Whistle repertoire analysis of the short-beaked common dolphin, *Delphinus delphis*, from the Celtic Deep and the Eastern Tropical Pacific Ocean

By Emily T. Griffiths



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<u>Abstract</u>:

Understanding the vocal repertoire of a cetacean species enables us to understand how they interpret their environment and their social interactions. The short-beaked common dolphin *Delphinus delphis* is one of the most widely distributed dolphins in the world. They emit narrow-band tonal whistles generally between 5-20 kHz, but can range from 1-50 kHz. Whistle characteristics from two geographically separate populations of *D. delphis* were analyzed and compared: the Celtic Deep in the southern Irish Sea and Eastern Tropical Pacific Ocean communities. The whistle parameters of both populations were measured, external confounding factors were assessed to determine how they contributed to variation, and visual whistle contour classification was tested against a quantitative whistle contour classification. The range of frequencies emitted by dolphins in the ETP were generally broader than those emitted in the Celtic Deep (global R=0.043, p<0.001; ²=44.654, df=1, p<0.001). The different populations also showed differences in their whistle contour composition (2=8.535, df=1, p=0.003). Spatial and temporal factors such as water column depth, time of day, year and encounter location were examined and their effects on the common dolphin repertoire were investigated. Encounter location, water column depth and time of day were all found to have a significant influence. The visual classification system used by Ansmann et al. (2007) and the quantitative contour similarity (CS) technique used by McCowan (1995) were both applied to classify whistle contours from the ETP. The CS technique provided a good description (proportions of ascending and descending) of whistle slope tendencies, but ultimately did not identify general or clear whistle contour categories. The different vocal repertoires of the two communities could be attributed to the nature of the different locations, environmental and anthropogenic situational factors.

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Declaration:

This work has not previously been accepted in substance for any degree and is not being concurrently submitting for any degree.

This dissertation is being submitting in partial fulfilment of the requirement of Master of Science (M.Sc.) in Marine Biology.

This dissertation is the result of my own independent work / investigation, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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1. Introduction

The advanced development of the cetacean auditory system is indicative of their life history and behaviour. Unlike most mammals, cetaceans rely heavily upon emitting and receiving sound to describe their surroundings and it is believed pass information to one another (Au, 1993; Richardson *et al.*, 1995; Tyack, 2000). Understanding the vocal repertoire of cetacean species aids us to understand how they interpret their environment and their social interactions. In this study recordings from two populations of short-beaked common dolphins *Delphinus delphis* were analysed from geographically separate locations: the Celtic Deep in the southern Irish Sea between Ireland and Pembrokeshire, SW Wales, and the Eastern Tropical Pacific Ocean.

1.1 Auditory biology

Sound, if uninterrupted, can propagate further and faster in an aquatic environment than other forms of receptive energy (Au, 1993). By having a sensitive receiving system over a wide frequency range, cetaceans can maximise this mode of perception. Figure 1.1.1 shows a cross-section of a dolphin's sound reception complex. Cetacean auditory biology is highly modified from their terrestrial ancestors. External auditory features are severely reduced to a barely visible meatus, and it is argued whether or not indeed the meatus is used in sound transmission at all (Au, 1993). The more common theory is that sound conduction takes place in a fat pad found along the mandible (Norris, 1964; McCormick et al., 1970; Brill et al., 1988; Møhl et al., 1999). As sound is received, it vibrates the fat pad that is directly connected to the tympano-periotic bone complex of the middle ear (Norris 1964, 1968a). The impedance of the mandible fat pad is similar to the impedance of seawater, which allows an easy transmission of sound vibrations to the high impedance of the cochlea (Au, 1993). In a typical terrestrial mammalian ear, the malleus is suspended in the middle ear cavity by the tympanic membrane, or the eardrum, to conduct sound vibrations. Since in a cetacean bulla sound vibrations are received from the mandible, the malleus is fused with the tympano-periotic bone complex allowing sound to travel down a solid ear cannel (McCormick *et al.*, 1970). The tympanoperiotic bone complex is surrounded by soft tissue or air sinuses in addition to having a medial synostosis between the tympanic and periotic bones, thus making the dense bulla completely separated from the skull (McCormick *et al.*, 1970). This evolutionary adaptation enables cetaceans to receive sound independently in each ear, allowing them to determine the direction of the sound detected (Au and Moore, 1984).

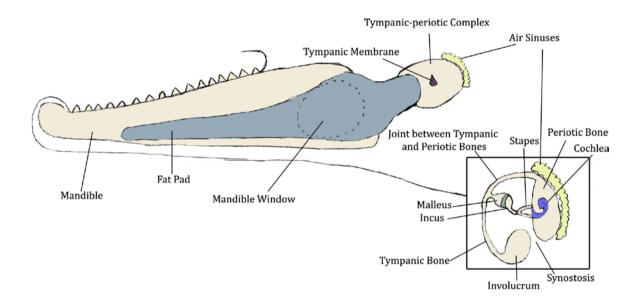


Figure 1.1.1. Drawing of general delphinid sound reception cross-section from the left-hand side. Inset: 90° counter-clock wise rotation cross-section of tympano-periotic bone bulla.

All mammalian ears measure sound via frequency bands. Cetaceans have a greater sensitivity to detect subtle and high frequencies due to an increased density of ganglion cells within the ear (Tyack, 2000). It is believed that delphinids can hear upwards of 150 kHz (Au, 1993; Nummela, 2009); in captivity the bottlenose dolphin and Risso's dolphin were able to detect well over 100 kHz (Tyack, 2000; Nachtigall *et al.*, 2005). Harbour porpoises, which are closely related to delphinids, have been documented detecting frequencies up to 180 kHz (Kastelein *et al.*, 2002). Acoustic energy, as apposed to visual or olfactory, can be more accurately directed and interrupted in an aquatic environment (Au, 1993).

1.2 Vocalisations and communication

There are four different types of sounds emitted by cetaceans; tonal whistles, echolocation pulses, burst pulses and non-vocal splashes and claps (Richardson *et al.* 1995; Gordon and Tyack, 2001; Dudzinski *et al.*, 2009; Frankel, 2009). The act of echolocation is well studied in both dolphins and bats, providing the animals with a sense of the range, speed, size and direction of movement that the object of interest exhibits, as well as the overall marine environment it inhibits (Au, 1993). Other forms of vocalisations in cetaceans are believed to be used as a system of communication to facilitating social behaviours such as hunting coordination, mating and/or dominance displays or simple play (Richardson *et al.*, 1995, Connor *et al.*, 2000; Dudzinski *et al.*, 2009). There are six functions of animal communication, all derived from the classic view; the conveying of information directed to the recipient from the sender. Delphinids use vocalisations and acoustic perception when performing or learning from an advertisement, tonic communication, deception, environmental, interception or associative learning (Tyack, 2000).

Large brains evolved to integrate complex echolocation and other vocalisations into delphinid ecology and behaviour. Their high glial cell to neuron ratio allows us to speculate that complex communication is occurring within their behavioural vocal repertoire (Marino *et al.*, 2007). Cetaceans have been known to demonstrate advanced cognitive abilities such as learning, self-recognition, imitation, complex social behaviour and memory (Tyack, 1986a; Evans, 1987; Nikol'skayo and Petrov, 1992; Tyack, 2000; Reiss and Marino, 2001; Marino *et al.*, 2007; Würsig, 2009).

1.2.1 Narrow-banded tonal whistles

Narrow-banded tonal whistles (hereby known as whistles) are thought to be a method of communication throughout a cetacean community as they can travel through water for longer distances than other sounds produced by odontocetes, but generally with less direction than the higher frequency pulses (Dudzinski *et al.*, 2009). Not all odontocetes can produce whistles, and those that can are generally considered to be large herders (Richardson *et al.*, 1995; Murphy *et al.*, 2008). The time span of a whistle is generally referred to as its waveform, shape or contour (Au, 1993). Whistles can be continuous or contain breaks; they can be unmodulated, trilled, ascending, descending, slow wavering or any combination of the aforementioned (Richardson *et al.*, 1995).

Different authors have used different methods to classify whistle contours, but an upsweep is always present and notably the most commonly emitted amongst different species (McCowan, 1995; McCowan and Reiss, 1995a; Bazúa-Durãn and Au, 2002; Erber and Simão, 2004; Scullion, 2004; Ansmann, 2005; Azevedo and Van Sluys, 2005; Pivari and Rosso, 2005; Ansmann et al., 2007). Other commonly observed whistle contours were downsweep (McCowan and Reiss, 1995b; Bazúa-Durãn and Au, 2002; Ansmann et al., 2007; Petrella, 2009), concave (McCowan and Reiss, 1995b), and 'L' (Scullion, 2004) whistles. Bottlenose dolphin calf whistles are known to be highly variable and unstable, although 66% of productions were upsweeps (McCowan and Reiss, 1995b). Bazúa-Durãn and Au (2002) reclassified the whistles of spinner dolphins Stenella longirostris to account for time as well as contour, and found that 44% of their whistles were less than 300ms duration. When these 'chirps' were removed from the main body of spinner dolphin whistles as a separate whistle category, upsweeps became the second most common whistle found at 27%, and the sine contour was third with 11%. Many of the whistles originally found to be upsweeps were reclassified as chirps indicating that chirp whistles could be an independent whistle type. It is difficult to make comparisons between the whistle contours of different populations and species due to the different classification systems have been used between studies (McCowan; 1995; Janik, 1999; Bazúa-Durãn and Au, 2002).

Whistle parameters, as seen in Figure 1.2.1, are often used to describe whistle contours. Start frequency, end frequency, minimum frequency, maximum

frequency, mean frequency, absolute frequency gradient, frequency range, whistle duration, number of inflections and number of steps are just some of the whistle characteristics that are measured while analysing delphinid whistles (Steiner, 1981; Bazúa-Durãn and Au, 2002; Rasmussen and Miller, 2002; Erber and Simão, 2004; Oswald *et al.*, 2004; Azevedo and Van Sluys 2005; Pivari and Rosso, 2005; Ansmann *et al.*, 2007; Oswald *et al.*, 2007; May-Collado and Wartzok, 2008; Petrella, 2009).

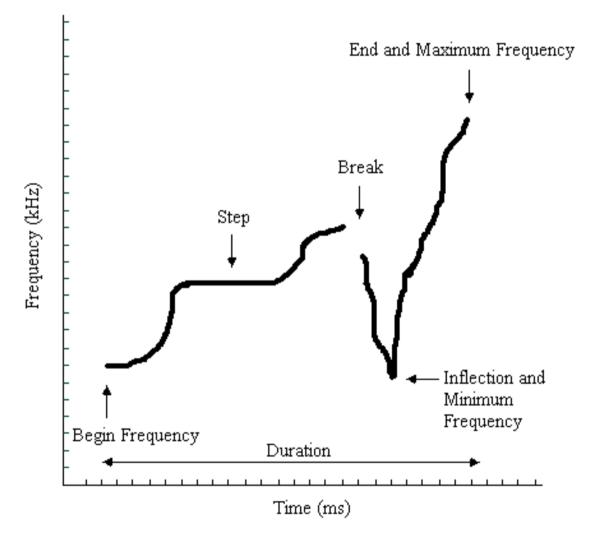


Figure 1.2.1. An illustration of whistle parameters noted and measured in different Delphindea species. *Adapted from*: Ansmann *et al.*, 2007.

1.2.2 Community communication

One of the best examples of delphinid community communication is the resident killer whales *Orcinus orca* in the Northeastern Pacific. Killer whale pods have

distinct differences in their vocal characteristics in resident populations. These dolphins can emit calls that are used to coordinate and communicate within a closed population (Ford, 1989; Ford, 1991). The different 'dialects' in the structural parameters of the dolphin's calls are unique to each of the different populations and are constantly evolving (Deecke *et al.*, 2000). Dialects are not documented in transient killer whales, only in resident populations of the northeastern Pacific Ocean. A phylogenetic analysis confirmed a distinct difference between the mitochondrial DNA halotypes of resident and transient killer whales (Hoelzel *et al.*, 1998), indicating that certain populations of *O. orca* have not only evolved a higher means of communication but are evolving differently to other populations.

Community communication in other delphinids is not as clear. Even though it is more likely that dolphin species with a larger habitat range will have more variation in their whistle characteristics between communities (Steiner, 1981), distance has proven to be a poor indicator of vocal similarities of the smaller, coastal species. The bottlenose dolphin, *Tursiops truncatus*, a species with global distribution, has demonstrated that the location of a community's home range can have a larger impact on vocal variation than distance (May-Collado and Wartzok, 2008). Bottlenose dolphin pods that reside in areas with other dolphin species, with low visibility, low boat traffic and steady ambient noise levels used a common frequency range while dolphins in areas that are isolated from other delphinid species, high visibility, high boat activity and varying levels of ambient noise used significantly different frequencies between pods (May-Collado and Ansmann et al. (2007) speculated that the cause for the Wartzok, 2008). difference in short-beaked common dolphin Delphinus delphis whistle parameters between the Celtic Deep and the English Channel was the higher level of background noise found in the English Channel due to the high boat traffic. These variations are not thought to be dialects due to the fission-fusion nature of common dolphin communities but rather based upon different behaviours and environmental variation (Ansmann, 2005). Therefore the differences in whistle parameters in neighbouring communities of Delphinus *delphis* and *Tursiops truncatus* are likely to be area specific and may be affected by external factors such as background noise.

1.2.3 Signature whistles

There has been some controversy on the possible existence of signature whistles. Highly mobile cetaceans have a higher need for an effective method of communication and recognition in a social community. Signature whistles, a highly stereotypic unique whistle contour that an individual dolphin repeats, satisfy that need (Tyack, 1986a, 2000; Sayigh and Janik, 2009). Many researchers have presented results that indicate that up to 90% of a dolphin's repertoire consists of signature whistles (Caldwell and Caldwell, 1965; Sidorova and Markov, 1992; Janik and Slater, 1998). Other studies, using similar methodology to the studies that found signature whistles to be present, found no evidence to suggest dolphins have a vocal system of individual recognition (Steiner, 1981; McCowan and Reiss, 1995a; McCowan and Reiss, 2001). What has been suggested to combine these two schools of thought is that large social groups may share similar repertoires, or that different whistles may convey 'signature information' within a whistle type and parameter variations (McCowan and Reiss, 1995a; McCowan and Reiss, 2001). Perhaps because some studies find evidence of signature whistles while others do not, it may be that groups of dolphins share a unique signature whistle (McCowan, 1995). This is plausible considering that in studies that find signature whistles present, captive dolphins have been known to whistle other dolphins' unique calls (Tyack, 1986a; Janik and Slater, 1998).

1.3 The short-beaked common dolphin, *Delphinus delphis*

The short-beaked common dolphin *D. delphis* is in the taxonomic family of Delphinidea that contains roughly 34-36 marine species with a noticeable beak, conical teeth and falcated dorsal fin (Jefferson *et al.*, 1993; Evans, 2008). This family of odontocetes has been referred to as the 'taxonomic trash basket' as

various sized odontocete have been included, ranging from the 1 metre long members of the genus Sotalia to the possibly 9.8 metres long Orcinus (Jefferson et al., 1993). There has been much discussion about how many species there are in the genus of *Delphinus*. The two currently recognised species are *D. delphis* (the short-beaked common dolphin) and D. capensis (the long-beaked common This division arises from the distinct separate colour patterns (D.dolphin). delphis has more colouration), vertebra count (D. delphis have less vertebrate on average), tooth count (*D. delphis* have fewer and larger teeth), shape of the skull (significant difference in the ratio between rostrum length and zygometric width), and overall body shape. D. delphis are a stouter species while D. *capensis* are elongated by comparison. While *D. delphis* grow shorter but heavier, D. capensis grow larger but remain lighter than D. delphis at the same length (Heyning and Perrin, 1994). D. capensis prefer coastal, shallower and warmer waters than D. delphis, such as the coastal waters of California (Heyning and Perrin, 1994; Perrin, 2009).

There are a number of possible sub-species in *Delphinus*. The extremely longbeaked common dolphin, or the Indo-Pacific common dolphin, is currently known as *D. capensis tropicalis* Van Bree. This dolphin is closely related to the longbeaked common dolphin but differs in size, coloration, vertebra count, tooth count and rostral length to zygomatic width ratio (Heyning and Perrin, 1994; Jefferson and Van Waerebeek, 2002). This dolphin is only found in limited areas around the world. Even more limited by its habitat is the Black Sea common dolphin, or *D. delphis ponticus*, identified by Amaha in 1994. It is believed that this is a possible subspecies of the short-beaked common dolphin, although it has yet to be determined. Possible sub-speciation is also speculated with *Delphinus* sp. in New Zealand waters (Stockin and Visser, 2005; Stockin, 2008).

D. delphis is a slender member of the family Dephinidae, although it is bulkier in those localities where its home range is in cooler, pelagic offshore waters. It has a slightly falcate dorsal fin and anywhere between 40-61 pairs of conical teeth (Jefferson *et al.*, 1993). The short-beaked common dolphin (hereby referred to as the common dolphin), is one of the most widely distributed dolphins in the world and is found between the latitudes 50°S and in the northern Pacific Ocean, 50°N, and in the northern Atlantic Ocean, 60°N, as seen in Figure 1.3.1 (Jefferson *et al.*, 1993; Reeves *et al.* 2002; Reid *et al.*, 2003). Although the common dolphin inhabits both warm and cold waters it believed that they favour waters between $11.5-15^{\circ}$ C. In northeastern Atlantic waters, common dolphins were most commonly visually recorded in deeper, pelagic waters (Anderwald, 2002; Reid *et al.*, 2003;). In warmer latitudes, *D. delphis* mainly reside in cooled upwelling areas (Wade and Gerrodette, 1993). However, these areas also recruit the highest tonnage of fish per square kilometre and therefore are an invaluable source of food for not only common dolphins but also other marine mammals (Mangel and Hofman, 1999; Perrin, 2009).

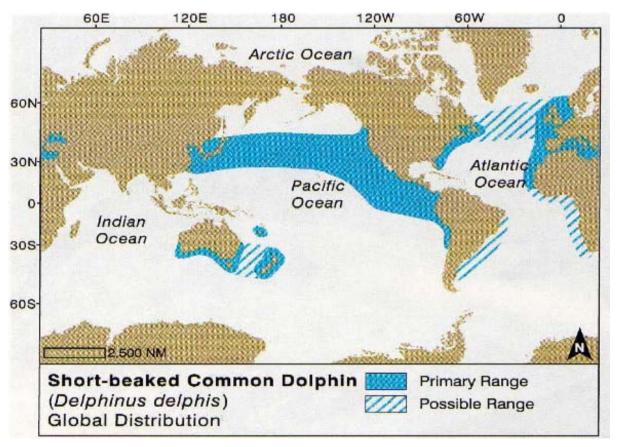


Figure 1.3.1. Global distribution of the short-beaked common dolphin *Delphinus delphis* Linnaeus. *Source*: Reeves *et al.* 2002.

Figure 1.3.2 is an illustration of the coloration patterns typically found on a common dolphin, best known for its hourglass shading of black, grey, white and

yellow. The spinal field of the dolphin's dorsal surface is dark, fading out to grey and white in the flank patch. The thoracic patch behind the eye of the dolphin is brown-yellow underlined with a white streak. The eye itself has a patch of black, but is separate from the dark spinal field and beak coloration. The flipper is a dark colour and often has a strip leading from the beak. There is also a flipperto-anus strip leading from below the eye or the flipper patch to the anus on the ventral side of the dolphin, lining the abdominal field. The coloration of common dolphins varies within communities and in different populations across the world. The distinct coloration *D. delphis* potentially could have evolved from the need for social signals or to deceive prey and/or predators (Dudzinski *et al.*, 2009).

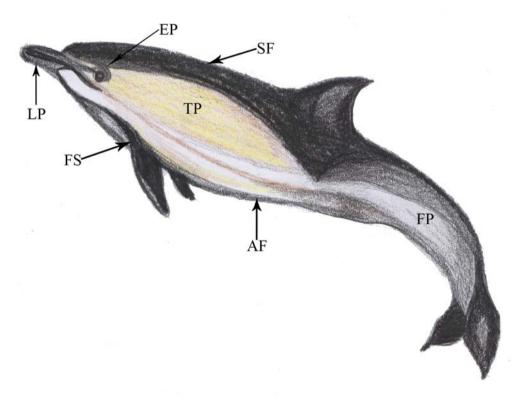


Figure 1.3.2. Typical coloration and patterns found on *Delphinus delphis*, the short-beaked common dolphin. AF = abdominal field, EP = eye patch, FP = flank patch, FS = flipper strip, LP = lip patch, SF = spinal field and TP = thoracic patch.

