme five started with a siren followed by a mini siren, and then continued with a modulated moan followed by a modulated whistle. Theme six started with a groan/moan followed by a modulated ascending moan.

5.4 Differences between themes found in 2012, 2013, 2015:

Table 2: Differences of themes between individuals 2012

Differences of themes between individuals 2012	
Theme #6- Individual #1	**Theme #6- Individual #2**

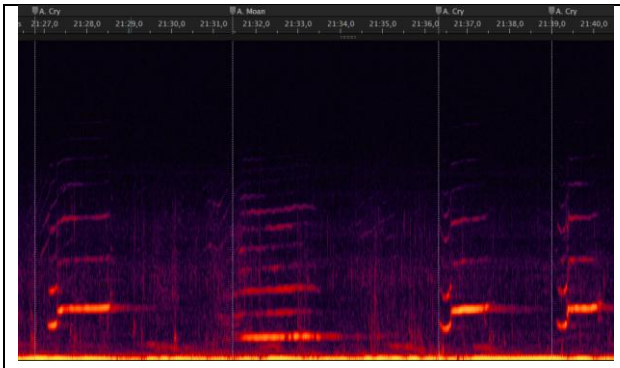
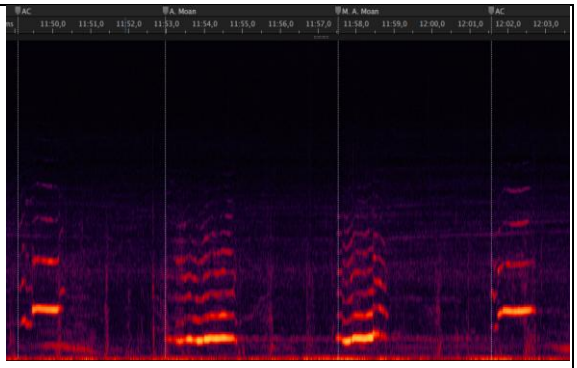
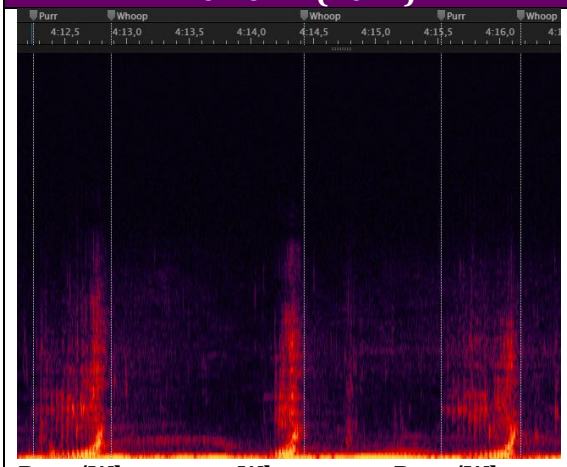
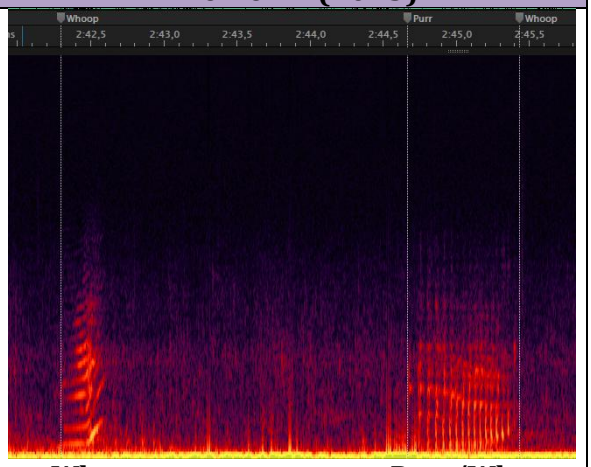
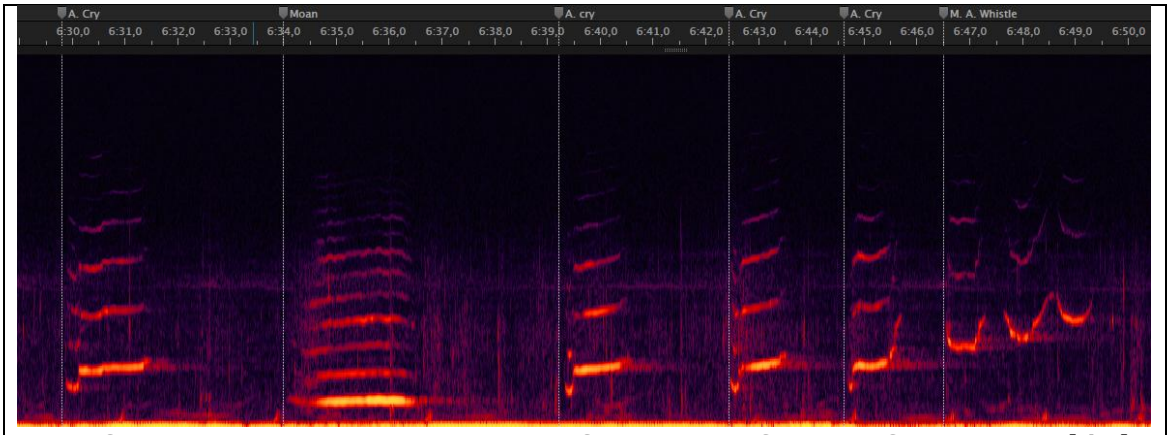
 **A. Cry - Moan - A. Cry - A. Cry**	 **A. Cry - Moan - M. A. Moan - A. Cry**
Theme#1 was similar to theme #6, but the diferentiated in one unit , and this change make it visible that there is a difference bewteen individuals.	