Common dolphins display slight sexual dimorphism (Evans, 1994; Murphy *et al.*, 2008; Perrin, 2009). Males differ in body length, cranial and post anal hump measurements (Murphy *et al.*, 2008). Overall body length of *D. delphis* ranges between 155-233cm but vary in different regions across the world (Ohizumi *et al.*, 1998; Murphy *et al.*, 2008; Perrin, 2009). The largest male on record is

260cm, while the largest female is 230cm (Jefferson *et al.*, 1993). The heaviest common dolphin on record is 200kg (Perrin, 2009) but they typically range from 52-91kg (Ohizumi *et al.*, 1998). It is not well known how long these animals can live, although the oldest common dolphin recorded in the NE Atlantic was a male aged 28 years old (Murphy *et al.*, 2008).

Seasonal mating for common dolphins occurs between May and September when mature males' testes shift in biomass and cellular activity and mature females gain the ability to become pregnant (Murphy et al., 2008). D. delphis are known to be promiscuous. The males have large sperm cells to assist their seed in being good competitors against other sperm cells (Murphy et al., 2005). Common dolphins are thought to become sexually mature when individuals are older than 10 years. In the North Pacific Ocean average age of maturity was determined to be 10.5 years, while in the Northeast Atlantic Ocean the average age was 11.68 years (Ferrero and Walker, 1995; Murphy et al., 2005). Copulating and birthing are timed to occur in the same season since gestation lasts between 10-12 months (Ferrero and Walker, 1995; Murphy et al., 2005; Murphy et al., 2008; Perrin, 2009). Calving could potentially stimulate the next generation of mature common dolphins to reproduce. At birth, calves are 80-85 cm in length (Jefferson et al., 1993) and can feed on their mother's milk for 10.4 months, but are capable of digesting solid food at 3 months old (Murphy et al., 2008). It is believed that male calves perhaps suckle from their mother for longer periods than females so as to improve their strength and size (Tyack, 1986a), but this has not been comprehensively proven. Common dolphins, like many members of the family Delphinidae, have a long calf-rearing period of 42.5 months (Murphy et al., 2008).

It is believed that the diet of common dolphins varies seasonally, and they consume whatever is abundant in terms of local fish and squid stocks as their primary prey source (Silva, 1999; Murphy *et al.*, 2008). Stomach samples reflect a diet of large quantities of deep scattering layer migrating, epipelagic shoaling

fish and squid averaging 4-5cm in length and 27g in weight (Young and Cockcroft, 1994; Ohizumi *et al.*, 1998; Silva, 1999; Meynier *et al.*, 2008).

Group size of common dolphin schools varies depending on location. Average group size is thought to be around 12-20 but can range from a single dolphin to hundreds or, in some instances, even thousands (Evans, 1987; Jefferson *et al.*, 1993; Bush, 2006; Murphy *et al.*, 2008). The benefits of living in a group include aid in finding food, defence against predators, access to reproductive members and group assistance in calf rearing (Evans, 1987). Large groups are known to associate with mass feeding or migration in common dolphins (Evans, 1987; Murphy *et al.*, 2008). The common dolphin frequently associates with other closely related species such as the striped dolphin *Stenella coeruleoalba*. Calves of both species have even been recorded in these mixed schools (Frantzis and Herzing, 2000). In New Zealand however, where common dolphin populations are less threatened, 74.3% of observed schools were noted to be single species (Stockin *et al.*, 2008). This social behaviour suggests that the common dolphin prefers to reside in large numbers and will rely on similar species for protection if their community is in decline.

D. delphis are playful, gregarious mammals and are often spotted jumping out of the water, bow-riding and darting around at high speed (Jefferson *et al.*, 1993; Richardson *et al.*, 1995). Common dolphins are known to be attracted to moving vessels to come and aerially demonstrate and 'play' (Murphy *et al.*, 2008). Because of this behavioural tendency, obtaining common dolphin acoustic recordings is more feasible than when working with a more reclusive species. Whistles of the common dolphin average between 5-20 kHz but can range from 1-50 kHz at 172dB (Moore and Ridgway, 1995; Murphy *et al.*, 2008).

1.4 North Eastern Atlantic (The Celtic Deep)

Local to British waters, *Delphinus delphis* is one of nine odontocete species that can be found regularly in northeastern Atlantic waters surrounding the United Kingdom and is the only dolphin species regularly occurring in the Celtic Deep (www.seawatchfoundation.org.uk). The common dolphin is the most commonly spotted cetacean in the Bay of Biscay, the English Channel, and the Irish and Celtic Seas with an estimated population of 63,400 (CoV=0.46) individuals (Hammond, 2008; Murphy *et al.*, 2008). Figure 1.4.1 demonstrates the overall distribution of the species in British and Irish waters.

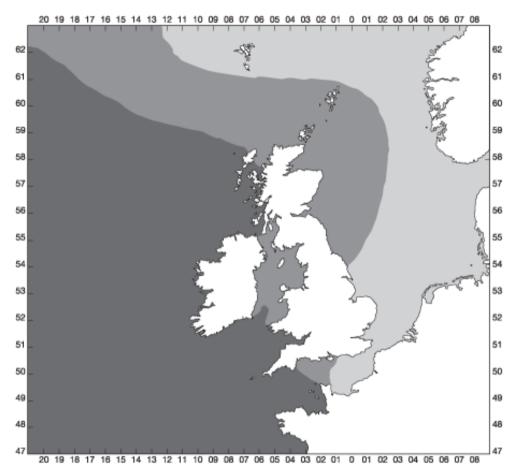


Figure 1.4.1. The overall abundance distribution in the northeastern Atlantic of *Delphinus delphis*. Darkest grey = regular; and common intermediate grey = less common; light grey = occasional. *Source*: Evans, 2008.

Previous students from the School of Ocean Sciences alongside Sea Watch Foundation researchers have collected acoustic and visual recordings of *Delphinus delphis* from the southern Irish Sea (Scullion, 2004; Ansmann, 2005; Bush, 2006). Narrow-banded whistles were generally recorded while cetacean monitoring surveys were being conducted. Ansmann (2005) evaluated the data for a possible relationship between whistle characteristics and short-beaked common dolphin behaviour documented on surveys. Her analyses provided insight into possible behavioural correlations with whistle parameters as well as suggested different common dolphin populations in the Celtic Deep and the English Channel (Ansmann, 2005; Ansmann et al., 2007). Bush (2006) compiled D. delphis whistles from all three years for a more general analysis. However, her analyses concentrated more on environmental influences upon the shortbeaked common dolphin than whistle characteristics and their relationship with dolphin behaviour. Trends in common dolphin local distribution in terms of depth, sea surface temperature, and chlorophyll-a concentrations were determined. Bush speculated that common dolphin abundance was not affected by intolerance to chlorophyll-a, but rather that chlorophyll-a exists in higher concentrations in coastal waters that are warmer and shallower than waters that are cooler and deeper. In her thesis, Ansmann (2005) found that whistle characteristics were significantly related to the encounter. Whistle parameters within the same encounter in the Celtic Deep were found to be more similar than whistles from other encounters. Whistles were also found to be highly variable. To account for some of the variability, a temporal analysis using the acoustic data collected from the Celtic Deep will be conducted here and the spatial factors discussed in Bush's (2006) thesis, will be applied.

1.5 Eastern Tropical Pacific Ocean

Both the short-beaked and the long-beaked common dolphin are present in Eastern Tropical Pacific Ocean (ETP) waters. Frequently, while conducting population estimates on the abundance and distribution of cetaceans in the ETP, the two species are pooled if sufficient information to distinguish them is not available in the field (Wade and Gerrodette, 1993). Divided into three areas, *Delphinus* sp. is more commonly found in the southern region of the ETP with a population estimate of 2,210,900 (CV=0.217). In the northern and central regions population estimates are 476,300 (CV=0.367) and 406,100 (CV=0.383), respectively (Wade and Gerrodette, 1993).

Table 1.4.1. Common dolphin whistle parameters collected from the Celtic Sea, English Channel, Eastern Tropical Pacific Ocean, and the Hauraki Gulf in New Zealand given as means and standard deviations (in parenthesis). English Channel values marked with an asterisk (*) were significantly different from the corresponding Celtic Sea whistle characteristics in Ansmann *et al.* (2007).

	Celtic Sea (Ansmann <i>et</i> <i>al.</i> 2007)	English Channel (Ansmann <i>et al.</i> 2007)	Eastern Tropical Pacific Ocean (Oswald <i>et al.</i> 2007)	Hauraki Gulf, New Zealand (Petrella, 2009)
Start	12.03	12.64 *	11.63	12.593
Frequency	(3.47)	(3.95)	(4.84)	(4.069)
	11.97	12.48 *	12.18	12.295
End Frequency	(3.25)	(3.97)	(4.38)	(4.075)
Minimum	9.45	9.80 *	8.30	11.393
Frequency	(2.06)	(2.46)	(2.69)	(3.895)
Maximum	14.69	15.84 *	15.04	13.605
Frequency	(3.13)	(3.28)	(4.39)	(4.131)
Mean	11.89	12.67 *		12.461
Frequency	2.05	(2.37)	-	(3.807)
Frequency	0.38	0.51		-0.893
Gradient	(9.73)	(11.63)	-	(14.395)
Absolute	6.97	8.36 *		
Frequency	(6.79)	(8.09)	-	-
Gradient	(6.79)	(8.09)		
Frequency	5.24	6.03 *		2.213
Range	3.25	(3.42)	-	(2.606)
Duration	0.65	0.64	0.70	0.27
Duration	(0.33) (((0.32)	(0.39)	(0.319)
Traffaction	0.64	0.56 *	1.64	0.56
Inflections	(0.98)	(0.91)	(1.87)	(0.863)
94.0	0.13	0.10	1.76	0.06
Steps	(0.39)	(0.34)	(2.31)	(0.349)

Table 1.4.1 lists the short-beaked common dolphin whistle parameters measured by Ansman *et al.* (2007) in the Celtic Deep and English Channel, by Oswald *et al.* (2007) in the ETP and the *Delphinus* sp. whistles parameters from Hauraki Gulf, New Zealand. Acoustic studies in the ETP have been directed towards species identification of delphinid whistles. Using the methodology outlined in Oswald *et al.* (2007), many species of odontocetes local to ETP waters can be acoustically identified in real-time. Unfortunately, the short-beaked common dolphin in that region can be vocally confused with other small delphinid species that have similar whistle parameters. In their study, it was found that *Delphinus delphis* and *D. capensis* whistle characteristics were not statistically different, and therefore had to be pooled. In the ETP the vocal repertoire of the short-beaked common dolphin is not easily distinguishable from other delphinids. The purpose of this study was to explore the vocal repertoire of the short-beaked common dolphin in two geographically separate locations: the Celtic Deep in the southern Irish Sea and the Eastern Tropical Pacific Ocean. To accomplish this, two approaches were taken:

- Location effects on whistle characteristics and type. Analysis of the whistle parameters and type to determine how and if they differ between the two samples.
- Confounding factors effects on whistle characteristics and type. Investigation whether spatial and temporal factors such as encounter location, time of day, year and water column depth impact upon common dolphin whistle parameters and type.

Additionally, two different methodologies of whistle contour classification were examined: Visual Classification and the Contour Similarity (CS) techniques. Both systems were used in this study to evaluate how a subjective system based upon visual observations fares against an objective system based on quantitative similarities.

From these objectives, the following hypotheses were developed:

- 1) The CS technique will more accurately identify whistle contour types than the previously used visual classification techniques.
- 2) Both whistle characteristics and type are significantly different between the Celtic Deep and Eastern Tropical Pacific Ocean.
- Both whistle characteristics and type are significantly different between the Celtic Deep and the ETP due to present confounding factors such as year, time of day, encounter location and water column depth.

2. Materials and Methods

2.1 Passive Acoustic Monitoring (PAM)

All recordings used in this analysis were collected using a towed hydrophone. As one of the earliest methods of acoustic monitoring, towed PAM configurations are very versatile and therefore have become a heavily-used technique in both academic and commercial circles (Thode, 2009).

2.1.1 Celtic Deep data collection

Acoustic data collected for two previous MSc theses with the Sea Watch Foundation (SWF) supplied most of the data for the UK. In June and July of 2004, the SWF conducted cetacean surveys in the Celtic Deep aboard the chartered boat *Liberty of White*. Two of these surveys were incorporated into this study. A twin array hydrophone aperture was towed 200-250 metres behind the sea vessel at approximately 10 knots between 5-10 metres below the surface of the water (Scullion, 2004). In the summer of 2005, four surveys were conducted by the SWF on the vessels *Llanstadwell* and *Predator*. For the first three surveys, a twin array hydrophone aperture was also deployed, towed behind the vessel at 88 metres (first survey) and 230 metres (second and third surveys). For the fourth survey, a single array hydrophone was towed 130 metres behind the boat (Ansmann, 2005).

Figure 2.1.1 shows a diagram of a basic hydrophone setup. In both years, the hydrophone used was composed of a screen cable and two Benthos AQ4 transducers. The hydrophone connects directly to an amplifier, which then feeds the acoustic signal through a BCN T-bar cable to 5V plugs of a filter box. The 3kHz filter box reduces the low frequency engine noise. From the filter box, the acoustic equipment is than plugged into a Sony Walkman Digital Audio Tape (DAT) TCD-D8 recorder with another BNC cable (TCD-D8 sensitivity: 20Hz to

22kHz). An 'acoustic observer' aboard the vessel listens to the audio input in real time with stereo headphones. The actual model of headphones used has varied over the years of data collection (Scullion, 2004; Ansmann, 2005), but is not thought to have affected the data collection procedures at all.



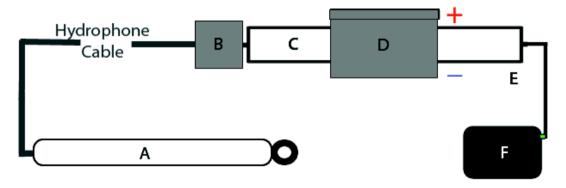


Figure 2.1.1. Basic hydrophone set-up. Upper photograph (by E. Griffiths) shows a deployed hydrophone being towed behind a research vessel to record delphinid vocalisations. Lower diagram illustrates the different components of a hydrophone complex: A) Hydrophone apparatus, B) amplifier, C) BCN T-bar cable, D) filter box, E) BCN Y-cable and F) DAT recorder.

SWF line transect cetacean surveys were conducted over the Celtic Deep between Pembrokeshire, SW Wales and the south coast of the Republic of Ireland from 51°30'N and 52°00'N latitude and 005°30'W and 006°20'W longitude (Figure 2.1.2). Surveys were completed on 21/06/04, 23/07/04, 16-17/05/05, 22/06/05,13-14/07/05 and 16-17/08/05. Cetacean surveys consisted of two primary observers, at least one extra independent observer, an acoustic observer, and a data collector who recorded effort every 15 minutes and at every change in conditions. Participants in the survey switched roles every hour to avoid fatigue, and usually there were extra surveyors on board to allow for breaks. Observers in these surveys documented each species sightings, noting the species seen, number of animals, group composition (adults, juveniles and calves), distance to vessel, direction of swim, behaviour when first observed, and behavioural reaction to survey vessel. Throughout a cetacean encounter, behaviours exhibited by the animals were recorded. These included bow riding, foraging, socialising, and travelling. The different behaviours were documented in the order they were observed. The hydrophone was towed behind the vessel during the line transect surveys but also opportunistically to and from the start and end of transects, when the water column was deep enough to avoid equipment damage.

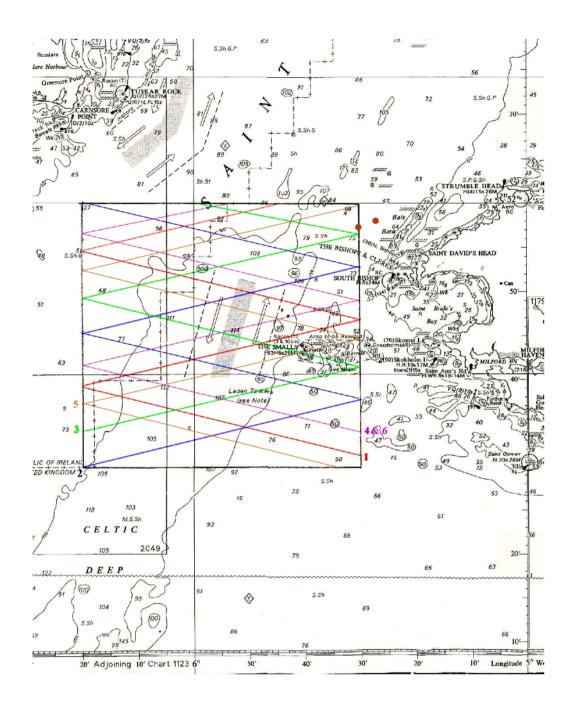


Figure 2.1.2. Area of the Celtic Deep surveyed by the Sea Watch Foundation and Ecologic. Each line indicates a different transect. $1 - \text{conducted on } 16 \cdot 17/05/05$. 2 - conducted on 22/06/05. $3 - \text{conducted on } 13 \cdot 14/07/05$. $4 - \text{conducted on } 16 \cdot 17/08/05$. 5 - conducted on 21/06/04. 6 - conducted on 23/07/04. The two red dots indicate the common dolphin encounters made by Jonathan Gordon and his crew in the summer of 2009.

Each 'sighting' of common dolphins and any other cetacean species was classified as an individual group. Analysing the sightings individually is impractical because it is not possible to distinguish two or more different groups of vocalising dolphins when both are in range of the hydrophone. Since sightings frequently overlapped one another, the acoustic information has been grouped together into 'encounters'. An encounter starts at the beginning of a sighting and ends after the last sighting has not been visually or acoustically detected for five minutes.

Jonathan Gordon from the environmental consultancy Ecologic, provided an additional two encounters recorded in stereo in the summer of 2009 during an acoustic porpoise monitoring survey (Figure 2.1.2). The towed hydrophones consisted of pairs of Magree HP03 hydrophone units separated by 25cm mounted in a 5m long 35mm diameter oil-filled polyurethane tube towed on 100m of strengthened cable. Each HP03 is made up of a 12.7mm piezoelectric ceramic sphere connected to a 35dB preamplifier that incorporates a 2kHz low cut filter to reduce lower frequency background noise. The nominal bandwidth of the element and preamplifier is 2–150 kHz. Signals from the hydrophone pairs were conditioned and further amplified using a Magree HP27ST amplifier filter box. Acoustic signals ranging from 2-24kHz were recorded continuously through an Edirol sound card with a 48kHz sampling rate.

Water column depth measurements, time of day, and location information were generally taken from the ship's survey effort log when available. Occasionally, however, water depth was not documented when an encounter occurred. In these cases, water column depth was acquired from the GEBCO General Bathymetric Chart of the Oceans (1984).

2.1.2 Eastern Tropical Pacific data collection

Julie Oswald of JASCO Research and the Scripps Institute of Oceanography supplied short-beaked common dolphin recordings collected from the Eastern Tropical Pacific (ETP) from 1998 and 2000. A single array hydrophone was towed approximately 200 metres behind the research vessel *Endeavor* (1998) and the NOAA ship *McArthur* (2000), at 10 knots 4-6 metres below the surface of the water. Much like the acoustic observer used by the SWF, an acoustic technician monitored the signal from the hydrophone on a single channel. In order to reduce engine, system, flow, and low frequency background noise, the signals were high-pass filtered up to 2kHz. Because the lowest frequency a common dolphin whistle has been recorded was above 3kHz, this high-pass filter was not thought to eliminate any whistles from the collected repertoire that would influence the results (Scullion, 2004; Ansmann *et al*, 2007). In 1998, signals of interest were recorded to a Sony TSD-D7 and -D8 DAT recorders (20Hz-22kHz \pm 1dB). In 2000, audio signals were directly converted into digital from analog with a Data Translation conversion card (*DT-3809*). High-pass and low-pass filters were applied before signals were recorded (Oswald *et al.*, 2003; Oswald *et al.*, 2004).