Table 3: Differences between themes (2012-2013)

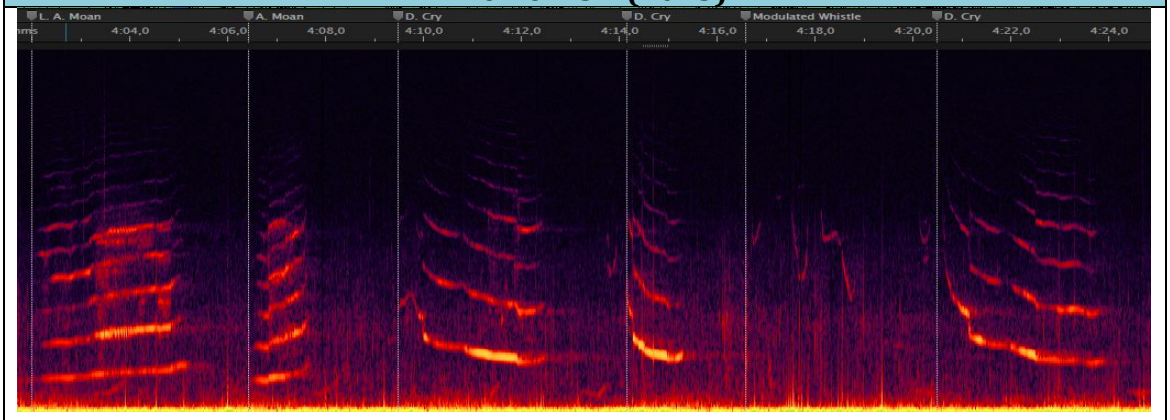
Differences of themes between years (2012-2013)	
Theme #4 (2012)	**Theme #2 (2013)**
 **Purr/Whoop - Whoop - Purr/Whoop**	 **Whoop - Purr/Whoop**
Theme #4 and theme #2 were similar in their units, but they differentiated in the order they units were organized to make phrases.	

Theme #6- (2012)



A. Cry - Moan - A. Cry - A. Cry - A. Cry - M. A. Whistle

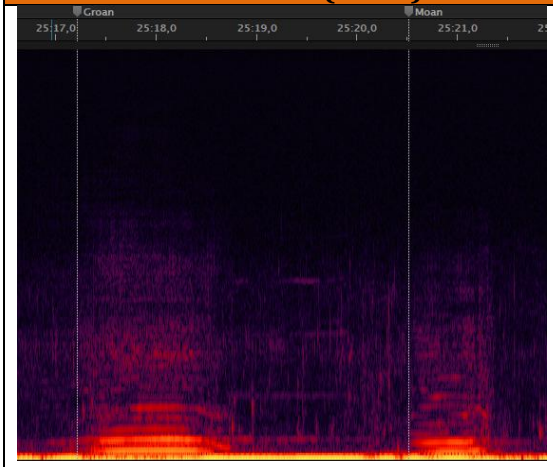
Theme # 3 – (2013)



A. Moan A. Moan D. Cry D. Cry M. Whistle D. Cry

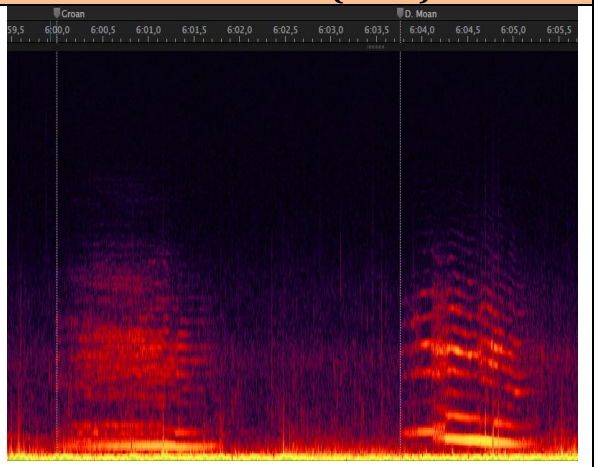
In 2012 theme #6 had ascending cries, but it changed in 2013 to descending cries, so this themes changed in this period of time.

Theme #8 – (2012)



Groan - Moan

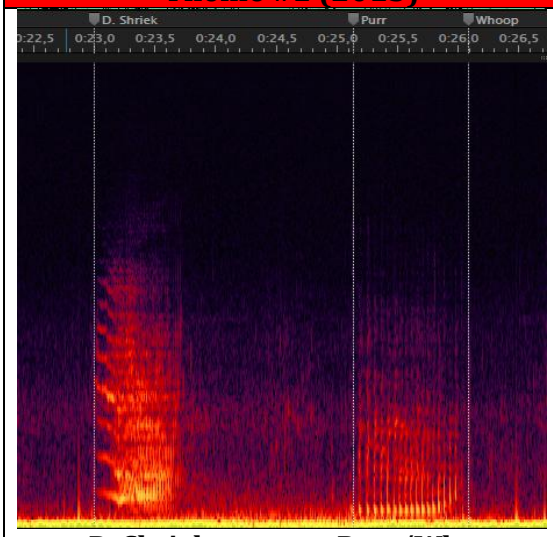
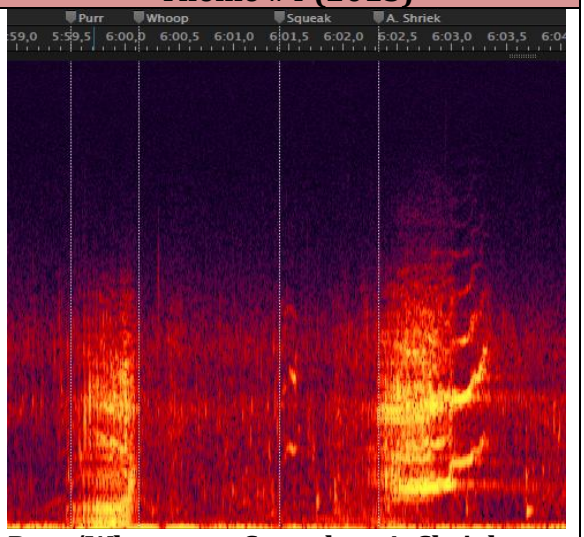
Theme #4 – (2013)



Groan - D. Moan

Theme #8 in 2012 had a moan , but in 2013 this moan changes to a descending moan , which means that this theme also change during that period of time.