The survey area is outlined in Figure 2.1.3. The location coordinates of the 21 common dolphin acoustic encounters incorporated into this study can be found in Appendix 8.1. The area ranges north-south from the United States/Mexico border to the territorial waters of Peru and east-west from the continental shores of the Americas to the longitude of Hawaii. Visual line-transect cetacean surveys accompanied all acoustic recordings. All depth measurements for the ETP were acquired from GEBCO (1984).

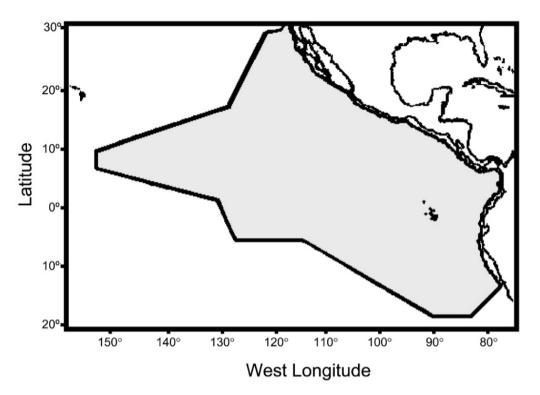


Figure 2.1.3. Area of the Eastern Tropical Pacific Ocean surveyed in 1998 and 2000 by Julie Oswald and team. Survey dates in which common dolphin recordings were made are 21-22/10/98, 29-30/11/98, 7/12/98, 11/08/00, 11/10/00, 20/10/00, 23/10/00, 1/11/00, 4-6/11/00, 1/12/00 and 6/12/00. *Image source*: Oswald *et al.*, 2004.

2.2 Spectrographic analysis

Whistles collected and analysed in 2004 and 2005 from the Celtic Deep were incorporated into this study. The audio files from those surveys were not re-sampled. The precise methodologies for how the whistles from Scullions's (2004) and Ansmann's (2005) work varies slightly from what is detailed below and can be found in their dissertations.

Audio files that only contained recordings of *Delphinus delphis* were imported into *Adobe Audition* version 3.0, as seen in Figure 2.2.1, at a 44.1 kHz sample rate and 16-bit precision as PCM .wav files. *Audition* creates a spectrogram window (Hanning window, 512 band resolution), dual channel if a twin array hydrophone was used in recording. Overall, the density of whistles present within the spectrogram rendered it impossible to determine the number of whistles in each recording. Using a random number table, a maximum of 50 whistles were selected from each encounter to avoid over sampling of a group or an individual. Each whistle was labelled as 'strong,' 'moderate' or 'weak' on the basis of their loudness. Strong whistles stood out clearly from the background noise being 10 dB louder or more, and were continuous. Whistles classified as 'moderate' were 'present and clear' such that the contour of the whistle was easily recognisable from the background at 5-10 dB, and were mostly continuous. Weak whistles were 'present': the whistle was detected but was not much louder (5dB or less) than the background noise and sometimes had breaks in the contour. Figure 2.2.2 gives examples of all three classifications.

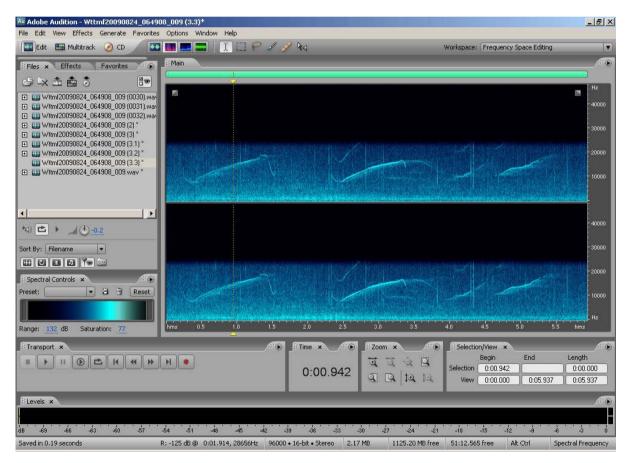


Figure 2.2.1. Example of audio files (.wav) being processed *Adobe Audition* v. 3.0. The whistles presented in this output are 'strong' whistles. The centre whistle has a harmonic present.

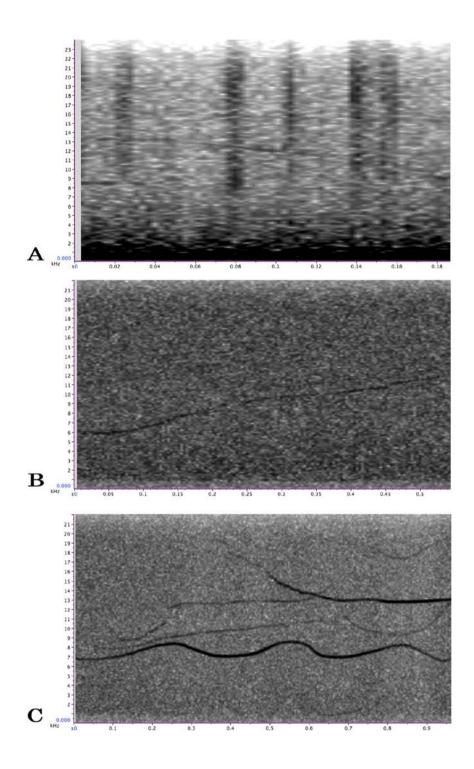


Figure 2.2.2. Example of A) weak (5dB or less), B) moderate (5-10dB) and C) strong (10dB or more) whistle power strengths.

Whistles from each encounter were then imported into *Raven Pro* version 1.3 for Mac OS X, developed at the Bioacoustics Research Program (2003-2008 Cornell

Lab of Ornithology). Figure 2.2.3 shows the spectrogram (setting: Hann window, 512 band width) within *Raven Pro* where points can be marked along the contour, allowing the user to 'trace' the whistle contour. The coordinates time (s), frequency (Hz) and power (dB) were saved for each point to a table that was exported to Microsoft Excel. Whistles were easily identifiable from other sounds produced by delphinids, such as burst pulses seen in the centre left of the Figure 2.2.3 display.

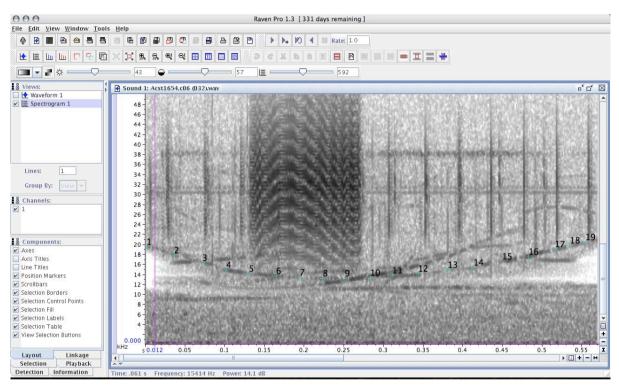


Figure 2.2.3. Example of individual whistle audio files (.wav) presented by *Raven Pro* 1.3. Due to the high whistle density the 'erased' areas were created by the author in *Adobe Audition* to identify the whistle selected in each file. Twenty points have been traced that mark the time(s), frequency (Hz) and power (dB) coordinates along the whistle.

2.3 Whistle characteristics

Eleven to thirteen parameters were measured from each whistle. Mean power and harmonics were only measured in whistles from the ETP and from those whistles collected in 2009 from the Celtic Deep. These parameters included:

Duration:	Time length of whistle in s.
Start Frequency:	Frequency whistle started in Hz.
End Frequency:	Frequency whistle ended in Hz.
Minimum Frequency:	Lowest frequency of the whistle in Hz.
Maximum Frequency:	Highest frequency of the whistle in Hz.
Mean Frequency:	Average frequency of all points marked while
	tracing whistle in Hz.
Frequency Gradient:	Total steepness of whistle calculated in Hz/s as:
	(End Frequency – Start Frequency)/Duration
Absolute FG:	The absolute value of the Frequency Gradient in
	Hz/s .
Frequency Range:	The full span the whistles frequency calculated
	in Hz as:
	Maximum Frequency – Minimum Frequency
Mean Power:	Average power of all points marked while
	tracing whistle in dB.
Harmonics:	Number of harmonics, or echoes, with the
	whistle. Harmonics mirror the whistles contour
	in a different frequency range.
Inflections:	Number of inflections within the whistle. An
	inflection was defined as a dramatic change in
	direction of the whistle's slope.
Step:	Number of steps present within the whistle. A
	step was defined as a section of constant
	frequency between two or more points within
	the whistle.

Statistical tests were performed on the whistle characteristics in order to determine whether a correlation was present with dolphin location, year, time of day, depth and between encounters.

2.4 Whistle classification

Both visual and quantitative classification systems were used to determine whistle contour categories. These systems were compared against one another to determine which provided a clearer classification system.

2.4.1 Visual whistle classification

In order to standardise comparisons between this study and other research conducted in UK waters, the methodology used by Ansmann et al. (2007) for classifying whistle contours, was adopted. As illustrated in Figure 2.4.1, this method outlines six basic contour types: A, constant frequency; B, upsweep; C, Each general contour downsweep; D, convex; E, concave; and F, sine. classification represents the overall whistle contour while the minor contour classifications, or subcategories, considered frequency modulations at the beginning (2), at the end (3), at both ends (4) of the whistle or no modulation at all (1). With upsweep and downsweep contours, subcategory 5 describes a predominant step present in the middle of the contour. Sine whistle contour subcategories describe the number of peaks within a whistle. A peak was defined as a change in frequency slope from ascending to descending, or vice versa. F1 and F2 have two whistle peaks, F3 and F4 have three whistle peaks, F5 and F6 have four whistle peaks, and F7 and F8 have five or more whistle All whistles analysed for this study were classified with this peaks. methodology. Graphical outputs of whistles from 2004 were used to determine whistle contour shape.

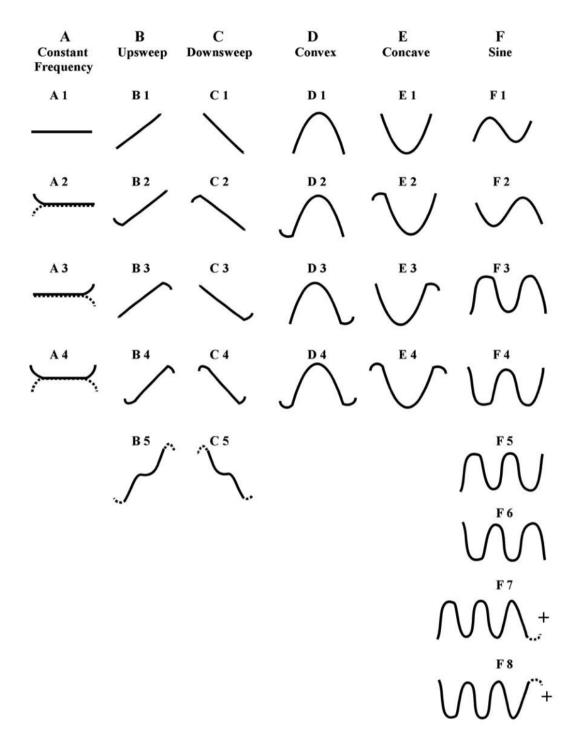


Figure 2.4.1. Illustrations of each whistle category and subcategory used in visual classification methodology. *Source:* Ansmann *et al.*, 2007.

2.4.2 Contour Similarity (CS) whistle classification

McCowan (1995) suggested using the CS technique which takes a quantitative approach to assess the mathematical similarities between whistles rather than a subjective human interpretation of contour shape. Her method marks an equal number of frequency points on each whistle equidistant from one another. To avoid losing contour information, a minimum of 20 points per whistle was determined, therefore in this study 20 points were selected along each whistle, as seen in Figure 2.2.3.

To create an index of similarity between the individual whistles and the data set, whistle frequency measurements were used to produce a Pearson correlation matrix. Correlation coefficients were generated for each whistle and its relationship to other whistle samples. In order to reduce the number of co-linear variables, a Principal Components Analysis (PCA) was conducted on the coefficients. Factors with an eigenvalue of 1.0 or greater were included in further analysis. Finally a k-means cluster means analysis on the factor scores was used to group the whistles together based on contour similarity. Because the statistical software BMDP was not available to the author, Primer (v.6) was used to create the Pearson correlation matrix, Minitab (v.15) was used to conduct the PCA, and the k-means cluster analysis was completed in SPSS (v.16). The clusters created using this method will be compared to the visual classification methodology introduced by Ansmann et al. (2007).

3. Results

From the work undertaken with the Sea Watch Foundation 1,343 whistles were incorporated into this study from 45 common dolphin encounters in 2004 and 2005. An additional 100 whistles were collected from the two encounters in 2009. A total of 1,443 whistles from the Celtic Deep were used in this analysis. From the seven common dolphin encounters in 1998 and the 14 encounters in 2000, 1,012 whistles from the Eastern Pacific Ocean were included into this study. From both locations, a total of 2,455 whistles were analysed. Recordings were only used in this analysis if surveyors were positive that *Delphinus delphis* was the only delphinid species in the hydrophone's range. Of the 1,112 whistles processed from the original audio files in this analysis, 14.66% were weak, 50.00% were moderate and 35.34% were strong.

Homogeneity of variance tests were conducted on the data in this study. Predominantly, the data were found to be non-parametric and therefore any test used was non-parametric unless otherwise noted.

3.1 Whistle contour type classification – the Contour Similarity (CS) technique

A random sampling of 100 whistles was used to assess this technique. To determine k, McCowan (1995) used BMDP software to create a twodimensional plot, continuously increasing the correlation percentage until there was no overlap in order to identify all separate whistle categories. However Janik (1999) discussed that these plots exclude dimensions where overlap does not exist, or vice versa. Therefore, cluster solutions ranging from $2 \le k \ge 25$ were conducted and the F ratios were summed (Figure 3.1.1). The k-means with the highest summed F value, 3 (F=397.058), was used in this analysis.

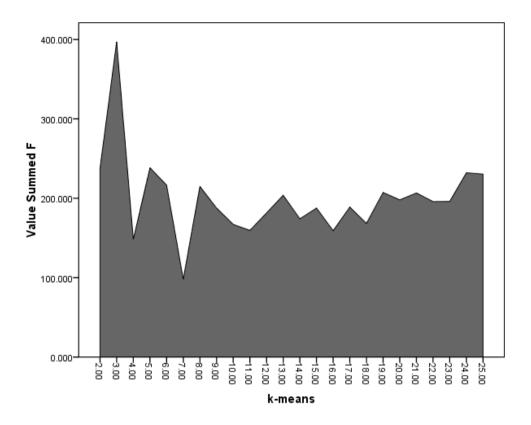


Figure 3.1.1. Summed F values for k-means cluster analysis, $2 \le k \ge 25$.

Figure 3.1.3 gives examples of three randomly selected whistles from the three clusters. Cluster 2 (N=37) appears to consist of whistles that have a descending tendency; cluster 3 (N=53) contains whistles with an ascending tendency; and cluster 1 (N=10) could only be classified as 'other' because the whistles within it could not be defined as similar.

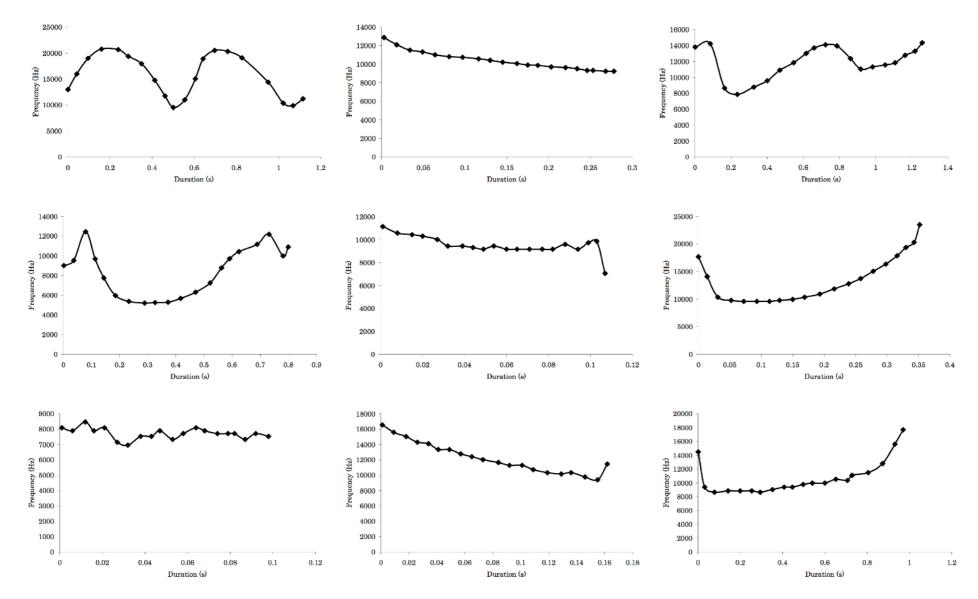


Figure 3.1.2. Graphical representations of three randomly selected whistles from clusters 1 (first column), 2 (second column) and 3 (third column).

Figure 3.1.3 shows the three clusters in a two dimensional space. Selecting the value of k, based on a high summed F value, provided no overlap between clusters when plotted. Cluster 1, or the 'other' category, demonstrated a less dense assemblage than clusters 2 and 3, reinforcing the concept that contours within cluster 1 exhibit a high amount of variation.

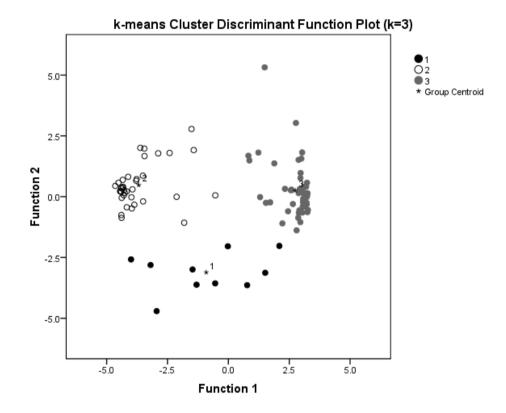


Figure 3.1.3. Two-dimensional discriminant function plot when k=3.

Descriptions, such as ascending tendency, descending tendency and other (clusters 3, 2 and 1, respectively), provide a good overview of the composition of whistle slopes which is consistent with what is already known about common dolphin whistle contours: upsweeps are dominant while downsweeps are the second most commonly emitted whistle contour (Ansmann, 2005). However, 3 is a very low value for k and as a result the CS technique has created very vague criteria for classifications. The first whistle selected in cluster 3, for example, is not strictly an upsweep but rather has sine or convex qualities. In an effort to create more specific general whistle contour categories, additional larger k values were examined. Figure 3.1.4 presents plots for k=5, 10, 15, and 20. As the integer k was increased, the clarity of the two-dimensional plots lessened.

Upsweeps and downsweeps were identified in all cluster analyses and plots, although most of the remaining clusters had three or less whistles within.

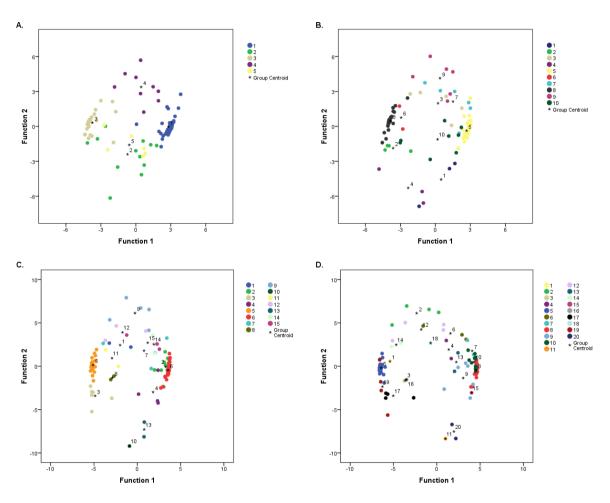


Figure 3.1.4. Discriminant function plots for A) k=5, B) k=10, C) k=15 and D) k=20.

Since general or clear whistle contour categories could not be identified using the CS technique, the visual classification system created by Ansmann *et al.* (2007) was solely used for the categorising of whistle types in this study.