Table 4: Differences between themes (2013-2015)

Differences of themes between (2013-2015)	
Theme #1 (2013)	**Theme #4 (2015)**
	
D. Shriek - Purr/Whoop	**Purr/Whoop - Squeak - A. Shriek**
In 2013 Theme #1 had a descending shriek , but it changed in 2015 for a ascending shriek, these theme changed bewteen a longer period of time (2013-2015)	

6 Discussion:

We have presented the first evidence on how song patterns of the Southeastern pacific humpback whale population change within breeding seasons 2012, 2013 and 2015 in the tropical wintering grounds off Esmeraldas.

Two types of song change occurred off the coast of Ecuador. The first was a progressive cultural evolution in which songs changed from one type to another; (blue song in 2012 to light blue song in 2013). This type of song change has been clearly documented in other ocean basins, especially in Hawaii, and most notably in Bermuda in the Caribbean North Atlantic, where they found that the song goes through slow changing years and begin to differentiate in a another song type slowly (Payne et al., 1983, 1985; Cerchio et al., 2001; Eriksen et al., 2005; Winn

and Winn, 1978). The second type of song change documented in this study involved rapid replacement of a cultural trait, in which a novel song type appeared in the population and rapidly replaced the existing song (Noad et al., 2000); the light blue song in 2013 was replaced by the green song in 2015. A similar pattern of rapid cultural replacement of songs was observed during the 2003 breeding season of the eastern Australian humpback whale population (Garland et al., 2011).

The song recorded in 2013 off the coast of Manabí in deep waters of more than 200m depths could be interpreted as a window of the flow of information between individuals of different populations (the light blue song recorded in 2013 shared 3 themes with the blue song recorded in 2012 and only one theme with the green song recorded in 2015). see table #3 , table#4.

Rojas et al. (2014) found using DNA analysis a male biased sex ratio of 3, 7males to 1 female off the coast of Esmeraldas (Ecuador), do to the uneven (male/female) sex ration, a promiscuous mating system may be occurring, and some males humpback whales may be visiting several breeding grounds to increase their mating opportunities (Parson et al., 2008).

So perhaps song is changing because cultural transmission, between males from different breeding ground may be occurring at some point along the migratory cycle, on the feeding grounds, at subsequent winters if some males migrate to different breeding grounds, or if some males visit different breeding grounds within a single season (Murray et al., 2012; Payne et al., 1971). Noad et al., (2000) showed that an entire population could rapidly adopt a song type, introduced at a very low initial prevalence. If only a few individuals are required to enter a population to induce a song change.

7 Conclusion

Song is a complex and dynamic display that provides a cultural identity or marker for each population and geographic variation in humpback whale song present a novel means to study movements of whales within, and perhaps between populations (Garland et al., 2011, 2012, 2013). These changes are evident in the song types recorded in 2012, 2013 and 2015 off the coast of Esmeraldas Manabí,

however further studies are needed to really understand the way male humpback whale changes their songs every breeding season.

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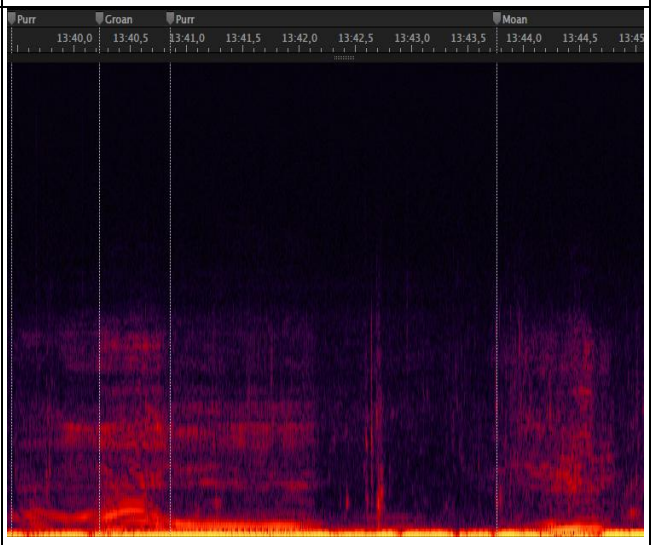
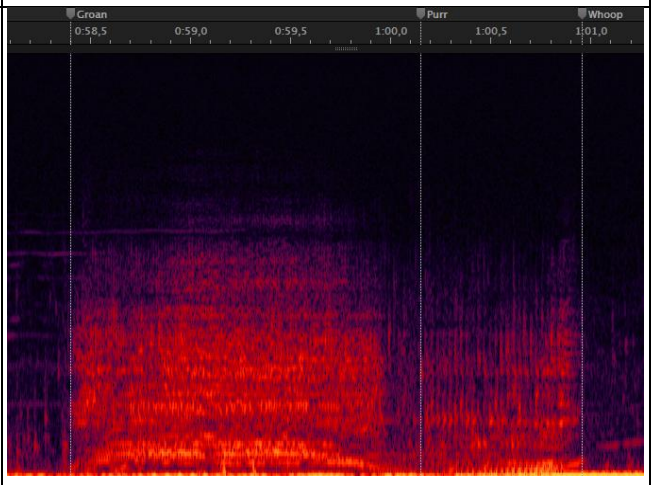
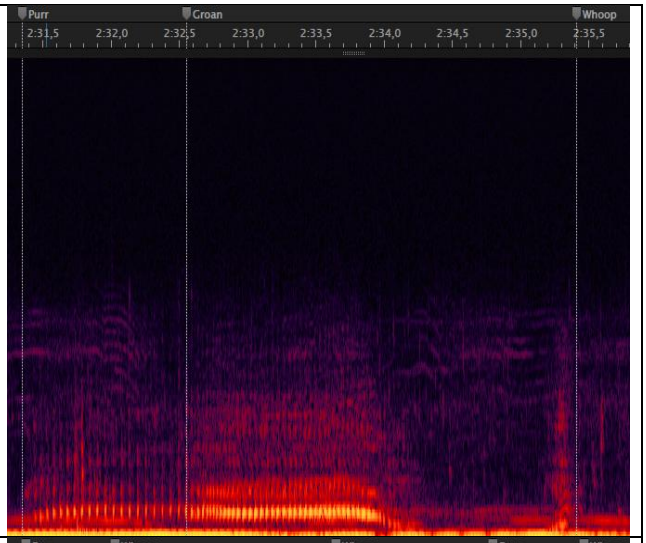
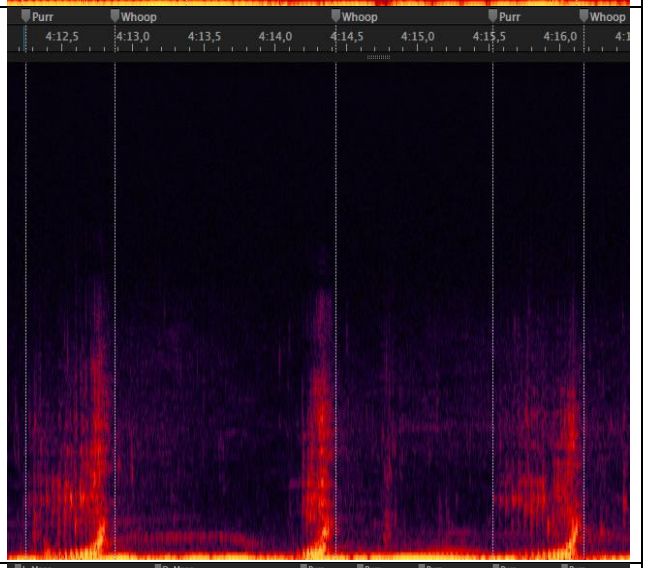
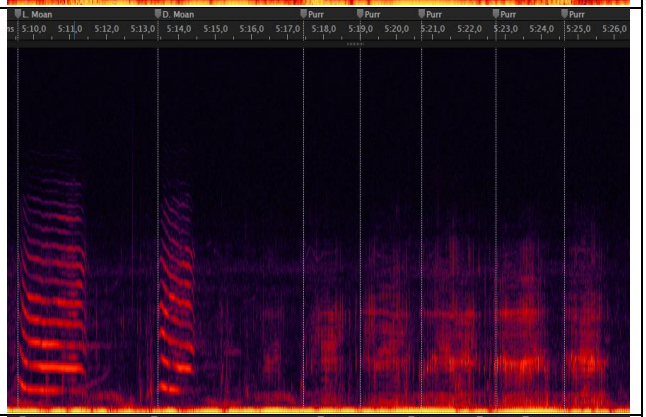