3.2 Celtic Deep and Eastern Tropical Pacific whistle comparison

3.2.1 Whistle characteristics

An Analysis of Similarity (ANOSIM) test in Primer (v.6) yielded a positive global R value of 0.043 (p<0.001) between Celtic Deep and ETP whistle characteristics, indicating that the two locations exhibited higher similarity within location parameters than between. A non-parametric Kruskal-Wallis test was carried out in SPSS (v.16) and found that most of the whistle characteristics between the ETP and the Celtic Deep were statistically different from one another. Only Start Frequency (χ^2 =2.707, df=1, p=0.100) had no significant effect. The other parameters gave the following significant results:

- Duration (χ²=15.803, df=1, p<0.001)</p>
- > End Frequency (χ^2 =4.05, df=1, p=0.043)
- > Minimum Frequency (χ^2 =55.176, df=1, p<0.001)
- > Maximum Frequency (χ^2 =5.749, df=1, p=0.016)
- > Mean Frequency (χ^2 =11.846, df=1, p=0.001)
- > Frequency Gradient (χ^2 =5.470, df=1, p=0.019)
- > Absolute Frequency Gradient (χ^2 =19.567, df=1, p=0.001)
- Frequency Range (χ²=44.654, df=1, p<0.001)</p>
- Mean Power (χ²=5.130, df=1, p<0.001)</p>
- Harmonics (χ²=9.535, df=1, p=0.002)
- Inflections (χ²=111.768, df=1, p<0.001)</p>
- Steps (χ²=654.99, df=1, p<0.001)</p>

Mean Power and Harmonics were only measured where they were present. Figure 3.2.1 plots all of the whistle parameters with a 95% confidence interval. A summary of the mean, standard deviation, minimum and maximum of the whistle characteristics in each location are shown in Table 3.2.1.

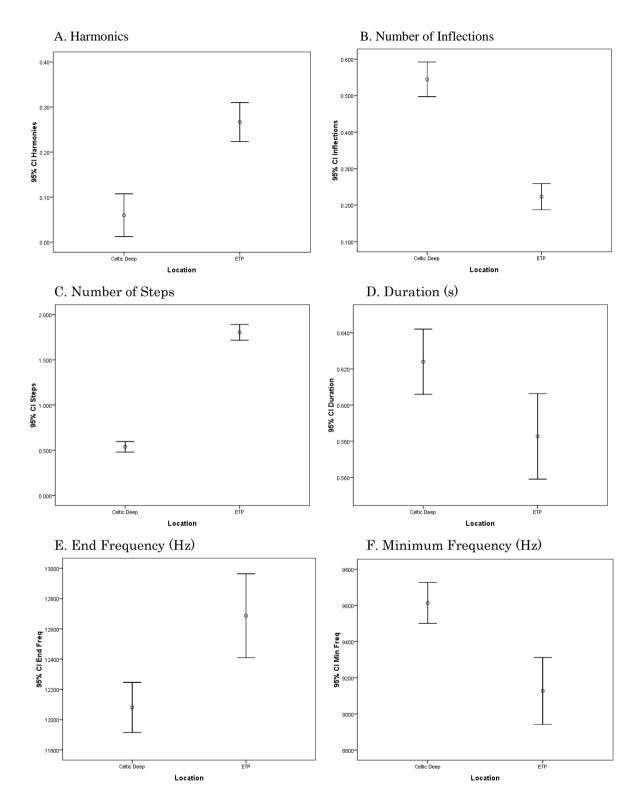


Figure 3.2.1(a).

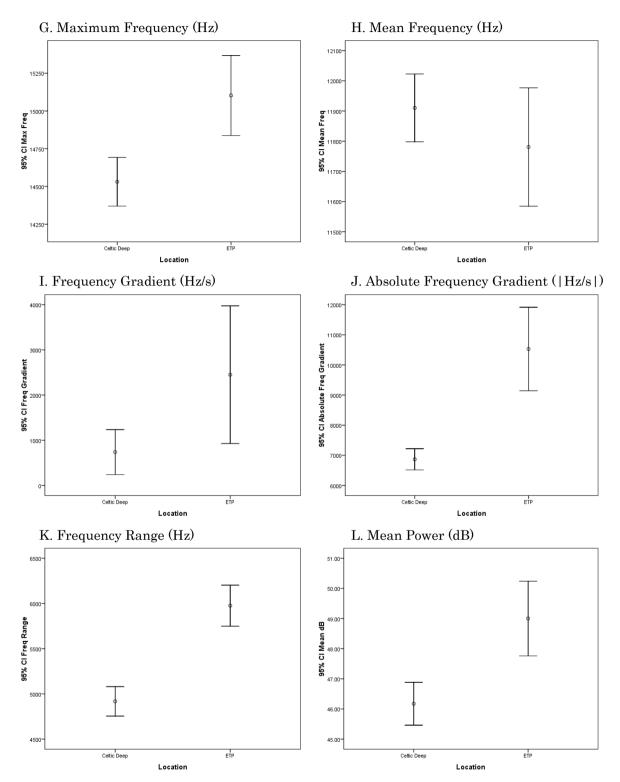


Figure 3.2.1(b). Whistle parameters with a 95% confidence interval that were significantly different between the Celtic Deep and the Eastern Tropical Pacific.

Celt	ic Deep and	willouico ioulio						
						Start	End	Minimum
					uration	Frequency	Frequency	Frequency
		Harmonics*	Inflections	Steps	(s)	(Hz)	(Hz)	(Hz)
Total	Mean	-	0.412	1.060	0.607	10780.312	11178.712	8423.599
whistles	SD	-	0.814	1.407	0.364	4923.339	5041.682	3522.485
	Minimum	-	0	0	0.015	477.9	414.5	337
	Maximum	-		10	2.748	32962.9	44282.7	24436.1
Celtic	Mean	-	0.545	0.538	0.624	11962.7	12081.024	9613.738
Deep**	SD	-	0.921	1.144	0.349	3407.562	3206.192	2192.354
	Minimum	-	0	0	0.0171	3555.377	4071.189	3370
	Maximum	-	9	10	2.748	23460.811	21281.011	19491.8
Eastern	Mean	0.267	0.223	1.804	0.583	11886.982	12686.869	9126.901
Tropical	SD	0.699	0.583	1.411	0.383	4266.771	4495.055	3001.983
Pacific**	Minimum	0	0	0	0.015	3384	3455.8	3190
	Maximum	7	7	7	2.087	32963	44282.7	24436.1
		35.						
		Maximum	Mean	Frequency	A	Absolute	Frequency	Mean
			Mean Frequency	Frequency Gradient		Absolute requency	Frequency Range	Mean Power
					Fi			
Total	Mean	Frequency	Frequency	Gradient	Fı Gradi	requency	Range	Power
Total whistles	Mean SD	Frequency (Hz)	Frequency (Hz)	Gradient (Hz/s)	Fi Gradi	requency ient (Hz/s)	Range (Hz)	Power
		Frequency (Hz) 13425.243	Frequency (Hz) 10697.172	Gradient (Hz/s) 1356.899	Fı Gradi	requency ient (Hz/s) 7677.213	Range (Hz) 5001.645	Power
	SD	Frequency (Hz) 13425.243 5458.995	Frequency (Hz) 10697.172 4135.554	Gradient (Hz/s) 1356.899 17207.282	Fı Gradi	requency ient (Hz/s) 7677.213 15458.619	Range (Hz) 5001.645 3636.694	Power
	SD Minimum	Frequency (Hz) 13425.243 5458.995 625.8	Frequency (Hz) 10697.172 4135.554 444.785	Gradient (Hz/s) 1356.899 17207.282 -102528	Fı Gradi	requency ient (Hz/s) 7677.213 15458.619 0	Range (Hz) 5001.645 3636.694 0	Power
whistles	SD Minimum Maximum	Frequency (Hz) 13425.243 5458.995 625.8 44282.7	Frequency (Hz) 10697.172 4135.554 444.785 29760.89	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9	Fr Gradi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9	Range (Hz) 5001.645 3636.694 0 23076.9	Power (dB)* - - -
whistles Celtic	SD Minimum Maximum Mean	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376	F1 Gradi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9 6869.724	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347	Power (dB)* - - -
whistles Celtic	SD Minimum Maximum Mean SD	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310 3127.820	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357 2173.025	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376 9642.105	Fr Gradi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9 6869.724 6803.670	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347 3150.434	Power (dB)* - - -
whistles Celtic	SD Minimum Maximum Mean SD Minimum	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310 3127.820 5740.349	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357 2173.025 4447.85	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376 9642.105 -53261.3	Fr Gradi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9 6869.724 6803.670 0	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347 3150.434 0	Power (dB)* - - -
whistles Celtic Deep**	SD Minimum Maximum Mean SD Minimum Maximum	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310 3127.820 5740.349 23460.811	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357 2173.025 4447.85 20376.617	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376 9642.105 -53261.3 72372.245	Fi Gradi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9 6869.724 6803.670 0 72372.245	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347 3150.434 0 17147.241	Power (dB)* - - - - - - - - - - - -
whistles Celtic Deep** Eastern	SD Minimum Maximum SD Minimum Maximum Mean	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310 3127.820 5740.349 23460.811 15102.922	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357 2173.025 4447.85 20376.617 11780.789	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376 9642.105 -53261.3 72372.245 2449.977	Fi	requency ient (Hz/s) 7677.213 15458.619 0 589540.9 6869.724 6803.670 0 72372.245 10528.986	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347 3150.434 0 17147.241 5975.952	Power (dB)* - - - - - - - - - - 49.001
whistles Celtic Deep** Eastern Tropical	SD Minimum Maximum SD Minimum Maximum Mean SD	Frequency (Hz) 13425.243 5458.995 625.8 44282.7 14531.310 3127.820 5740.349 23460.811 15102.922 4295.033	Frequency (Hz) 10697.172 4135.554 444.785 29760.89 11910.357 2173.025 4447.85 20376.617 11780.789 3174.141	Gradient (Hz/s) 1356.899 17207.282 -102528 589540.9 738.376 9642.105 -53261.3 72372.245 2449.977 24684.892	Fi	$\begin{array}{r} \text{requency} \\ \hline \text{ient} (\text{Hz/s}) \\ \hline 7677.213 \\ 15458.619 \\ 0 \\ \hline 589540.9 \\ \hline 6869.724 \\ 6803.670 \\ 0 \\ \hline 72372.245 \\ 10528.986 \\ 22458.680 \\ \end{array}$	Range (Hz) 5001.645 3636.694 0 23076.9 4318.347 3150.434 0 17147.241 5975.952 3687.028	Power (dB)* - - - - - - - - - - 49.001 20.082

Table 3.2.1. The mean, standard deviation (SD), minimum and maximum of the thirteen whistle parameters measured in all of the whistles incorporated into this study, whistles found in the Celtic Deep and whistles found in the ETP.

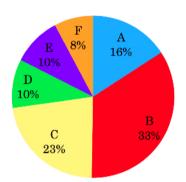
*Summaries for Harmonics and Mean Power were only calculated if all whistles in the category had been measured for them.

** Statistically different in most shared characteristics which were measured except Start Frequency.

3.2.2 Whistle contour type

Using a Kruskal-Wallis test, there was also a significant difference in whistle type, for both general categories ($\chi^2=8.535$, df=1, p=0.003) and subcategories ($\chi^2=4.848$, df=1, p=0.028). Figure 3.2.2 shows the whistle type composition of the total amount of whistles analysed in this study, for both Celtic Deep whistles and ETP whistles. Overall, upsweeps (B) were the most dominant whistle type in all locations, comprising approximately a third of all emitted whistles. In general, downsweeps (C) were the second most dominant whistle type. However,

in the ETP, constant frequency (A) whistles were the second most commonly emitted, followed by downsweeps. Downsweeps remained second in the Celtic Deep, and continuous frequency whistles were found to be third.



Whistle Classification Composition



ETP Whistle Classification Composition

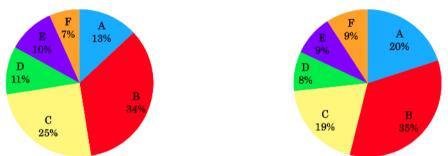


Figure 3.2.2. Whistle classification composition of the total whistles analysed (2455), whistles from the Celtic Deep (1443) and whistles from the ETP (1012).

Figure 3.2.3 illustrates the frequency and distribution of the whistle subtypes for the total whistles analysed at both locations. The dominant whistle subtype in the Celtic Deep was B1 (upsweep without modulation), as was demonstrated by Ansmann (2005) for the subset of whistles she examined. In the Celtic Deep, with the exception of sine (F), the first subcategory (without modulation) exhibited the greatest frequency within each general category. In the ETP, B2 (upsweep with modulation at the start of the duration) was the dominant whistle subtype, followed by B1. In the constant frequency general category, A2 was dominant. C3 was dominant in the downsweeps. The mean, standard deviation, minimum and maximum of the six general whistle categories can be found in Tables 3.2.2-4.

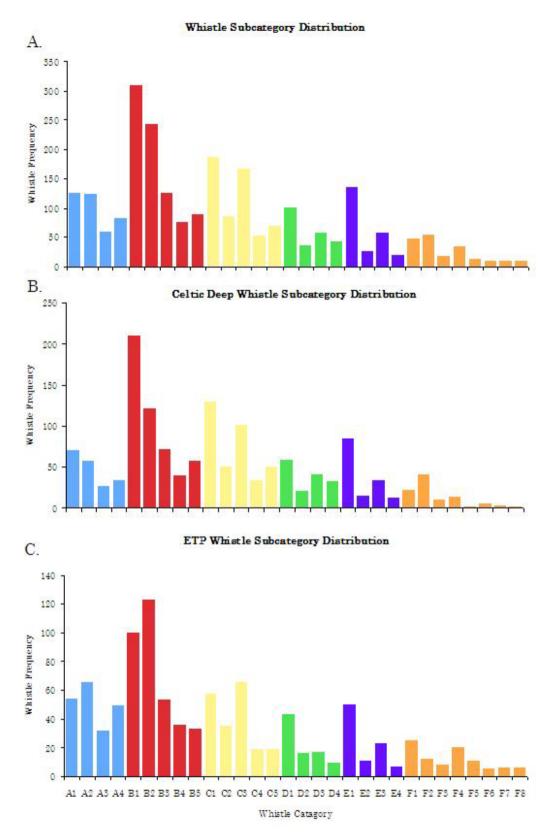


Figure 3.2.3. Frequency of whistle contour subtypes of the 2455 total whistles (A), 1443 whistles from the Celtic Deep (B) and 1012 whistles from the ETP (C).

			contour type ch			End	Minimum	Maximum	Mean	Frequency	Absolute	Frequency	Mean
				- ()		1 0	Frequency	1 0			Frequency	0	Power
		Harmonics'	* Inflections Ste	ps Duration (s)	Frequency (Hz)	(Hz)	(Hz)	(Hz)	(Hz)	(Hz/s)	Gradient	(Hz)	(dB)*
	Mean	-	$0.134 \ 1.7$	14 0.445	11180.449	11182.793	10030.544	12189.883	11005.882	1488.425	5863.563	2159.339) -
Α	SD	-	$0.391 \ 1.6$	81 0.294	3051.519	3004.762	2781.265	3140.123	2817.276	31148.119	30626.071	2265.784	-
11	Minimum	-	0.000 0.0	00 0.022	3665.400	4105.300	3665.400	5503.800	4545.115	-98732.300	0.000	0.000) -
	Maximum	-	3.000 6.0	00 1.850	22932.300	30075.200	22368.400	31203.000	28684.210	589540.900	589540.900	14849.600) -
	Mean	-	$0.174 \ 1.0$	91 0.558	10164.419	14612.221	9375.509	15080.779	12081.271	10744.039	11589.823	5705.270) -
в	SD Minimum	-	0.430 1.4	32 0.330	3096.007	3875.757	2688.176	3745.155	2761.069	12756.937	11992.806	3295.682	-
D	Minimum	-	0.000 0.0	00 0.015	3516.500	5498.100	3203.000	6344.800	4784.930	-50975.100	0.000	211.000) -
	Maximum	-	3.000 8.0	00 2.017	25563.900	44282.700	24436.100	44282.700	29760.890	128538.200	128538.200	23076.900) -
	Mean	-	0.254 0.9	57 0.558	14749.751	10193.694	9560.847	15260.293	12002.327	-10495.215	10938.847	5699.448	; -
С	SD	-	0.515 1.3	15 0.311	3501.650	2712.979	2544.014	3392.515	2510.102	10678.031	10222.260	3265.861	-
U	Minimum	-	0.000 0.0	00 0.048	4793.200	3455.800	3190.000	6258.000	4447.850	-102528.000	0.000	352.000) -
	Maximum	-	3.000 7.0	00 1.614	32962.900	22180.500	22180.500	32962.900	26038.540	35841.950	102528.300	20112.800) -
	Mean	-	$0.773 \ 0.7$	06 0.776	10661.218	10340.868	9187.103	15826.590	12507.205	-548.400	2694.996	6639.489) -
Б	SD Minimum	-	0.871 1.0	09 0.335	3123.293	2657.805	2476.997	3344.721	2514.334	4059.856	3080.715	3009.086	; -
D	Minimum	-	0.000 0.0	00 0.104	3555.377	4145.900	3555.400	5740.349	4763.285	-33452.500	0.000	71.000) -
	Maximum	-	7.000 4.0	00 1.945	28091.300	21379.100	21379.100	28091.300	25398.140	11251.640	33452.540	17147.200) -
	Mean	-	0.686 0.7	80 0.661	13456.928	13201.819	9084.113	14420.258	11283.552	-639.041	3396.422	5336.146	; -
F	SD Minimum	-	$0.740 \ 1.2$	66 0.397	3335.601	3209.651	2040.354	3367.623	2095.121	4924.358	3615.886	3155.042	-
Ц	Minimum	-	0.000 0.0	00 0.035	5639.100	5512.500	5007.500	8107.200	6367.650	-24391.400	0.000	282.000) -
	Maximum	-	4.000 10.0	00 2.087	30827.100	24456.300	16917.300	30827.100	17937.030	15037.550	24391.430	22368.500) -
	Mean	-	1.702 0.6	86 1.017	12705.850	12251.165	8579.846	16280.539	12068.463	305.123	5053.833	7700.696	; -
ъ	SD	-	$1.619 \ 1.0$	44 0.393	4247.774	3665.473	1989.980	3291.964	2247.598	7724.761	5838.653	2895.830) -
г	Minimum	-	0.000 0.0	00 0.148	3383.500	4677.400	3383.500	8773.000	6562.510	-12617.400	0.000	141.000) -
	Maximum	-	9.000 5.0	00 2.748	25375.900	25375.900	15977.400	27255.600	22189.850	54041.880	54041.880	16917.300) -

Table 3.2.2. Whistle contour type characteristics for the total whistles analysed (2455).

			contour type cha			End	Minimum	Maximum	Mean	Frequency	Absolute	Frequency	Mean
							Frequency	1 0	1 0		Frequency	U	Power
		Harmonics	*Inflections Ste	ps Duration (s)	Frequency (Hz)	(Hz)	(Hz)	(Hz)	(Hz)	(Hz/s)	Gradient	(Hz)	(dB)*
	Mean	-	$0.128 \ \ 0.5$	24 0.446	11101.992	11144.702	10510.562	11695.695	11084.840	272.116	2333.875	1185.133	-
А	SD	-	0.394 1.2	20 0.241	2354.548	2343.029	2279.260	2331.091	2261.475	3547.138	2679.623	1087.706	; -
11	Minimum	-	0.000 0.0	00 0.068	6246.269	5646.922	4927.705	6421.644	5897.759	-13438.515	0.000	0.000) -
	Maximum	-	3.000 5.0	00 1.434	19911.381	19791.511	19491.838	20031.250	19731.577	15966.613	15966.613	8183.400	- (
	Mean	-	$0.191 \ 0.5$	76 0.556	9898.619	14217.138	9541.408	14474.200	11980.929	9511.233	9729.266	4932.792	-
B	SD Minimum	-	0.442 1.1	92 0.307	2420.289	2974.543	2184.890	2935.807	2174.206	7839.629	7566.788	2805.272	-
D	Minimum	-	0.000 0.0	00 0.017	4629.799	6611.000	4629.799	6611.000	5811.562	-17233.100	103.873	211.000) -
	Maximum	-	3.000 8.0	00 1.652	20459.000	20924.702	18228.000	20924.702	19385.095	72372.245	72372.245	13734.030	- (
	Mean	-	$0.292 \ \ 0.6$	17 0.586	14763.188	10054.712	9651.677	15016.049	11983.614	-9455.467	9538.670	5364.372	-
С	SD Minimum	-	0.554 1.1	75 0.303	2915.446	2351.124	2246.889	2908.035	2129.935	6939.234	6824.092	2966.425	-
U	Minimum	-	0.000 0.0	00 0.071	6258.000	4071.189	3370.000	6258.000	4447.850	-53261.300	214.221	352.000) -
	Maximum	-	3.000 6.0	00 1.614	23218.097	19467.654	19185.855	23218.097	19806.353	14887.226	53261.340	14776.709	- (
	Mean	-	$1.112 \ \ 0.3$	95 0.852	10711.280	10239.378	9340.845	16196.409	12759.546	-492.027	1985.049	6855.564	-
р	SD Minimum	-	0.881 0.8	31 0.302	2715.315	2403.228	2268.105	3018.586	2225.439	2430.728	1478.384	2910.998	; -
D	Minimum	-	0.000 0.0	00 0.112	3555.377	4145.910	3555.377	5740.349	4763.285	-6485.685	0.000	71.000) -
	Maximum	-	7.000 4.0	00 1.945	20051.738	18883.929	18883.929	22795.252	20376.617	7076.660	7076.660	17147.241	-
	Mean	-	$0.979 \ 0.4$	0.644	13627.550	13340.007	9479.218	14325.219	11481.623	-480.831	2747.388	4846.002	-
E	SD Minimum	-	$0.721 \ 1.2$	31 0.367	2856.557	2629.346	1886.157	2938.592	1900.390	4042.700	2995.941	2742.513	-
Ľ	Minimum	-	0.000 0.0	00 0.035	7866.268	7683.800	5267.923	8301.000	7183.682	-24391.429	0.000	282.000) -
	Maximum	-	4.000 10.0	00 1.768	21408.036	21281.011	16474.000	21408.036	17141.628	9001.365	24391.429	12375.300	, -
	Mean	-	2.551 0.3	98 1.066	13198.423	11512.013	8751.781	16159.147	12172.846	-1481.226	4783.339	7407.366	; -
F	$_{M}^{SD}$	-	1.451 0.8	82 0.400	3983.539	2929.092	1556.820	2968.241	1826.184	5991.896	3873.404	2828.438	; -
T,	Minimum	-	0.000 0.0	00 0.244	6972.564	4677.390	4677.390	9076.000	8939.825	-12617.418	40.351	141.000) -
	Maximum	-	9.000 4.0	00 2.748	23460.811	20941.714	12495.000	23460.811	16905.285	20811.728	20811.728	14136.639	, -

Table 3.2.3 Whistle contour type characteristics for the Celtic Deep (1443).