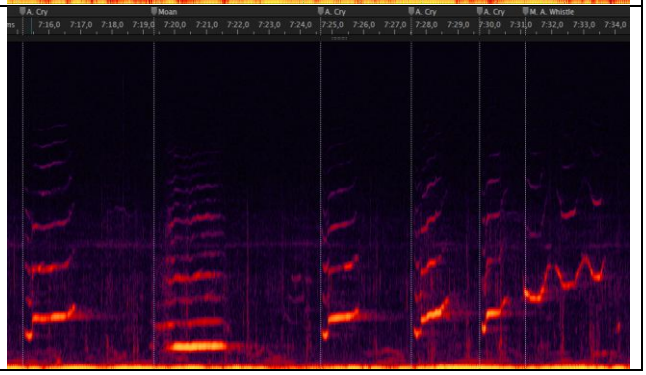
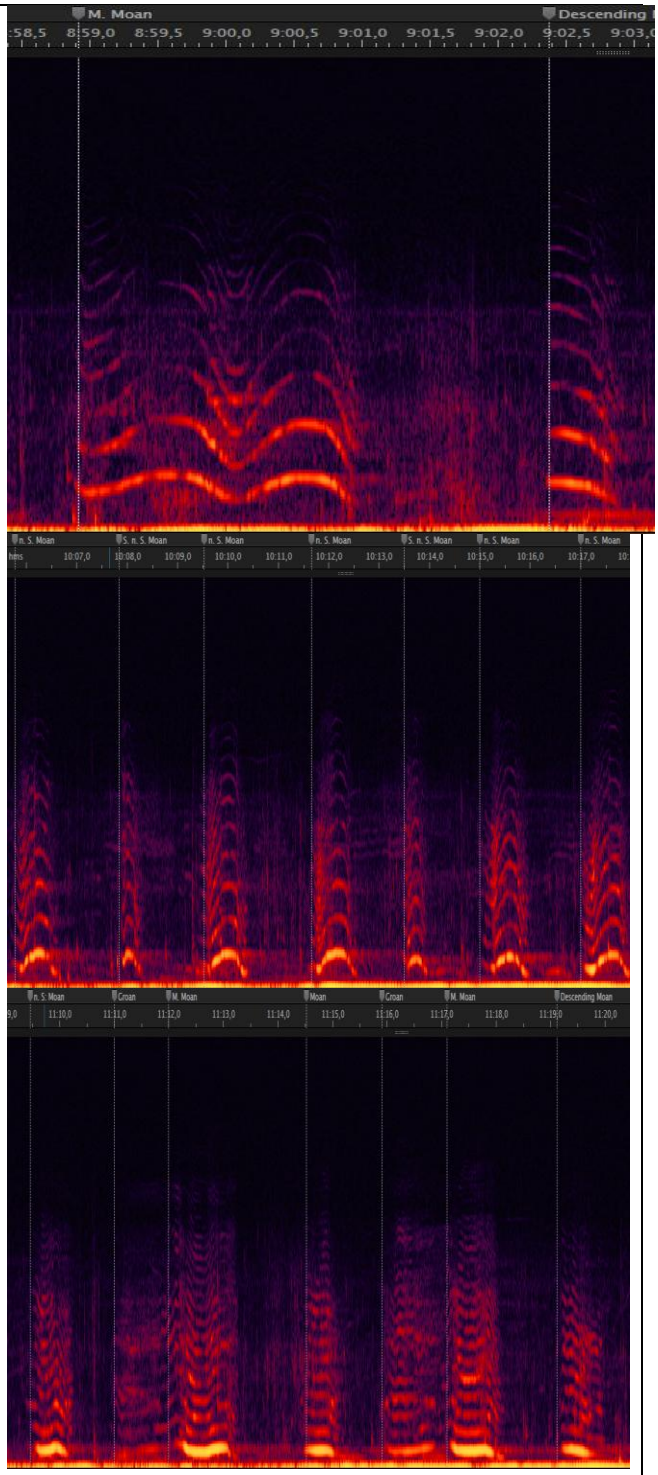
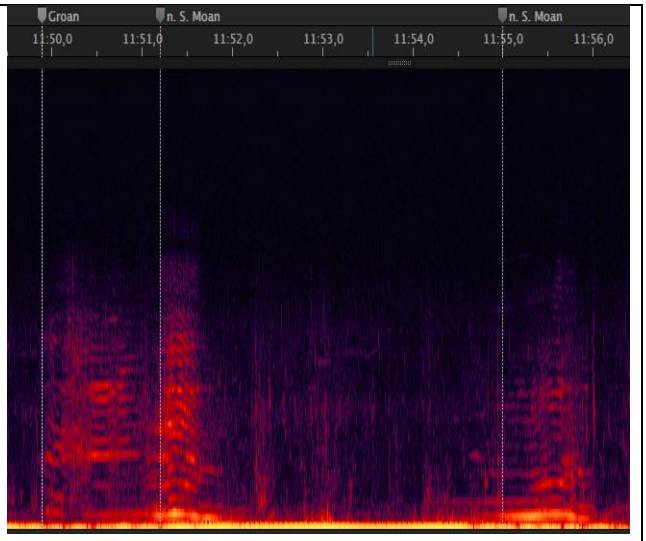
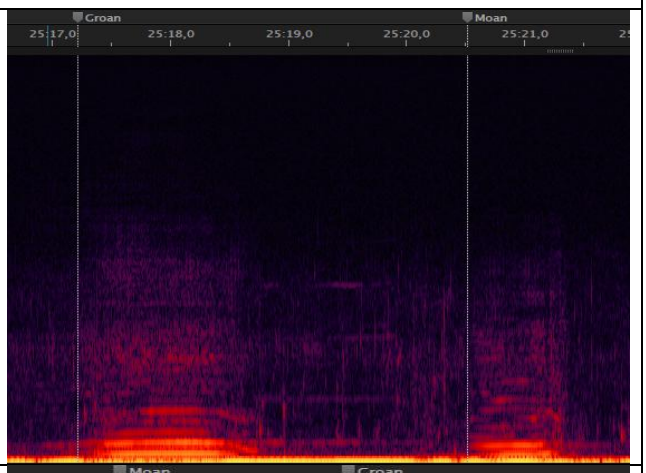
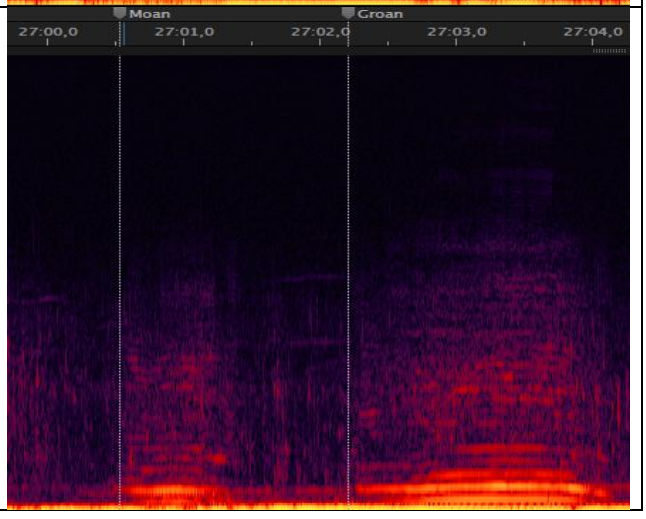
9 Appendix A: Songs 2012, 2013 and 2015

Tabla 5: Blue Song (2012)

Theme Number	Units in a typical phrase for each theme	Spectrographs of each Theme
1	Purr Groan Purr – Moan	
2	L. Groan – Purr Whoop	

3	Purr Groan – Purr	
4	Purr Whoop– Whoop– Purr Whoop	
5	D. Moan – D. Moan - Purr – Purr – Purr – Purr – Purr – Purr	
6	A. Cry – Moan– A. Cry – A. Cry – A. Cry – M.A. Whistle	

7	M. Moan – D. Moan n. S Moan – n. S Moan – n. S Moan – n. S Moan – n. S Moan – n. S Moan– n. S. Moan n. S Moan –<u>Groan M. Moan</u> – Moan–<u>Groan n. S. Moan</u>– D. Moan	

	Groan n. S Moan –n. S Moan	
8	L. Groan – Moan	
9	Moan – Groan	

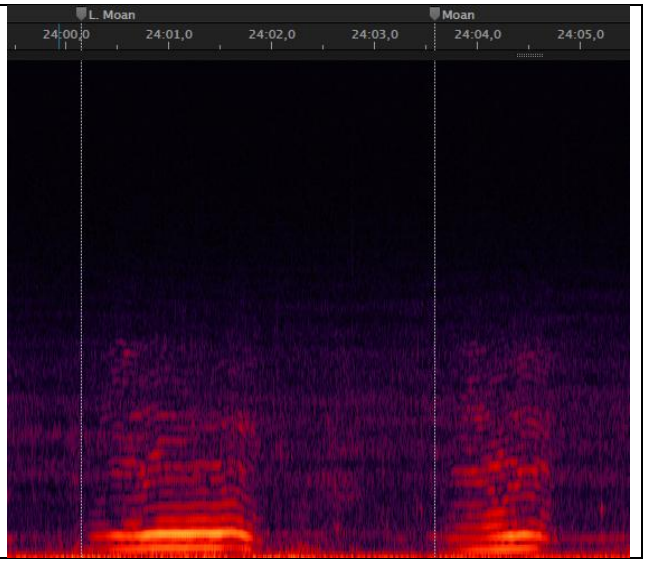
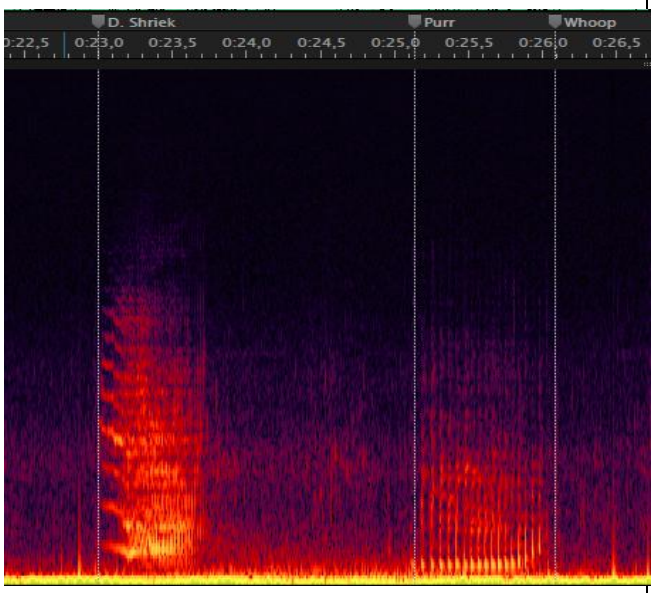
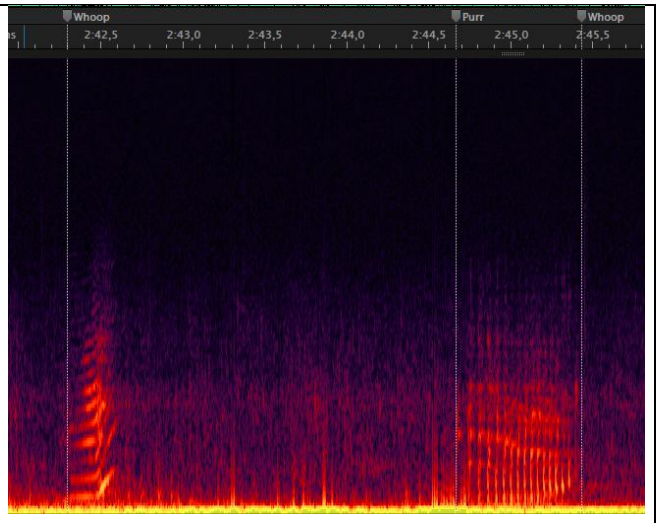
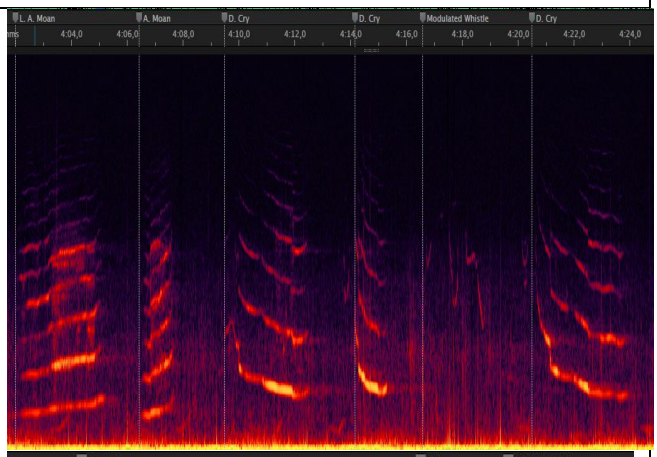
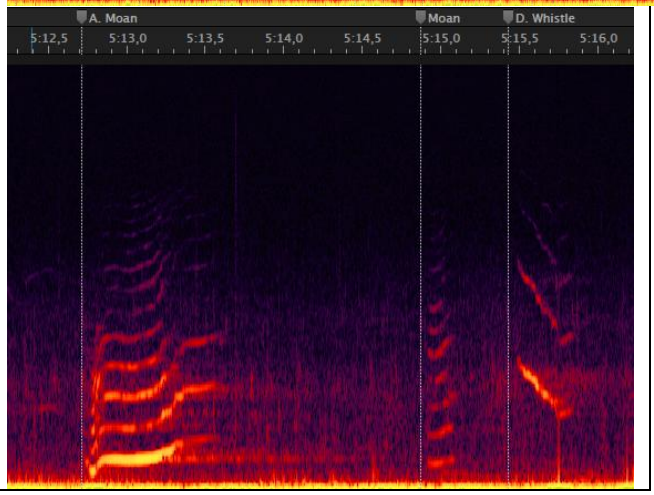
10	L. Moan – Moan	

Tabla 6: Light Blue Song (2013)

Theme Number	Units in a typical phrase for each theme	Spectrographs of each Theme
1	D. Shriek– Purr Whoop	