			<u> </u>				End	Minimum	Maximum	Mean	Frequency	Absolute 1	Frequency	Mean
					_		1 0	Frequency		· · · ·		Frequency	<u> </u>	Power
	Ha	armonics*	Inflections	Steps	Duration (s) Fi	requency (Hz)	(Hz)	(Hz)	(Hz)	(Hz)	(Hz/s)	Gradient	(Hz)	(dB)*
Mean		0.095	0.139	2.821	0.445	11253.440	11218.232	9583.959	12649.650	10932.421	2620.016	9147.402	3065.692	2 49.111
Δ SD		0.341	0.388	1.236	0.336	3584.877	3515.995	3117.820	3685.842	3254.329	43162.203	42258.504	2668.445	$5\ 20.545$
Minim	um	0.000	0.000	0.000	0.022	3665.400	4105.300	3665.400	5503.800	4545.115	-98732.323	0.000	274.200	0 17.300
Maxim	um	2.000	2.000	6.000	1.850	22932.300	30075.200	22368.400	31203.000	28684.210	589540.909	589540.909	14849.600	86.765
Mean		0.301	0.151	1.835	0.560	10548.096	15182.514	9136.035	15956.363	12226.109	12523.567	14275.497	6820.328	8 49.255
B ^{SD} _{Minim}		0.768	0.411	1.424	0.360	3840.380	4840.702	3270.060	4536.255	3434.322	17440.241	16033.573	3620.078	3 19.832
^D Minim	um	0.000	0.000	0.000	0.015	3516.500	5498.100	3203.000	6344.800	4784.930	-50975.141	0.000	538.900	0 18.345
Maxin	um	7.000	3.000	6.000	2.017	25563.900	44282.700	24436.100	44282.700	29760.885	128538.235	128538.235	23076.900	96.470
Mean		0.194	0.184	1.587	0.508	14724.867	10451.092	9392.624	15712.643	12036.983	-12420.875	13532.032	6320.019	9 48.610
C ^{SD}		0.610	0.426	1.331	0.321	4393.948	3270.670	3017.282	4113.166	3099.313	15203.374	14218.190	3686.304	4 21.087
Minim	um	0.000	0.000	0.000	0.048	4793.200	3455.800	3190.000	6860.900	6033.840	-102528.283	0.000	660.700	0 18.515
Maxin	um	5.000	2.000	7.000	1.491	32962.900	22180.500	22180.500	32962.900	26038.535	35841.949	102528.283	20112.800	97.875
Mean		0.349	0.174	1.256	0.643	10572.736	10520.244	8915.373	15172.955	12061.205	-648.036	3949.787	6257.581	49.513
D_{M}^{SD}		0.589	0.411	1.065	0.351	3753.520	3063.482	2802.070	3785.319	2917.814	5953.573	4481.692	3156.205	5 19.302
Minim	um	0.000	0.000	0.000	0.104	3947.400	4646.600	3947.400	6860.900	6339.285	-33452.542	0.000	638.700	0 18.455
Maxin	um	2.000	2.000	4.000	1.382	28091.300	21379.100	21379.100	28091.300	25398.140	11251.643	33452.542	16776.300	85.520
Mean		0.363	0.220	1.264	0.686	13185.058	12981.632	8454.548	14571.692	10967.941	-891.135	4430.598	6117.144	52.241
E ^{SD}		1.017	0.490	1.172	0.442	3984.260	3969.636	2127.384	3969.641	2349.309	6087.984	4244.784	3599.138	3 21.586
^L Minim	um	0.000	0.000	0.000	0.057	5639.100	5512.500	5007.500	8107.200	6367.650	-16781.159	0.000	1594.900	0 20.465
Maxim	um	6.000	2.000	5.000	2.087	30827.100	24456.300	16917.300	30827.100	17937.025	15037.548	16781.159	22368.500	87.410
Mean		0.495	0.806	0.989	0.965	12186.795	13030.062	8398.662	16408.457	11958.465	2187.513	5338.870	8009.795	6 45.007
F ^{SD}		0.802	1.271	1.118	0.382	4472.372	4184.080	2357.586	3613.764	2625.418	8854.400	7377.280	2948.814	16.548
^{F} Minim	um	0.000	0.000	0.000	0.148	3383.500	7142.900	3383.500	8773.000	6562.510	-12030.000	0.000	2067.700) 16.595
Maxim	um	5.000	7.000	5.000	1.754	25375.900	25375.900	15977.400	27255.600	22189.850	54041.875	54041.875	16917.300	84.930

Table 3.2.4 Whistle contour type characteristics for the Eastern Tropical Pacific (1012).

* Summaries for Harmonics and Mean Power were only calculated if all whistles in the category had been measured for them.

3.2.3 Regional locals within the Eastern Tropical Pacific

Comparatively, the ETP covers a vastly larger area than the Celtic Deep. The area surveyed in the ETP included in this study has a perimeter of approximately 15,500 kilometres, while the perimeter of the area surveyed in the Celtic Deep is only an estimated 280 kilometres. Therefore the ETP was further subdivided into 9 regional locals. Whistle parameters and types were tested to determine if there was a significant difference between them. Encounters were not included in multiple locals. The locals were divided as follows (number of encounters present in the local in parenthesis):

- > All encounters recorded over the Peru-Chile Trench (6)
- ➤ Longitude: 90.0°W coastal Americas Latitude: 10.0°S 15.0°S (1)
- > Longitude: $90.0^{\circ}W$ coastal Americas Latitude: $5.0^{\circ}S$ $10.0^{\circ}S$ (5)
- ▶ Longitude: 90.0°W coastal Americas Latitude: Equator 5.0°S (2)
- Longitude: 90.0°W coastal Americas Latitude: 5.0°N Equator (1)
- ➤ Longitude: 95.0°W 85.0°W Latitude: 15.0°N 10.0°N (2)
- ➤ Longitude: 110.0°W 130.0°W Latitude: 15.0°N 5.0°N (2)
- ➤ Longitude: 115.0°W 125.0°W Latitude: 30.0°N 20.0°N (1)
- > Longitude: $100.0^{\circ}W 90.0^{\circ}W$ Latitude: Equator $-5.0^{\circ}S(1)$

An ANOSIM test generated a positive global R value of 0.026 (p=0.012), showing that whistles recorded within these locals were more similar with each other than with whistles from other locals. A Kruskal-Wallis test was conducted to see which whistle characteristics were significantly different between the locals. The results are as follows:

- Duration (χ²=46.641, df=8, p<0.001)</p>
- Start Frequency (χ²=38.919, df=8, p<0.001)</p>
- End Frequency (χ²=70.531, df=8, p<0.001)</p>

- Minimum Frequency (χ²=81.821, df=8, p<0.001)</p>
- Maximum Frequency (χ²=841.467, df=8, p<0.001)</p>
- Mean Frequency (χ²=108.755, df=8, p<0.001)</p>
- Frequency Gradient (χ²=10.179, df=8, p=0.253)
- > Absolute Frequency Gradient (χ^2 =9.659, df=8, p=0.290)
- Frequency Range (χ²=34.010, df=8, p<0.001)</p>
- Mean Power (χ²=312.119, df=8, p<0.001)</p>
- Harmonics (χ²=77.330, df=8, p<0.001)</p>
- Inflections (χ²=15.986, df=8, p=0.043)
- Steps (χ²=121.700, df=8, p<0.001)</p>

Whistle contour types were not significantly different between the 9 locals in either the general categories (χ^2 =11.857, df=8, p=0.158) or the subcategories (χ^2 =8.641, df=8, p=0.373).

Even though the locals within the ETP proved to have parameter differentiation, since four out of the nine locals only incorporated one encounter and the global R value was close to zero, the differences found could be attributed to a higher amount of variation than had been previously observed by common dolphins in different encounters (Ansmann, 2005). Further acoustic samples would need to be analysed before any conclusions can be drawn from these results. Therefore the ETP was further analysed in this study as a single location.

3.3 External factor effects on whistle type and characteristics

ANOSIM (in Primer v.6) and Spearman rank correlation (in SPSS v.16) tests were used to examine if the whistle parameters inside the encounters (year, depth, and time of day [hour]) were different between the samples. Results for the Celtic Deep can be found in Table 3.3.1, and for the ETP in Table 3.3.2.

		Encounter	Year	Depth	Hour
	Global R	0.038	0.001	0.008	0.001
	Sig.	0.001	0.483	0.029	0.415
Duration(s)	ρ	.188	.181	.073	023
	Sig. (2-tailed)	.000	.000	.006	.391
Start Frequency (Hz)	ρ	.004	033	.019	003
	Sig. (2-tailed)	.884	.209	.468	.924
End Frequency (Hz)	ρ	.012	.039	022	012
	Sig. (2-tailed)	.657	.139	.411	.648
Minimum Frequency (Hz	ο (z	102	112	074	015
	Sig. (2-tailed)	.000	.000	.005	.559
Maximum Frequency (H	z) ρ	.086	.061	.063	.022
	Sig. (2-tailed)	.001	.020	.016	.413
Mean Frequency (Hz)	ρ	.004	030	012	.014
	Sig. (2-tailed)	.883	.249	.646	.593
Frequency Gradient	ρ	015	.012	038	.001
(Hz/s)	Sig. (2-tailed)	.557	.640	.148	.978
Absolute Frequency	ρ	055	058	018	$.065^{*}$
Gradient (Hz/s)	Sig. (2-tailed)	.038	.027	.490	.013
Frequency Range	ρ	.169	.155	.117	.033
	Sig. (2-tailed)	.000	.000	.000	.210
Inflections	ρ	.145	.163	.216	.010
	Sig. (2-tailed)	.000	.000	.000	.708
Steps	ρ	251	278	307	.005
	Sig. (2-tailed)	.000	.000	.000	.838

Table 3.3.1. Non-parametric ANOSIM and Spearman rank correlation results for the factors Encounters, Year, Depth and Hour effect, and the eleven whistle parameters in the Celtic Deep. First line shows the ρ (rho) value or global R. Second line shows the p value. Significant p values are shown in **bold**. N=1443

The ANOSIMs in both locations revealed that whistles within an encounter had more similar characteristics than whistles from other encounters. The same applies to whistles within the same depth range in both areas. Additionally, ETP whistles also had more similarities with whistles in the same hour of the day than with whistles from other hours. For all four external factors in both locations, whistle characteristics showed a large amount of variation.

Table 3.3.2. Non-parametric ANOSIM and Spearman rank correlation results for the factors Encounter, Year, Depth and Hour effect, and the thirteen whistle parameters in the Eastern Tropical Pacific. First line shows the ρ (rho) value or global R. Second line shows the p value. Significant p values are shown in **bold**. N=1012.

		Encounter	Year	Depth	Hour
Global R		0.025	-0.009	0.023	0.015
Sig.		0.001	0.87	0.001	0.032
Duration (s)	ρ	.027	011	104	035
	Sig. (2-tailed)	.397	.717	.001	.267
Start Frequency (Hz)	ρ	.128	.131	051	.053
	Sig. (2-tailed)	.000	.000	.103	.093
End Frequency (Hz)	ρ	.186	.188	014	.039
	Sig. (2-tailed)	.000	.000	.668	.217
Minimum Frequency	ρ	.147	.122	.012	065
(Hz)	Sig. (2-tailed)	.000	.000	.712	.038
Maximum Frequency	ρ	.253	.279	069	.119
(Hz)	Sig. (2-tailed)	.000	.000	.028	.000
Mean Frequency (Hz)	ρ	.261	.245	024	.050
	Sig. (2-tailed)	.000	.000	.447	.115
Frequency Gradient	ρ	.028	.033	.036	002
(Hz/s)	Sig. (2-tailed)	.377	.292	.257	.950
Absolute Frequency	ρ	.033	.087	014	.115
Gradient (Hz/s)	Sig. (2-tailed)	.296	.006	.655	.000
Frequency Range	ρ	.141	.187	095	.153
	Sig. (2-tailed)	.000	.000	.002	.000
Mean Power (dB)	ρ	555	790	147	248
	Sig. (2-tailed)	.000	.000	.000	.000
Harmonics	ρ	.128	.088	176	.115
	Sig. (2-tailed)	.000	.005	.000	.000
Inflections	ρ	102	089	.039	039
	Sig. (2-tailed)	.001	.005	.212	.219
Steps	ρ	.220	.305	.052	082
	Sig. (2-tailed)	.000	.000	.101	.009

In the ETP, only four out of the seven encounters from 1998 were recorded in areas that overlapped with nine out of the 14 encounters recorded in 2000. These 13 encounters (48-51, 55, 56, 58-64; N=650) were isolated, and so an

additional Spearman rank correlation test was conducted. It concluded that this subset had the same whistle parameters have a correlation with year recorded, as listed in Table 3.3.2. The results are as follows: harmonics (ρ =0.207, p<0.001), inflections (ρ =-0.088, p=0.024), steps (ρ =0.254, p<0.001), duration (ρ =0.061, p=0.118), start frequency (ρ =0.201, p<0.001), end frequency (ρ =0.252, p<0.001), minimum frequency (ρ =0.090, p=0.022), maximum frequency (ρ =0.393, p<0.001), mean frequency (ρ =0.304, p<0.001), frequency gradient (ρ =0.024, p=0.548), absolute frequency gradient (ρ =0.148, p<0.001), frequency rage (ρ =0.327, p<0.001) and mean power (ρ =-0.799, p<0.001).

To test if there was a correlation between whistle contour and the external factors measured in this study, a Spearman rank correlation test was used. This showed that in the Celtic Deep, the general whistle categories were correlated with time of day (ρ =0.069, N=1443, p=0.009) and depth (ρ =0.106, N=1443, p<0.001). The subcategories were correlated with the same external factors: hour (ρ =0.102, N=1443, p<0.001) and depth (ρ =0.056, N=1443, p<0.001). In the ETP, a Spearman correlation also found that the time of day was related to both general whistle categories (ρ =0.111, N=1012, p<0.001) and subcategories (PC=0.115, N=1012, p<0.001).

3.3.1 Celtic Deep whistles and common dolphin behaviour

Behaviour correlation analyses were conducted on whistles characteristics and contour type from the Celtic Deep. Recordings collected in the ETP did not document dolphin behaviour, so this analysis excluded that location. A Spearman rank correlation test was run on the documented behaviour of common dolphins and the general whistle type and the whistle parameters. Encounters where behaviour was not recorded were omitted, leaving 1252 whistles in this analysis. The correlation value was ρ =-0.81 (p=0.004) between whistle type and animal behaviour, and therefore was determined to be

significant. Whistle type subcategories were also tested to yield a rho value of ρ =-0.78 (p=0.005). Whistle parameters that were found to have a significant correlation with animal behaviour were:

- > Maximum Frequency (Hz): ρ =-0.060, p=0.035
- Mean Frequency (Hz): ρ=-0.058, p=0.041
- Frequency Range (Hz): ρ =-0.58, p=0.041
- Steps: ρ=-0.191, p<0.001</p>

To further investigate the influence that a particular behaviour (travelling, foraging, socializing and bow riding) might have on whistle parameters, Mann-Whitney U-tests were conducted on the presence or absence of a behaviour. The total results can be found in Table 3.3.3. The tests found that:

- The means of duration and number of steps varied significantly for all behaviours depending on presence or absence.
- For travelling, the means of whistle parameters end frequency, minimum frequency, frequency gradient and frequency range varied significantly depending on presence or absence.
- The means of minimum frequency and frequency range also varied significantly for the presence or absence of foraging behaviour, as did the mean for mean frequency.
- No other means of whistle parameters varied significantly for the presence or absence of socialising or bow riding.
- The means for whistle parameters start frequency, maximum frequency, absolute frequency gradient and number of inflections did not vary when dolphins exhibited any behaviour.
- Whistle contour type general categories varied significantly in the presence and absence of foraging (Z=-2.091, p=0.036), socialising (Z-4.767, p<0.001) and bow riding (Z=-1.980, p=0.048)</p>

		Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)		Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Number of Inflections	Number of Steps
	Mann- Whitney U	110486.000	123916.500	120630.000	118428.500	122533.000	129275.000	119895.500	131049.500	112480.000	122833.000	117572.000
Travelling	Z p Mean SD	-3.944 0.000 0.565 0.308	-1.374 0.169 12093.17 3130.17	-2.003 0.045 12442.60 3165.78	-2.424 0.015 10158.68 2330.17	-1.639 0.101 14676.63 3334.95	349 0.727 12187.61 2305.98	-2.143 0.032 1738.72 9183.07		-3.562 0.000 4517.95 3274.30	-1.813 0.070 0.641 0.876	-3.815 0.000 0077 0.351
	Mann- Whitney U	151148.000	161839.000	152947.500	142277.000	161586.000	149835.000	153600.500	157004.500	147446.500	153308.500	154005.000
Foraging	Z p Mean SD	-2.012 0.044 0.625 0.350	177 0.860 12300.72 3526.01	-1.703 0.089 12389.58 3217.70	-3.535 0.000 9846.30 2123.17	220 0.826 14957.39 3158.17	-2.238 0.025 12184.61 2117.77	-1.591 0.112 699.45 11914.50	0.314		-1.882 0.060 0.543 0.929	-2.243 0.025 0.591 1.510
	U	112403.000		122463.500					117536.500	116826.500	115539.500	105672.000
Socialising	r Z p Mean SD	-2.234 0.025 0.623 0.304	761 0.447 11978.79 4977.22	253 0.800 12077.13 3611.34	-1.407 0.159 8497.04 2403.10	602 0.547 15430.26 3911.66	006 0.995 11644.73 2482.82	040 0.968 -431.75 11478.75	0.221	-1.363 0.173 6933.22 3661.92	-1.853 0.064 0.640 0.851	-5.247 0.000 0.140 0.351
Bow	U	130923.000										
Riding	Z p Mean SD	-2.763 0.006 0.576 0.304	702 0.483 11796.04 3202.46	520 0.603 12454.19 3308.18	355 0.723 9756.61 1982.45	353 0.724 14420.68 3050.19	397 0.691 11956.45 2111.32	626 0.531 1379.91 10068.73	-1.808 0.071 7580.10 6753.15	101 0.920 4664.07 2920.14	-1.647 0.100 0.375 0.780	-3.966 0.000 0.597 1.139

Table 3.3.3. Results of Mann-Whitney U tests for behaviour (travelling, foraging, socialising and bow riding) against eleven whistle parameters. Presented with mean and standard deviation (SD). Significant p values are highlighted in **bold**.

3.3.2 ETP whistle strength

Analyses were conducted on strength of ETP whistles. The Celtic Deep was excluded from this examination because only two of the encounters were measured for whistles strength in 2009. This was deemed not to be a large enough sample to accurately represent whistle strength in that location. Descriptive statistics for the mean power, and harmonics, of those encounters can be found in Appendix 7.1.

A homogeneity of variances test on whistle strength (dB) confirmed that general whistle type categories and subcategories were normally distributed. A one-way Analysis of Variance (ANOVA) revealed a significant difference between whistle strength and whistle type general categories (F=4.226, df=2, p=0.015) and subcategories (F=4.196, df=2, p=0.015). Figure 3.3.1 shows the proportion of whistle contour types present in weak, moderate and strong whistles. Weak whistles had more constant frequency whistles than any other type, while upsweeps were most common in moderate and strong whistles.

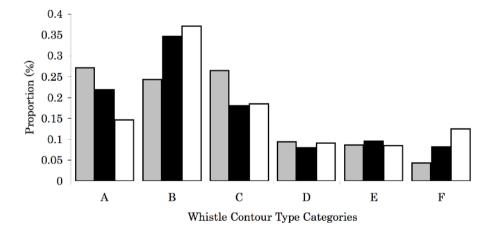


Figure 3.3.1. Proportion of whistle contour in weak (grey), moderate (black) and strong (white) whistles.

Homogeneity of variances test also identified a normal distribution in the whistle parameters maximum frequency and number of steps. While maximum frequency proved to be significantly different between weak, moderate and strong whistles (F=8.359, df=2, p<0.001), the number of steps did not (F=2.663, df=2, p=0.070). A non-parametric Kruskal-Wallis test on the remaining whistle parameters revealed that the number of harmonics (χ^2 =6.957, df=2, p=0.008), duration (χ^2 =34.015, df=2, p<0.001), minimum frequency (χ^2 =8.872, df=2, p=0.003), and frequency range (χ^2 =14.956, df=2, p<0.001) all varied between the three whistle strengths.

4. Discussion

4.1 The Contour Similarity (CS) technique verses visual classification

It is important to note that previous studies that used the CS technique have been analysing bottlenose dolphin whistles only (McCowan, 1995; McCowan and Reiss, 1995; Janik, 1999; McCowan and Reiss, 2001; Sayigh *et al.*, 2007). Whistles parameters of *Tursiops truncatus* along with *Delphinus delphis* can be found in Table 4.1.1. When compared, the bottlenose dolphin whistle is—on average—longer in duration and has an increased number of inflections. This makes the average contour of a bottlenose dolphin whistle more complicated than the average contour of a common dolphin whistle. The differences in basic structure could explain why in this study the CS technique optimised when k=3, while in other studies that used the same k selection method it optimised at k=23.

Further research is needed to assess why the CS technique, or more specifically an objective classification system, has been proven to work in some cases but not in others. This study did not aim to research why the CS technique did or did not work. It aimed to compare how a predetermined visual system fared against a quantitative one. The quantitative method did not provide an accurate classification of whistle contours; rather, it identified the trend of their slope. Therefore, no statistical comparison could be performed.

To further assess how the CS technique preformed with an increased value of k, k=15 was selected. This was the amount of clusters identified by McCowan in her original study. Figure 4.1.1 shows three whistles randomly selected from the two dominant clusters, 5 and 6, representing downsweeps and upsweeps respectively. Looking at a breakdown of the remaining clusters, six out of 15 contain two or less whistles, and eight clusters contain three or less (Appendix 8.6). When many of the clusters have few cases within, it suggests that the

value of k is too high (Noruśis, 2009). When using the same method to select k as used in this study, Janik (1999) found k=23. Ten of those clusters only accommodated 1-3 whistles. The CS technique has no clear, definitive way of stating what k equals. It does not objectively define the limit of whistle classification, but rather depends on subjective reasoning.

	North Eastern Atlantic (Steiner, 1981)	Eastern Tropical Pacific (Oswald <i>et al.</i> , 2003)	Costa Rica: Gandoca- Manzanilla (May- Collado and Wartzok, 2008)	Celtic Deep (Present study	English Channel (Ansmann et al., 2007)	Eastern Tropical Pacific (Present study)	Haurski Gulf, New Zealand (Petrella, 2009)
Species	T. truncatus	T. truncatus	T. truncatus	D. delphis	D. delphis	D. delphis	D. delphis
Start Frequency (kHz)	11.264 (3.986)	11.2 (4.6)	3.67 (3.67)	11.96 (3.41)	12.64 (3.95)	11.89 (4.27)	12.593 (4.069)
End Frequency (kHz)	10.225 (3.646)	9.0 (3.7)	5.34 (11.21)	12.08 (3.21)	12.48 (3.97)	12.87 (4.50)	12.295 (4.075)
Minimum Frequency (kHz)	16.235 (2.688)	7.4 (2.2)	5.52 (2.05)	9.61 (2.19)	9.80 (2.46)	9.13 (3.00)	11.393 (3.895)
Maximum Frequency (kHz)	7.332 (1.658)	17.2 (3.1)	16.5 (4.83)	13.43 (5.46)	15.84 (3.28)	15.10 (4.30)	13.605 (4.131)
Duration (s)	1.3 (0.63)	1.4 (0.7)	1 (0.72)	0.624 (0.349)	0.64 (0.32)	0.583 (0.383)	0.27 (0.319)
Number of Inflections	2.86 (2.45)	3.7 (3.0)	3.2 (3.81)	0.545 (0.921)	0.56 (0.91)	0.223 (0.583)	0.56 (0.06)

Table 4.1.1. Six whistle parameters for different populations of the bottlenose dolphins (*Tursiops truncatus*) and the short-beaked common dolphin (*Delphinus delphis*).

When the value of k is predetermined, the CS technique has been proven to inaccurately describe the data set. In their work with bottlenose dolphin signature whistles, Sayigh *et al.* (2007) selected 20 random whistles produced from 20 dolphins. Independent visual classifiers correctly grouped whistles together from the same dolphin, indicating that there were 20 distinct categories of signature whistles. When using the CS technique, the study found that if

k=20, many whistles produced by different dolphins were grouped together. One cluster contained all whistles from six of the 20 dolphins. Again, many of the whistle clusters contained few cases. A trend seen in all of the studies conducted on dolphins (including the present study) that have incorporated the CS technique, is when k is large, 1-3 clusters generally contain the majority of whistles (McCowan, 1995; McCowan and Reiss, 1995; McCowan and Reiss, 2001; Sayigh *et al.*, 2007). Out of the 29 categories in McCowan and Reiss's study (1995), 21 had only 1-2 whistles present; again suggesting the value of k is too high. Even though an increased amount of clusters eliminates two-dimensional overlap, it calls into question the quality of the data produced by the CS technique. Further research is needed to determine if this 'dominant cluster' trend is accurately describing the whistle contour body, or is a by-product of data analysis that would render the results of the CS technique of little value.

A quantitative approach to whistle contour classification was analysed in addition to the visual technique in an attempt to use an objective system. Even though the system recommended by Ansmann (2005) is comprehensive and concise, it is only one of many. To compare whistles of the tucuxi dolphin in Brazil. six general categories were established: ascending (upsweeps), descending (downsweeps), ascending-descending (convex), descending-ascending (concave), constant (constant frequency) and other (various) (Azevedo and Van Sluys, 2005). The whistles of the white-beaked dolphin off the coast of Iceland, for example, were categorised by upsweeps, downsweeps, constant frequency or as various combinations of those three basic contours (Rasmussen and Miller, These systems share similar categories (upsweeps, downsweeps and 2002).constant frequency generally present as a classification) but the differences make comparing different populations and different species difficult. The present study and a recent study on the common dolphin population in Hauraki Gulf in New Zealand have both adapted the visual classification system established in Ansmann *et al.* (2007) to describe whistle contours (Petrella, 2009). To this author's knowledge, other than this occurrence nothing in the literature suggests a general consensus on standardising a system for visual contour classification.

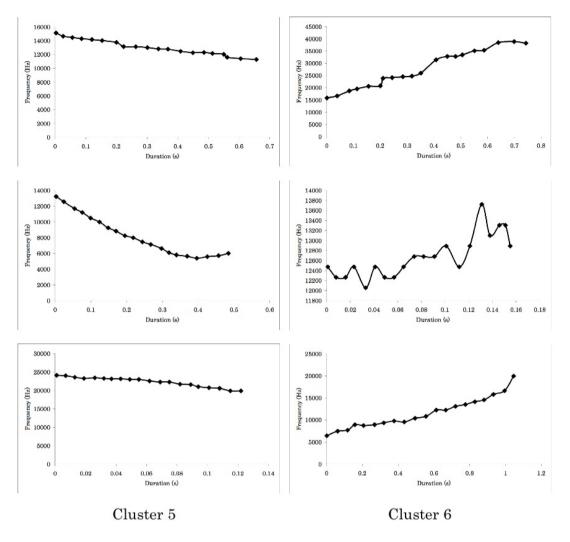


Figure 4.1.1. Three randomly selected whistles from clusters 5 and 6 when k=15.

Another disadvantage with visual classification is that it is subjective, and therefore susceptible to human error (Bazúa-Durãn and Au, 2002). Janik (1999) found low agreement when using different visual classifiers to categorise the same set of non-signature whistles. Human error can lead to both type I and II errors in statistics. Though it may reduce human labelling error, the CS technique does not appear to be suitable for classifying whistle contours. Nevertheless, it originates from a correct way of thinking, that an objective system is needed. But what the CS technique does not do, in the same manner as other quantitative methods, is look at the gestalt of the whistle contour. The CS technique only evaluates the coordinates selected for analysis. Though flawed, the visual system used in this study is currently more apt to assess each whistle as a whole than the CS technique.

4.2 Whistle repertoire for the Celtic Deep and ETP

The presence of geographical variation in the vocal characteristics of common dolphin communities is rather to be expected. In other species of highly vocal odontocetes, such as the well-studied sperm whale and bottlenose dolphin, vocal variation between locations and different communities is well documented. Evidence suggests that sperm whale codas within 200-1000 kilometres, or within the same home range, are more similar than codas from a greater distance, or from different populations (Rendell and Whitehead, 2004). Jones and Savigh (2002) found geographical variation in the production rates of whistles and echolocation in bottlenose dolphins from four different locations on the east coast of the United States. Between the Celtic Deep and the English Channel, which are only separated by approximately 100 kilometres, Ansmann et al. (2007) found vocal variation in the whistle characteristics of the short-beaked common Due to the common dolphin's fluid fission-fusion social behaviour, dolphin. Ansmann et al. (2007) speculated that when vocal variation is present in a species between two areas close in proximity, it could be attributable to a high amount of man-made background noise at one of the localities. The English Channel is well known as an area of high boat traffic in British waters, indeed some of the highest in the world (Evans, 2003; Ansmann et al., 2007). The differences between the Celtic Deep and the ETP vocal repertoires, on the other hand, are clearly examples of two separate populations.

When pooled, from the 1443 whistles, the parameters and contour type between 2004, 2005 and 2009 are consistent with previous studies in the Celtic Deep.

Upsweeps, specifically upsweeps without modulation, were the most common whistle emitted in all three years. Whistles ranged from 3.370 - 23.461 kHz, on average were 624ms long, but ranged from 17 - 2748ms. Whistles were mostly simplistic in structure, having 0-1 of both inflections and steps. Whistles from ETP common dolphins were slightly more intricate, averaging almost two steps per whistle. Exhibiting more modulation than whistles recorded in the Celtic Deep, whistles are somewhat more complex and varied in the ETP. Whistles ranged from 3.190 - 44.283kHz, averaged 583ms in duration but were documented between 15-2087ms. Both locations demonstrate a positive mean for the whistle characteristic frequency gradient. This suggests a positive slope pattern, labelled an upsweep or otherwise, for the majority of whistles recorded. When compared, the ETP mean minimum frequency (9.126kHz) was lower and the mean maximum frequency was higher (15.103kHz) than the whistles produced in the Celtic Deep (9.613kHz and 14.531kHz, respectively). This indicates that common dolphins use a much broader frequency range and variety of whistles than dolphins in the Celtic Sea.

4.2.1 Equipment limitations

The recordings made in the ETP had an upper bandwidth of 150kHz (1998) and 45kHz (2000) in the two different years sampled. Because the Celtic Sea recordings had an upper bandwidth limit of 24kHz, this discrepancy potentially allows a broader spectrum of whistles to be recorded in the ETP. In her study, Ansmann (2005) determined that an upper bandwidth limit of 24kHz was appropriate for British acoustic recordings, since a small percentage (1.15%) of recordings made in the English Channel exceeded 24kHz. This is also true for common dolphins in the ETP. Only 2.57% of 1012 whistles recorded had a maximum frequency that exceeded 24kHz. Typically, most odontocete whistles of four dolphin species (including *Delphinus delphis*) local to the ETP, Oswald *et al.* (2004) determined that 24kHz was a suitable upper bandwidth to accurately

describe the whistles of most dolphins. It can be assumed therefore that recordings with an upper bandwidth of 24kHz did not remove enough whistles to significantly change the whistle parameters and contour types found in this study.

Another potential issue for this study was the varying distances at which the hydrophones were towed in the various study areas, which can have an effect on the quality of the acoustic recordings. The further a hydrophone is towed behind a vessel, the less likely is engine noise to mask certain frequencies that may be valuable to record (Ansmann, 2005). Conversely, towing a hydrophone too far behind a vessel compromises the equipment's ability to capture cetacean vocalisations when sighted and identified by human observers onboard the towing vessel (Thode, 2009). With the exception of the first and fourth surveys from 2005 and recordings collected in 2009 over the Celtic Deep, all encounters included in this study for both regions were recorded between 200-250 metres behind the towing vessel. This affords some standardisation between locations and years, however this is a problem with the data set used in these analyses. Duration, minimum frequency, maximum frequency and mean frequency of Celtic Deep whistles were effected by varying towing distances (Appendix 7.2). Because common dolphins whistles exhibit a high level of variation between encounters, the differences found with varying tow lengths could be attributed this occurrence. Regardless, towing lengths should be taken into consideration when reviewing these results.

4.2.2 Mean power, harmonics and whistle density

Although harmonics and mean power were only measured in 100 of the whistles recorded in the Celtic Deep, the ETP overall exhibited a higher mean whistle power and average number of harmonics. Only six out of the 100 whistles measured in 2009 had harmonics present, and each of those whistles had one echo. In the ETP, 17.79% of the 1012 whistles had harmonics present with an

average of one echo per whistle, but a maximum of seven echoes. The average, minimum and maximum level of power for a whistle in the Celtic Deep was 46.17dB, 38.01dB, and 58.65dB respectively. While in the ETP, the average, minimum and maximum was 49dB, 16.6dB and 97.88dB respectively. Again, the ETP demonstrates a larger range than the Celtic Deep, in addition to generally emitting louder whistles. These results are circumstantial given that different equipment was used to make the recordings between the locations and survey years.

The difference in mean power between the two locations could be attributed to the level of whistle congestion in the recordings. Examples of recordings from the Celtic Deep and ETP are shown in Figure 4.2.1. A total of 380 whistles were detected from five hours of recordings in the Celtic Deep in 2009. Of the three hours recorded for encounter 44, only 64 minutes included the 253 whistles that were identified. For encounter 45, 50 minutes of the two hours recorded contained the 127 whistles (details in Appendix 8.7). Only 50 whistles were selected from each of the encounters to avoid over sampling of an individual or a group. The D. delphis recordings from encounters in the ETP averaged 4.62 minutes long. Most of these recordings were far too dense with vocal activity, both whistles and echolocation, to conduct a temporal breakdown of whistle activity. The 50 whistles that were randomly selected from each encounter were done so by choosing a random millisecond within a minute and identifying a clear whistle along it. If more than one clear whistle was present, the whistle that was emitted first was selected. If a clear whistle could not be detected, another random millisecond was selected. One reason why the mean power of whistles in the ETP could have been higher than those in the Celtic Deep is that the dolphins were competing for vocal dominance. Dolphin pod size was not provided for encounters in the ETP, but assumedly because their population is larger the average group is much larger than dolphin pod sighted in the Celtic Deep. Previous studies have found that pod size for common dolphins in the ETP averages at 261.16 but with a large degree of variation (s=484.64) (Au and

Perryman, 1985). Other studies on pod size in the ETP have found groups to contain even more individuals, varying between 508-932 depending on the time of day (Scott and Cattanach, 1998). The average common dolphin group size in the Celtic Deep was found to be 6-10 animals (Scullion, 2004; Ansmann, 2005; Bush, 2006). A direct relationship between group size and whistle density has been witnessed with different populations of common dolphins (Ansmann, 2005; Petrella, 2009). It can be assumed that group size attributed to whistle density in the ETP recordings.

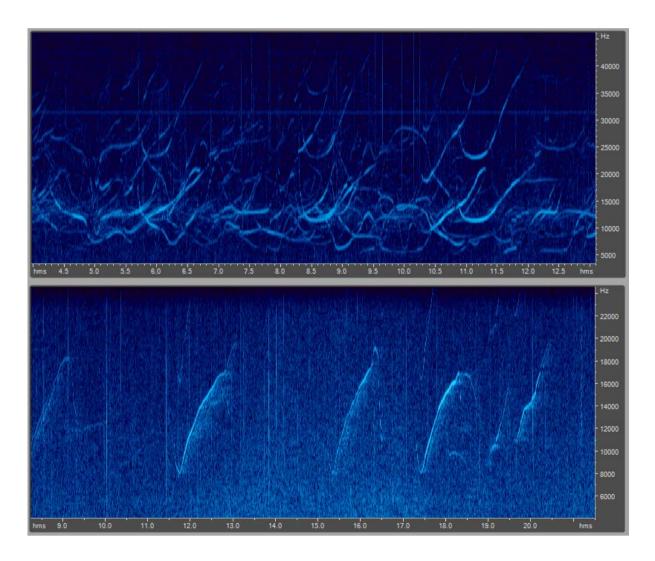


Figure 4.2.1. Examples of whistle recordings from the ETP (top) and the Celtic Deep (bottom) presented in *Adobe Audition* v.3.0. Repeat whistle types are also represented in both spectra.

As stated, vocal activity of common dolphins also correlates with dolphin behaviour. *Dephinus* sp. in New Zealand waters are known to decrease in whistle duration and increase the number of whistle emitted within a 60-minute time frame while foraging (Petrella, 2009). Ansmann (2005) found whistle durations to increase while dolphins were socialising in the Celtic Deep. In the present study mean duration was found to vary between all documented behaviours, the average whistle duration being longest while the dolphins were foraging (μ =0.625s) and socialising (μ =0.623s). Pod size is associated with the prominent dolphin behaviour in the Celtic Deep, and assumedly it is as well in the ETP. Common dolphins in the ETP, while recorded, could have been engaging in a behaviour associated with high vocal activity, such as socialising or foraging, while in large groups which could have contributed to the density of whistles in the ETP recordings.

Additionally, the large area that encompasses the ETP has varying levels of anthropogenic noise. In the ETP, evasive behaviour towards boats has been documented in some species of dolphin, but not the common dolphin (Mesnick *et al.*, 2002). Common dolphins are well known for their playful and positive behaviour in response to moving vessels. Bow riding is commonly witnessed (Perrin, 2009). The ETP supports some of the world's largest fisheries and is a popular area for eco-tourism boat traffic (Marx, 1968). If mean power had been measured in the whistles emitted by dolphins in the English Channel, an area of high boat traffic, perhaps it would have shown an increase in the average decibels that compare to the whistle strength levels found in the ETP.