2	Whoop – Purr Whoop	
3	L. A. Moan – A. Moan – D. Cry – D. Cry – M. Whistle – D. Cry A. Moan – Moan – D. Whistle	 

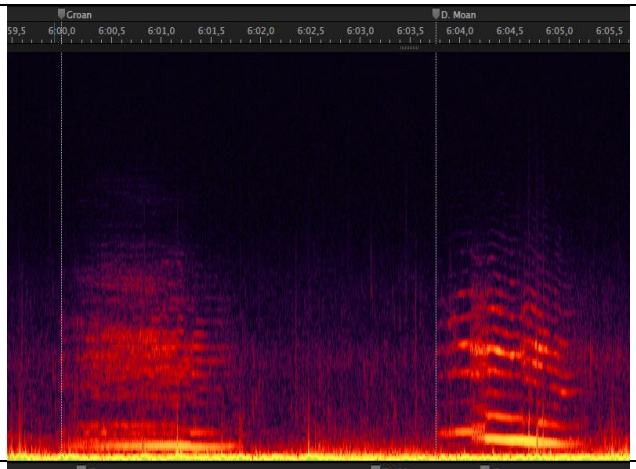
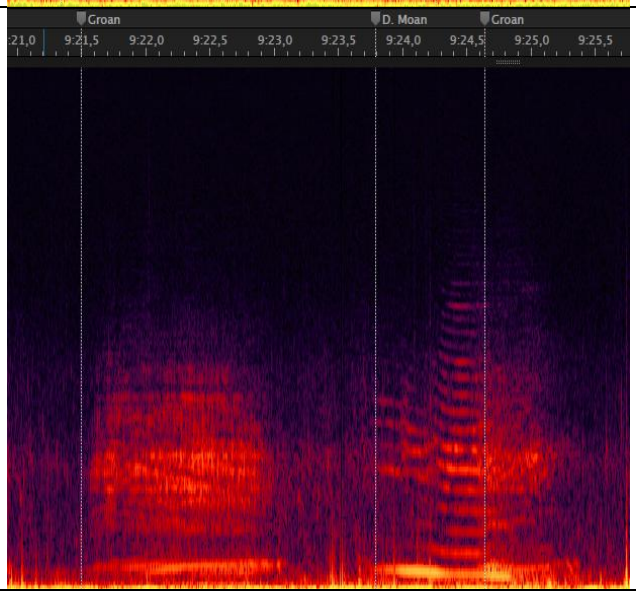
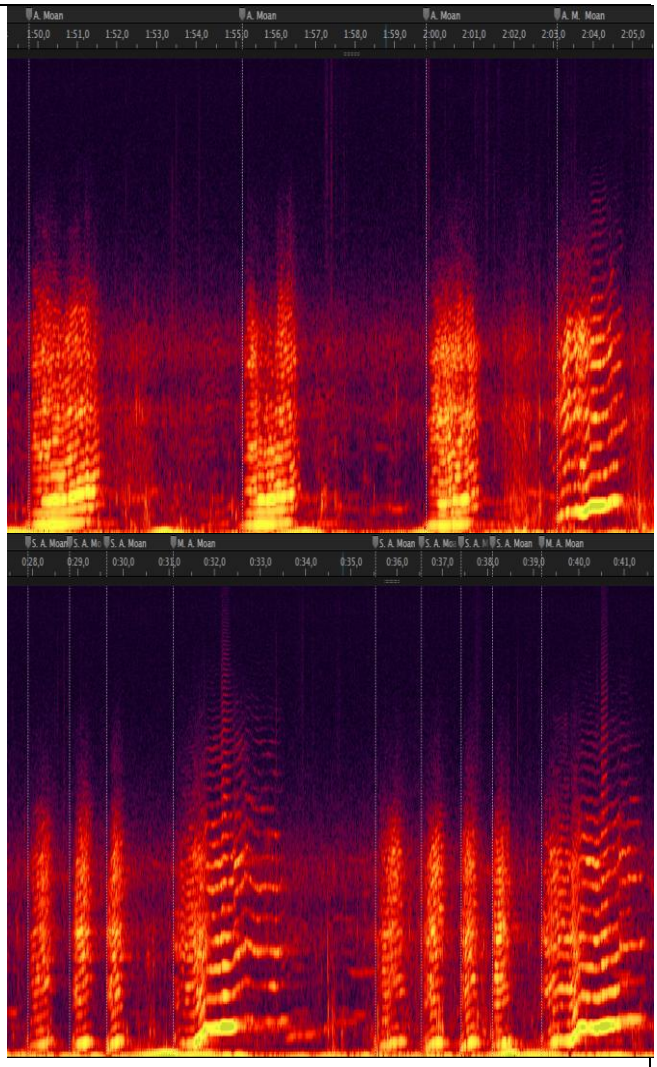
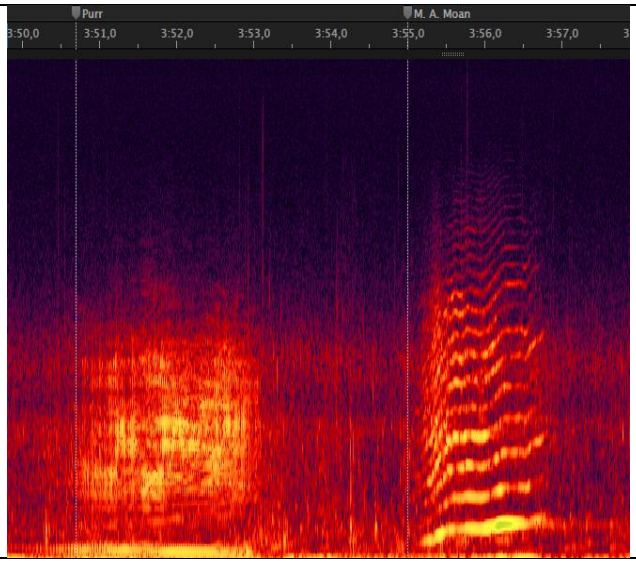
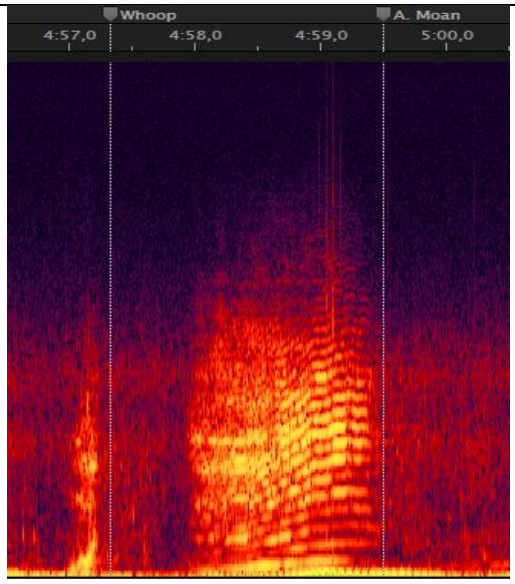
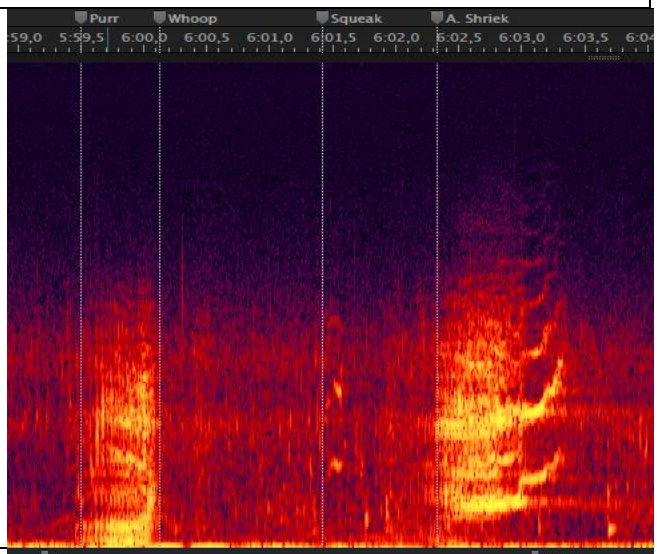
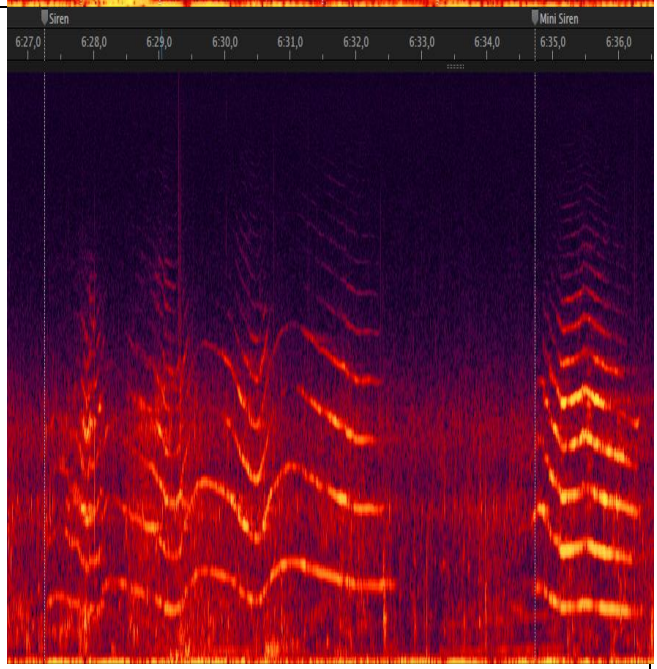
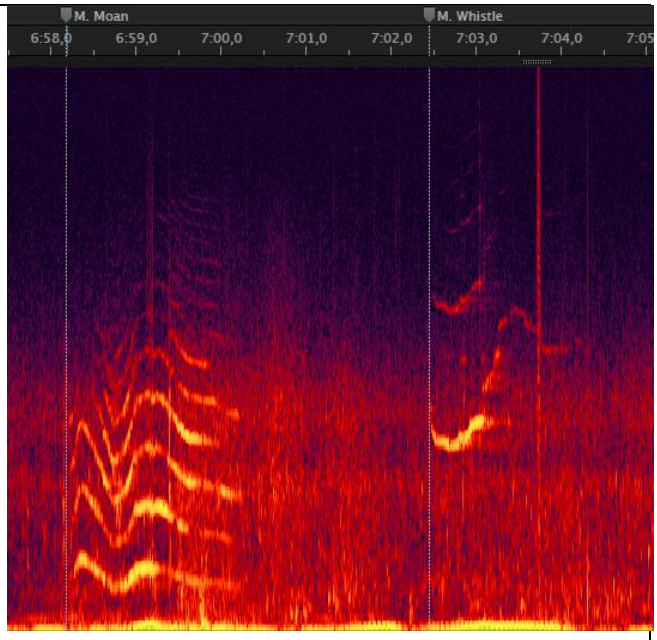
4	Groan – D. Moan	
5	Groan – D. Moan Groan	

Tabla 7: Green Song (2015)

Theme Number	Units in a typical phrase for each theme	Spectrographs of each Theme
1	A. Moan – A. Moan A. Moan – M. A. Moan	

	S. A. Moan– S. A. Moan– S. A. Moan– S. A. Moan– M. A. Moan	
2	L. Purr – M. A. Moan	

3	Whoop – A. Moan	
4	<u>Purr Whoop</u> – Squeak – A. Shriek	
5	Siren – Mini Siren	

	M. Moan – M. Whistle	
6	M. A. Moan – <u>Groan Moan</u>