4.2.3 Whistle strength

The differences between weak, moderate and strong whistles contributed to the overall composition of common dolphin whistles. Strong and moderate whistles, in which upsweeps were the principal contour, were representative for the majority of whistles analysed, and were consistent with previous studies. Weak whistles, however, composing less than 20% of whistles used in analysis, were found to be predominantly constant frequency whistles and downsweeps. The average length of a weak whistle was 0.355s, while moderate and strong whistles averaged 0.530s and 0.739s respectively. Additionally, weak whistles had a smaller frequency range and lacked the presence of harmonics. Analysing the different strengths of common dolphin whistles had an effect on the whistle composition. When observers are positive that only common dolphins are within range of the hydrophone eliminating whistles from analysis based on whistle strength can alter whistle characteristics and contour type results.

4.3 Confounding variable effects on common dolphin repertoire

4.3.1 Year correlations

Figure 4.3.1 gives the means and a 95% confidence interval for eight of the whistle parameters included in this study in each year. No obvious trend is noticeable. In the Celtic Deep, only minimum (p<0.001) and maximum (p=0.020) frequency characteristics are significantly different between the three years. Although there is a slight downward trend in minimum frequency, the means for maximum frequency do not show pattern in their variation. In the ETP, start, end, minimum, maximum and mean frequency, as well as absolute frequency gradient and frequency range varied significantly between the two years.

Although the data imply that there is temporal variation in common dolphin whistle characteristics between years, it should be borne in mind that only two and three years of data respectively were incorporated into this study. Common dolphins, like all cetaceans, have a K-selective life history. In order to acquire a more accurate depiction of how common dolphin whistle parameters vary between the years, a longer dataset would be required for analysis. These results do argue that further research to investigate the relationship between whistle characteristics and years is warranted.

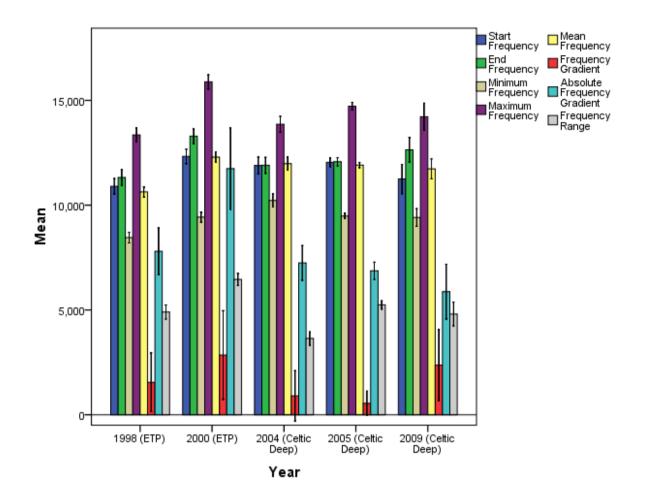


Figure 4.3.1. Histogram for the mean (with 95% confidence intervals) for start frequency, end frequency, minimum frequency, maximum frequency, mean frequency, frequency gradient, absolute frequency gradient and frequency range.

4.3.2 Diel correlations

The diel patterns in common dolphin vocalisations were detailed by Ansmann (2005). Dolphins in the Celtic Deep, recorded from 09:00 to 16:00h, were documented to decrease in vocal activity at midday increasing later in the afternoon. In the Celtic Deep and the ETP, common dolphins showed a correlation between the time of day and the contours of whistle emissions. This could be related to foraging behaviour, which in the Celtic Deep was also determined to have a relationship with whistle contour type. The small fish and cephalopods upon which common dolphins regularly feed frequently demonstrate epipelagic shoaling behaviour, migrating from the deep scattering layer (DSL) to

the surface at night (Jefferson *et al.*, 1993; Ohizumi *et al.*, 1998; Meynier *et al.*, 2008). It is believed that Pacific Ocean common dolphins frequently feed at night to take advantage of surfacing prey, therefore avoiding expending energy to dive deep during the day (Ohizumi *et al.*, 1998; Scott and Cattanach, 1998; Meynier *et al.*, 2008).

With *D. delphis* a correlation has been found between diel movement patterns, group size and density with the DSL behaviour of prey species (Scott and Cattanach, 1998; Meyniers et al., 2008). Common dolphins are more frequently found in offshore waters at night, following their prey (Meyniers et al., 2008). Hunting in large groups increases potential intraspecies and interspecies competition. As epipelagic shoaling fish come to the surface at night, they become more dispersed, so that in those circumstances, hunting in a smaller school becomes more beneficial. In the ETP, a significant difference was found between the slopes of the regression between dolphin school size and time of day between the late morning (larger herds) and the evening (smaller herds) (Scott and Cattanach, 1998). With what is already understood about the diel patterns of common dolphins in association with their foraging habits, the presence of a relationship between whistle contour and characteristics, time of day, and foraging behaviour strengthens the theory that the dolphins are using their whistles particularly as a method of communication.

4.3.3 Encounter and water column depth correlations

Appendix 7.1 lists the descriptive statistics (mean, standard deviation, minimum and maximum) for all whistle parameters measured in the different encounters and depth for the ETP and Celtic Deep. In both locations, whistles recorded within the same encounter and the same water column depth, exhibited closer similarity than with whistles recorded in other locations. There are a couple of possible reasons for this trend. Common dolphins may be forming dialects within pods, in a similar way to resident populations of Orcas off the coast of northwest North America. However, as Ansmann (2005) has pointed out, this is unlikely to be the case with common dolphins because of the fission-fusion nature of common dolphin societies. Pod sizes of common dolphins are known to shift within the same day (Scott and Cattanach, 1998), and massive gatherings of common dolphins have been witnessed sometimes containing thousands of individuals (Jefferson *et al.*, 1993; Evans, 1994; Murphy *et al.*, 2008; Perrin, 2009). To establish dialects, pods would need to possess highly stable group associations (Tyack, 1986a).

Signature whistles could cause similarities within encounters. It is not known if the common dolphin repertoire includes signature whistles. In his study, Petrella (2009) determined 20 whistles types that occurred in high repetition, which could not be described by the Ansmann et al. (2007) visual classification system. These stereotyped whistles, some occurring in multiple encounters but mostly observed in isolated encounters, could potentially be examples of common dolphin signature whistles. In this study the author did notice similar whistle types grouping together in close succession during analysis, as did Ansmann (2005). In Figure 4.2.1, repeating contours can be witnessed. However, these whistle types did not encompass the majority of whistles present. Additionally, to avoid over sampling of an individual or pod, only 50 whistles were randomly selected per encounter. Upsweeps in the Celtic Deep and ETP were the most commonly emitted whistle contour for common dolphins, which is akin to the vocal repertoires of similar delphinid species such as the spinner and tucuxi dolphins (Bazúa-Durãnn and Au, 2002; Erber and Simão, 2004; Azevedo and Van Sluys, 2005; Pivari and Rosso, 2005). The whistles most used by common dolphins were basic in structure with little to no modulation. The presence of a high amount of signature whistles, which are characteristically highly stereotyped (Cadwell and Cadwell, 1965), is unlikely.

It is possible that common dolphins experience situational vocal adaptation. Because of their worldwide distribution and fission-fusion society, they may adapt their vocal repertoires to correspond with the prevailing conditions. This could explain why in both ETP and UK waters, common dolphins have been found to be non-responsive to acoustic deterrents; they adapt to the ambient noise accordingly (Mesnick et al., 2002; Berrow et al., 2008). Dolphins within the same encounter might be expected to use similar whistles due to experiences the same social situation. Pod location factors, such as water column depth or regional local, would correlate with similar vocalisations because of the environmental situation. Whistle parameters and contour type change with the animal's behaviour, an example of social situation adaptation in the vocal repertoire of common dolphins. It is feasible that all delphinids experience situational vocal adaptation at different scales. In captive bottlenose dolphins, vocal mimicry of other dolphins or of computer generated whistles, has been observed (Tyack, 1986b; Reiss and McCowan, 1993). The discrete call types of resident Orca pods have demonstrated change over time in response to vocal learning and cultural drift (Deecke et al., 2000). In the Celtic Deep, whistle types without modulation were the most commonly emitted contour types. In the ETP, the whistles most commonly found had no or minimal modulation (variation at only one end). Common dolphins in Hauraki Gulf also exhibit minimal modulation in whistle contour (Petrella, 2009). The simple basic structure of the common dolphin whistle, when compared to other species such as the bottlenose dolphin, could afford situational vocal adaptation. However, further research is needed to verify the existence of this concept.

5. Conclusions

Visual classification remains a more reliable method of categorising whistle contours than a quantitative system. Different researchers are repeatedly identifying basic contours even if a variety of classification systems are being used (Bazúa-Durãnn and Au, 2002; Azevedo and Van Sluys, 2005; Ansmann *et al.*, 2007). For this study, the CS technique provided an accurate overview of whistle slope composition. However, it was not successful in recognising different whistle contour categories at a more specific scale. As k was increased, the quality and accuracy of the whistle contour clusters was reduced. Therefore:

The first hypothesis was rejected. The CS technique did not identify contour types more accurately than previously used visual classification techniques.

The vocal repertoires of common dolphins in the Celtic Deep and the Eastern Tropical Pacific Ocean proved to show similarities, but were still distinct. A noticeable difference was that while Celtic Deep whistles most commonly did not have modulation present, ETP whistle contours did. Whistle emitted in the ETP also used a broader frequency range in the parameters measured in this study. This argues that common dolphin whistles are somewhat more complex in the ETP than common dolphin whistles from the Celtic Deep. Therefore:

The second hypothesis was accepted. Both the whistle characteristics and contour type were significantly different between the Celtic Deep and the Eastern Tropical Pacific Ocean.

All external factors on whistle parameters and contour type, such as time of day and depth, were found to have varying effects on common dolphin whistles. This study concludes that common dolphins posses situational vocal adaptation. Whether they are foraging and following the diel patterns of epipelagic shoaling fish and squid, encountering and mingling with a different pod of dolphins as their fission-fusion social behaviour suggests, or reacting to their environment with changes in ambient noise levels or water column depth, their vocal repertoire adapts to their present situation. Therefore:

The third hypothesis was accepted. External confounding factors have an effect on the vocal repertoire, both in terms of the whistle parameters and contour type, of short-beaked common dolphins.

Recommendations for further research:

A quantitative technique. Imputing audio files into programs such as Adobe Audition or Raven software creates a matrix where x=time (duration in seconds), y=frequency (ranging from 0Hz to the upper bandwidth of the equipment used), and z=strength (power in decibels). This is what allows researchers to visualise cetacean vocalisations. While these programs can currently provide accurate descriptions of whistle parameters, whistle contours are still subjectively analysed. This is a widely held view with bioacoustic researchers (McCowan, 1995; Janik, 1999; McCowan and Reiss, 2001; Bazúa-Durãn and Au, 2002; Azevedo and Van Sluys, 2005). With the available programs and current technology, however, further research should be invested into using programs to create an objective whistle contour classification system. Perhaps this could be accomplished by using the matrix created by these programs as a whole rather than as signal frequency coordinates.

Temporal Analysis. The data for this study were sourced from various locations and research partnerships. Recordings from the same locations were not entirely consistent with respect to the recording protocols. Investing into maintaining a longer data set over several years, while keeping the protocals consistent, can aid to answer some issues raised by this study. For instance, the differences between years could simply reflect the fact that there was more coherence within the groupings sampled within a year than between years. Using standardized sampling methodology while recording the encounter details such as locations, dates, group sizes, behaviour will enable researchers to establish statistically where the main variation occurs: within groups, years and regions; between groups within years and regions; or between groups between years within regions.

Situational vocal adaptation. To expand the concept that short-beaked common dolphins adapt their vocal repertoires, more research would need to be conducted on different populations. Looking at populations off the coast of Japan, New Zealand, France and in the Mediterranean Sea, for instance, would give insights as to whether this is a worldwide species trait. Additionally, this adaptation may not exist in short-beaked common dolphins alone. Oswald et al. (2007) found that in the ETP, short-beaked common dolphin whistles and long-beaked common dolphin whistles were indistinguishable. Delphinus delphis has been known to associate heavily with other closely related species such as the striped dolphin Stenella coeruleoalba. In the Gulf of Corinth of Greece, even calves of both species have been recorded in mixed species schools (Frantzis and Herzing, 2000). Further research would be needed to identify if vocal adaptation is present in other species that are closely related to or associate with the common dolphin, or whether the common dolphin is solely adapting to the presence of an additional species. There is still much to learn about the vocal repertoire of one of the most common species of dolphin present in worldwide waters.

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		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mea Pow (dE
						Lo	ocations							
m 1	Mean	-	0.412	1.060	0.607	11931.467	12330.766	9413.054	14766.911	11856.946	1443.932	8378.145	5353.857	-
Total	SD	-	0.814	1.407	0.364	3787.879	3801.938	2569.807	3664.445	2633.405	17503.913	15435.377	3422.088	
whistles	Minimum Maximum	-	0 9	$\begin{array}{c} 0\\ 10 \end{array}$	$0.015 \\ 2.748$	3383.5 32962.9	3455.8 44282.7	$3190 \\ 24436.1$	5503.8 44282.7	4447.85 29760.885	-102528.283 589540.909	$0 \\ 589540.91$	$0 \\ 23076.9$	
	Mean	-	0.545	0.538	0.624	11962.700	12081.024	9613.738	14531.310	11910.357	738.376	6869.724	4318.347	
Celtic	SD	-	0.921	1.144	0.349	3407.562	3206.192	2192.354	3127.820	2173.025	9642.105	6803.670	3439.748	
Deep**	Minimum	-	0	0	0.0171	3555.377	4071.189	3370	5740.349	4447.85	-53261.3	0	0.000	
1	Maximum	-	9	10	2.748	23460.811	21281.011	19491.838	23460.811	20376.617	72372.245	72372.245	17147.241	
Eastern	Mean	0.267	0.223	1.804	0.583	11886.933	12686.869	9126.901	15102.853	11780.787	2449.977	10528.986	5975.952	49
Tropical	SD Minimum	0.699 0	$0.583 \\ 0$	$1.412 \\ 0$	$0.383 \\ 0.015$	4273.407 3383.5	$4495.331 \\ 3455.8$	$3005.790 \\ 3190$	$4295.113 \\ 5503.8$	$3176.148 \\ 4545.115$	24685.320 -102528.283	$22458.944 \\ 0$	$3689.148 \\ 274.2$	20 16
Pacific**	Maximum	07	7	7	2.087	32962.9	44282.7	24436.1	44282.7	29760.885	589540.909	589540.91	23076.9	97
	Maximum			·		tal Whistle			11202.1	20100.000	000010.000	000010.01	20010.0	
А	Mean	-	0.134	1.714	0.445	11180.449	11182.793	10030.544	12189.883	11005.882	1488.425	5863.563	2159.339	
	SD	-	0.391	1.681	0.294	3051.519	3004.762	2781.265	3140.123	2817.276	31148.119	30626.071	2166.386 2265.784	
	Minimum	-	0.000	0.000	0.022	3665.400	4105.300	3665.400	5503.800	4545.115	-98732.300	0.000	0.000	
		-												
В	Maximum	_	3.000	6.000	1.850	22932.300	30075.200	22368.400	31203.000	28684.210	589540.900	589540.90	14849.600	
D	Mean	-	0.174	1.091	0.558	10164.419	14612.221	9375.509	15080.779	12081.271	10744.039	11589.823	5705.270	
	SD	-	0.430	1.432	0.330	3096.007	3875.757	2688.176	3745.155	2761.069	12756.937	11992.806	3295.682	
	Minimum	-	0.000	0.000	0.015	3516.500	5498.100	3203.000	6344.800	4784.930	-50975.100	0.000	211.000	
	Maximum	-	3.000	8.000	2.017	25563.900	44282.700	24436.100	44282.700	29760.890	128538.200	128538.20	23076.900	
С	Mean	-	0.254	0.957	0.558	14749.751	10193.694	9560.847	15260.293	12002.327	-10495.215	10938.847	5699.448	
	SD	-	0.515	1.315	0.311	3501.650	2712.979	2544.014	3392.515	2510.102	10678.031	10222.260	3265.861	
	Minimum	-	0.000	0.000	0.048	4793.200	3455.800	3190.000	6258.000	4447.850	-102528.000	0.000	352.000	
	Maximum	-	3.000	7.000	1.614	32962.900	22180.500	22180.500	32962.900	26038.540	35841.950	102528.30	20112.800	
D	Mean	-	0.773	0.706	0.776	10661.218	10340.868	9187.103	15826.590	12507.205	-548.400	2694.996	6639.489	
	SD	-	0.871	1.009	0.335	3123.293	2657.805	2476.997	3344.721	2514.334	4059.856	3080.715	3009.086	
	Minimum	-	0.000	0.000	0.104	3555.377	4145.900	3555.400	5740.349	4763.285	-33452.500	0.000	71.000	
	Maximum	-	7.000	4.000	1.945	28091.300	21379.100	21379.100	28091.300	25398.140	11251.640	33452.540	17147.200	
Е		-	0.686	4.000 0.780										
Б	Mean	_			0.661	13456.928	13201.819	9084.113	14420.258	11283.552	-639.041	3396.422	5336.146	
	SD	-	0.740	1.266	0.397	3335.601	3209.651	2040.354	3367.623	2095.121	4924.358	3615.886	3155.042	
	Minimum	-	0.000	0.000	0.035	5639.100	5512.500	5007.500	8107.200	6367.650	-24391.400	0.000	282.000	
_	Maximum	-	4.000	10.000	2.087	30827.100	24456.300	16917.300	30827.100	17937.030	15037.550	24391.430	22368.500	
\mathbf{F}	Mean	-	1.702	0.686	1.017	12705.850	12251.165	8579.846	16280.539	12068.463	305.123	5053.833	7700.696	
	SD	-	1.619	1.044	0.393	4247.774	3665.473	1989.980	3291.964	2247.598	7724.761	5838.653	2895.830	
	Minimum	-	0.000	0.000	0.148	3383.500	4677.400	3383.500	8773.000	6562.510	-12617.400	0.000	141.000	
	Maximum	-	9.000	5.000	2.748	25375.900	25375.900	15977.400	27255.600	22189.850	54041.880	54041.880	16917.300	
							<u>Celtic Deep</u>							
	1					Whistle Typ	e Characte	ristics						
А	Mean	-	0.128	0.524	0.446	11101.992	11144.702	10510.562	11695.695	11084.840	272.116	2333.875	1185.133	
	SD	-	0.394	1.220	0.241	2354.548	2343.029	2279.260	2331.091	2261.475	3547.138	2679.623	1087.706	
	Minimum	-	0.000	0.000	0.068	6246.269	5646.922	4927.705	6421.644	5897.759	-13438.515	0.000	0.000	

Appendix 7.1. Full whistle characteristics descriptive statistics

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mei Pow (dB)
	Maximum	-	3.000	5.000	1.434	19911.381	19791.511	19491.838	20031.250	19731.577	15966.613	15966.613	8183.400	-
в	Mean	-	0.191	0.576	0.556	9898.619	14217.138	9541.408	14474.200	11980.929	9511.233	9729.266	4932.792	-
	SD	-	0.442	1.192	0.307	2420.289	2974.543	2184.890	2935.807	2174.206	7839.629	7566.788	2805.272	-
	Minimum	-	0.000	0.000	0.017	4629.799	6611.000	4629.799	6611.000	5811.562	-17233.100	103.873	211.000	-
	Maximum	-	3.000	8.000	1.652	20459.000	20924.702	18228.000	20924.702	19385.095	72372.245	72372.245	13734.030	-
С	Mean	-	0.292	0.617	0.586	14763.188	10054.712	9651.677	15016.049	11983.614	-9455.467	9538.670	5364.372	-
	SD	-	0.554	1.175	0.303	2915.446	2351.124	2246.889	2908.035	2129.935	6939.234	6824.092	2966.425	-
	Minimum	-	0.000	0.000	0.071	6258.000	4071.189	3370.000	6258.000	4447.850	-53261.300	214.221	352.000	-
	Maximum	-	3.000	6.000	1.614	23218.097	19467.654	19185.855	23218.097	19806.353	14887.226	53261.340	14776.709	-
D	Mean	-	1.112	0.395	0.852	10711.280	10239.378	9340.845	16196.409	12759.546	-492.027	1985.049	6855.564	-
	SD	-	0.881	0.831	0.302	2715.315	2403.228	2268.105	3018.586	2225.439	2430.728	1478.384	2910.998	-
	Minimum	-	0.000	0.000	0.112	3555.377	4145.910	3555.377	5740.349	4763.285	-6485.685	0.000	71.000	-
	Maximum	-	7.000	4.000	1.945	20051.738	18883.929	18883.929	22795.252	20376.617	7076.660	7076.660	17147.241	-
\mathbf{E}	Mean	-	0.979	0.476	0.644	13627.550	13340.007	9479.218	14325.219	11481.623	-480.831	2747.388	4846.002	-
	SD	-	0.721	1.231	0.367	2856.557	2629.346	1886.157	2938.592	1900.390	4042.700	2995.941	2742.513	-
	Minimum	-	0.000	0.000	0.035	7866.268	7683.800	5267.923	8301.000	7183.682	-24391.429	0.000	282.000	
	Maximum	-	4.000	10.000	1.768	21408.036	21281.011	16474.000	21408.036	17141.628	9001.365	24391.429	12375.300	
\mathbf{F}	Mean	-	2.551	0.398	1.066	13198.423	11512.013	8751.781	16159.147	12172.846	-1481.226	4783.339	7407.366	
	SD	-	1.451	0.882	0.400	3983.539	2929.092	1556.820	2968.241	1826.184	5991.896	3873.404	2828.438	
	Minimum	-	0.000	0.000	0.244	6972.564	4677.390	4677.390	9076.000	8939.825	-12617.418	40.351	141.000	
	Maximum	-	9.000	4.000	2.748	23460.811	20941.714	12495.000	23460.811	16905.285	20811.728	20811.728	14136.639	-
					En	counters Wh	istle Chara	acteristics						
s1	Mean	-	0	3.7	0.251	12458	13106	12147.900	13972.600	13150.348	8672.085	9408.848	1824.700	-
	SD	-	2.584	0.263	298.611	2984.878	3225.158	2979.903	3572.476	3110.266	11893.195	11253.737	2429.675	
	Minimum	-	0	0	0.017	8090	8865	7949	8865	8235.862	-2430.48	1253.333	352	
	Maximum	-	0	7	0.928	16826	18728	16826	19010	17793.85	32923.98	32923.98	8525	
s2	Mean	-	0	2.5	0.324	17248.500	13972.500	12317.000	17248.500	14260.095	-8888.905	8888.888	4931.500	
	SD	-	2.121	0.102	278.600	2789.536	6227.489	8568.720	2789.536	6768.660	7815.503	7815.471	5779.184	
	Minimum	-	0	1	0.251	15276	9569	6258	15276	9473.929	-14415.3	3362.515	845	
	Maximum	-	0	4	0.396	19221	18376	18376	19221	19046.26	-3362.51	14415.26	9018	
s3	Mean	-	0.257	2.743	0.616	13796.486	12053.371	10636.343	15012.229	12533.319	-2496.442	9118.270	4375.886	
	SD	-	0.852	2.571	0.375	4377.965	2608.566	2566.632	3390.390	2418.837	13352.546	9955.801	3138.756	
	Minimum	-	0	0	0.055	5343	7738	5343	8795	7338.108	-53261.3	334.1251	282	
	Maximum	-	4	10	1.299	20560	18094	16474	20560	17762.73	23114.75	53261.34	10709	
s4	Mean	-	0	1	0.183	10168.500	11612.500	10168.500	11612.500	10917.357	7955.487	7955.487	1444.000	
	SD	-	0	0	0.015	2341.231	2491.137	2341.231	2491.137	2745.898	1456.669	1456.669	149.907	-
	Minimum	-	0	1	0.173	8513	9851	8513	9851	8975.714	6925.466	6925.466	1338	-
	Maximum	-	0	1	0.193	11824	13374	11824	13374	12859	8985.507	8985.507	1550	
s5	Mean	-	0	1.2	0.892	6737.4	7885.7	6631.7	11669	9355.830	1297.537	1565.0644	5037.3	-
	SD	-	0	1.476	0.146	949.134	605.457	792.863	131.937	252.183	1329.507	957.430	888.717	-
	Minimum	-	0	0	0.604	5202	7104	5202	11472	9007.744	-1337.640	69.275	3945	-
	Maximum	-	0	4	1.097	8372	9076	7738	11965	9837.692	2906.017	2906.017	6763	-

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
$\mathbf{s6}$	Mean	-	0.1	1.66	0.527	11925.360	11891.540	10312.060	13933.180	12049.581	1038.245	6558.897	3621.120	-
	SD	-	0.364	1.319	0.383	3107.261	2684.212	2099.311	2738.685	2145.995	8106.778	4787.766	2298.093	-
	Minimum	-	0	0	0.051	6258	7949	6258	9006	8310.8	-14726.7	174.7815	141	-
	Maximum	-	2	5	1.945	18939	17389	17108	20701	18119	18743.12	18743.12	9088	-
$\mathbf{s7}$	Mean	-	0	5	0.877	10344.500	7949.500	7843.500	10344.500	8643.957	-2710.570	2710.569	2501.000	-
	SD	-	0	0	0.116	697.914	99.702	149.200	697.914	448.287	324.477	324.479	548.715	-
	Minimum	-	0	5	0.795	9851	7879	7738	9851	8326.97	-2940.01	2481.127	2113	-
	Maximum	-	0	5	0.959	10838	8020	7949	10838	8960.944	-2481.13	2940.01	2889	-
$\mathbf{s8}$	Mean	-	0.111	1.556	0.556	10947.222	11925.667	9851.222	13373.667	11715.303	3084.433	6136.035	3522.444	-
	SD	-	0.333	1.667	0.263	3375.425	2344.913	1149.207	3360.084	2305.633	6686.898	3613.892	2505.404	-
	Minimum	-	0	0	0.194	8301	8724	8301	9499	8594.211	-10774.2	1222.718	775	-
	Maximum	-	1	5	0.837	19503	15276	11472	19714	15365.52	11643.71	11643.71	9229	-
$\mathbf{s9}$	Mean	-	0.14	1.4	0.402	11595.680	11543.460	10038.680	13191.980	11578.089	1598.077	7892.925	3153.300	-
	SD	-	0.405	1.088	0.301	3073.954	2857.762	2553.745	2715.831	2434.512	10463.700	6966.010	2326.245	-
	Minimum	-	0	0	0.068	4779	5977	4779	7245	6560.286	-18219.4	0	0	-
	Maximum	-	2	4	1.431	18869	20066	15840	20066	17995.33	34932.77	34932.77	8806	-
s10	Mean	-	0.162	1.514	0.428	10675.730	11235.514	9377.189	12425.595	10902.231	2099.391	5478.270	3048.405	-
	SD	-	0.374	1.325	0.304	2927.967	3164.805	2593.293	3323.852	2897.429	6804.922	4471.213	2472.548	-
	Minimum	-	0	0	0.068	6117	4145	3370	6258	4447.85	-8970.53	0	0	-
	Maximum	-	1	4	1.614	19221	18376	14431	19221	16862.03	20745.83	20745.83	10075	-
s11	Mean	-	0	3.25	0.423	14377.500	11348.250	11031.000	14677.000	12195.587	-4325.864	6878.832	3646.000	-
	SD	-	0	0.957	0.253	2109.689	2872.592	2560.549	2054.991	1868.976	8109.594	5255.958	3675.997	-
	Minimum	-	0	2	0.187	12458	8301	8160	12740	9664.929	-12423.7	963.7731	282	-
	Maximum	-	0	4	0.769	17389	14642	13796	17530	14172.2	4142.17	12423.69	7820	-
s13	Mean	-	0	3	0.121	11471.667	11119.667	10884.667	11706.667	11274.061	-2395.455	6341.717	822.000	-
	SD	-	0	2.646	0.027	2104.441	1172.603	1576.208	1704.523	1631.996	7747.776	2882.576	538.125	-
	Minimum	-	0	0	0.095	9076	9781	9076	9781	9393.333	-9412.16	3693.599	352	-
	Maximum	-	0	5	0.150	13022	11965	11965	13022	12317.18	5919.395	9412.158	1409	-
s14	Mean	-	0.08	1.32	0.505	12564.780	13402.900	10967.160	15386.420	13188.568	392.235	8338.919	4419.260	-
	SD	-	0.340	1.362	0.286	2370.696	3683.921	2594.009	2620.953	2387.462	11037.218	7142.858	2721.102	-
	Minimum	-	0	0	0.075	9147	5906	5906	9640	7522.556	-30093.5	144.3089	71	-
	Maximum	-	2	5	1.339	17864	18869	17864	18939	18532.69	32158.65	32158.65	9370	-
a1	Mean	-	0.78	0.14	0.651	12213.16	11837.49	9704.944	14578.48	11863	-444.796	6288.991	4873.48	-
	SD	-	0.737	0.495	0.322	3259.257	2675.109	2044.673	2617.887	2009.821	9409.441	6955.638	2732.925	-
	Minimum	-	0	0	0.203	6153	5905	5905	9534	8247.26	-28863.6	125.5341	931.8	-
	Maximum	-	3	3	1.306	21088	19467.7	19185.9	21088	19806.35	24847.88	28863.64	11342.4	-
a2	Mean	-	0.84	0.5	0.541	11433.88	11736.42	8746.028	14004.88	11079.41	1445.316	8371.964	5258.862	-
	SD	-	1.283	0.707	0.326	4085.165	3798.798	2340.460	3880.940	2567.843	11466.672	7880.102	3326.285	-
	Minimum	-	0	0	0.056	4673	4461.9	4461.9	7421	5811.562	-33016.4	200.9235	505.9	-
	Maximum	-	7	3	1.159	23461	20009.5	15581.5	23461	17745.11	34154.31	34154.31	13023.6	-
a3	Mean	-	1.222	0	0.875	13588.89	11975.67	11301.18	16071.22	13434.39	-1725.13	3519.205	4770.089	-
	SD	_	0.833	0	0.240	1254.911	1861.576	494.736	1188.086	682,996	4087.067	2473.720	962.800	

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mea Pow (dB
	Minimum	-	0	0	0.511	11969	10466.8	10466.8	13033	11840.94	-6466.39	500.2723	2440.7	
	Maximum	-	2	0	1.158	15598	16662.3	11906.1	16787	14360.4	8073.339	8073.339	5757.5	-
a4	Mean	-	0.385	0.231	0.588	12377.92	12276.98	9898.715	14240.92	12001.9	-433.349	6267.976	4342.185	-
	SD	-	0.650	0.439	0.231	3423.343	2800.478	2396.752	2436.108	2271.035	7739.308	4187.947	1805.947	-
	Minimum	-	0	0	0.360	7338	6899.6	6899.6	10529	8839.721	-13608.8	125.0652	1376.8	-
	Maximum	-	2	1	1.126	18915	16161.6	14472	18915	17053.88	11716.55	13608.82	7760.1	-
a5	Mean	-	0.54	0.12	0.575	11993.78	12629.57	9146.288	14655.98	11532.37	-889.656	7726.503	5509.646	-
	SD	-	0.706	0.328	0.322	3646.050	3800.136	2116.736	3813.961	2466.614	9634.717	5719.986	3445.935	
	Minimum	-	0	0	0.148	5210	5335.1	5209.9	9215	7668.489	-28455.7	0	751	-
	Maximum	-	3	1	1.179	20104	20792.7	16724.9	22795	18407.98	22551.56	28455.69	17147.2	-
a6	Mean	-	0.484	0.065	0.492	11530.19	12806.22	10412.69	13796.13	11978.89	3428.863	6799.686	3383.406	
	SD	-	0.851	0.250	0.254	3188.917	3412.140	2827.584	3214.351	2717.312	8334.242	5816.496	2580.524	
	Minimum	-	0	0	0.086	6246	5646.9	4927.7	6666	5897.759	-15749.8	0	359.6	
	Maximum	-	3	1	1.115	17934	18712.7	16615	18713	17630.34	18765.7	18765.7	9529.6	
a7	Mean	-	0.38	0.08	0.400	11447.36	12339.23	10155.21	13290.92	11529.95	3968.612	7784.768	3135.788	
	SD	-	0.635	0.274	0.236	3068.048	2831.779	2616.058	2894.317	2556.648	12138.265	10078.165	1911.573	
	Minimum	-	0	0	0.075	4868	7804.6	4867.8	8584	6896.186	-16653.5	127.6584	419.5	
	Maximum	-	2	1	0.970	19911	19791.5	19491.8	20990	19731.58	54534.67	54534.67	8990.2	
a8	Mean	-	0.133333	0	0.417	12032.07	11852.17	10110.06	14145.67	12223.23	-759.404	7770.426	4035.6	
	SD	-	0.352	0	0.272	2579.052	3400.233	1535.547	3043.409	1738.497	9509.400	5133.631	3532.139	
	Minimum	-	0	0	0.069	8044	8164.2	8044.3	8284	8194.146	-14698.3	0	239.7	
	Maximum	-	1	0	0.859	16555	20211.1	13438.4	20211	14503.16	13822.95	14698.25	11867.1	
a14	Mean	-	0.56	0.16	0.704	11972.72	12265.77	9370.558	14672.4	11709.91	-69.5305	6778.405	5301.83	
	SD	-	0.929	0.548	0.262	3798.768	3251.562	1857.419	3233.204	1895.075	9295.161	6286.531	3282.199	
	Minimum	-	0	0	0.161	6390	6184.3	6083.9	6422	6238.666	-38708.5	239.7971	296.7	
	Maximum	-	4	3	1.316	20904	20534.5	12831.9	20904	16328.29	17493.64	38708.48	12077.5	
a16	Mean	-	0.22	0.02	0.612	12153.84	12079.4	10182.94	14377.28	12171.72	714.7043	6444.809	4194.332	
	SD	-	0.545	0.141	0.300	3438.810	2734.960	2165.629	2916.261	1855.901	8931.155	6156.581	3418.393	
	Minimum	-	0	0	0.155	6820	5768.9	5590.8	7752	7367.482	-19163.2	0	232.8	
	Maximum	-	3	1	1.274	20308	18765.2	14907.9	20783	16603.13	31249.49	31249.49	14776.7	
a17	Mean	-	0	0	0.194	12814.67	13183.3	12776	13183.33	13041.63	1907.607	1907.607	407.4	
	SD	-	0	0	0.010	174.500	33.602	121.153	33.486	55.820	963.548	963.548	116.4	
	Minimum	-	0	0	0.185	12640	13163.9	12640.2	13164	13003.91	904.6171	904.6171	291	
	Maximum	-	0	0	0.205	12989	13222.1	12873	13222	13105.75	2826.154	2826.154	523.8	
a18	Mean	-	0.76	0.16	0.617	11348.36	12028.11	9247.998	14330.32	11618.65	741.2639	7435.669	5082.25	
	SD	-	1.153	0.370	0.387	2854.463	3432.974	1715.944	3087.553	1775.094	9467.908	5812.435	3208.245	
	Minimum	-	0	0	0.056	6762	6354.8	5831.1	7344	7185.483	-18837.8	221.435	473.6	
	Maximum	-	4	1	2.017	20904	19158.3	12465.6	20904	15354.76	28256.79	28256.79	11581.3	-
a19	Mean	-	0.94	0.22	0.706	11561.88	12480.69	8566.498	15528.26	11912.11	3423.454	9494.204	6961.736	-
	SD	-	1.490	0.465	0.296	4830.842	2732.826	1913.062	3042.760	1704.073	14478.248	11384.172	3183.681	-
	Minimum	-	0	0	0.147	4630	7293.7	4629.8	10372	8131.852	-24840.9	0	592	-
	Maximum	-	7	2	1.412	23218	20909.4	12088.8	23218	16108.37	72372.24	72372.24	14089.2	-

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mea Pow (dB)
a20	Mean	-	0.78	0.12	0.724	12528.64	11427.91	9263.408	14854.14	11928.18	-385.973	5813.382	5590.716	-
	SD	-	0.932	0.385	0.344	3667.840	2847.936	1414.118	3223.947	1794.590	7354.701	4445.063	3286.510	-
	Minimum	-	0	0	0.074	7022	7257.8	7022.2	8259	7833.83	-19865.9	0	589.1	-
	Maximum	-	4	2	1.460	21337	19843.8	12559.6	21337	16119.67	13488.17	19865.95	12842.1	-
a22	Mean	-	0.96	0.14	0.792	11242.22	11573.5	8727.498	14840.64	11478.81	10.81806	4775.265	6113.22	-
	SD	-	1.049	0.452	0.394	3159.753	3177.439	1571.798	2830.014	1544.007	6349.969	4129.614	3153.864	-
	Minimum	-	0	0	0.168	6456	7094.2	6339.4	9242	8477.861	-15479.6	0	174.2	-
	Maximum	-	4	2	1.752	20680	20215.1	14177.1	20680	15113.32	13094.86	15479.62	13062.9	-
a23	Mean	-	1.226	0.032	0.761	13687.71	11714.28	10077.17	16879.29	13178.43	261.7363	7803.465	6802.039	-
	SD	-	0.990	0.180	0.345	3362.260	2668.777	1825.536	3297.006	1961.237	12615.716	9813.422	3249.476	-
	Minimum	-	0	0	0.051	8098	7870.5	7813.5	11231	9740.997	-14329.8	0	398.7	-
	Maximum	-	3	1	1.239	19718	19774.9	15503	20231	16855.77	43867.81	43867.81	11505.8	-
a25	Mean	-	0.234	0.064	0.565	12309.62	12619.14	10618.83	14187.89	12236.83	1446.364	5634.023	3569.064	-
	SD	-	0.476	0.247	0.280	2707.240	2892.014	1504.786	2866.698	1605.695	7449.062	5019.337	2834.972	-
	Minimum	-	0	0	0.139	7870	7328.8	7328.8	9522	8943.189	-14065.5	0	284.8	-
	Maximum	-	2	1	1.371	19775	21281	14933.4	21281	16267.87	18578.92	18578.92	10018.6	-
a26	Mean	-	0.82	0.08	0.791	12518.76	12271.67	9499.664	15131.04	11962.41	812.4158	6261.418	5631.3	-
	SD	-	1.119	0.274	0.322	3236.983	3982.691	2746.868	2674.091	2376.387	7977.670	4930.641	2661.666	-
	Minimum	-	0	0	0.215	5423	4132.7	4132.7	9910	7059.268	-14917.1	148.9162	553.2	-
	Maximum	-	4	1	1.598	18269	20297.6	15257.6	20298	17701.17	20920.14	20920.14	10633.2	-
a27	Mean	-	0.907	0.070	0.825	12660.44	11719.84	9760.153	16136.77	12985.08	-822.407	4661.122	6376.502	-
	SD	-	0.840	0.258	0.260	3530.045	3262.412	2230.273	2598.539	1956.185	6490.255	4535.694	2860.597	-
	Minimum	-	0	0	0.238	5792	6775.6	5792.2	8189	7368.275	-20702.3	143.7059	1229.3	-
	Maximum	-	4	1	1.148	20052	19683	18883.9	21465	20376.62	18235.96	20702.33	13276.1	-
a28	Mean	-	0.68	0.08	0.685	12008.34	12759.94	9406.128	15529.72	12214.86	1877.485	6904.271	6123.482	-
	SD	-	0.999	0.274	0.351	3315.047	3833.558	1894.939	3137.491	1781.354	9218.020	6318.780	3827.297	-
	Minimum	-	0	0	0.117	7022	4071.2	4071.2	7317	7162.105	-17595.1	203.5631	294.5	-
	Maximum	-	5	1	1.652	20175	20924.7	12799	20925	15490.62	23596.9	23596.9	14382.5	-
a31	Mean	-	0.429	0.286	0.922	13174	13493.76	9294.414	16717.29	12668.18	-88.1079	5990.246	7422.543	-
	SD	-	0.535	0.756	0.201	3166.824	4932.356	1634.934	2399.396	1808.886	7001.481	2676.980	2290.391	-
	Minimum	-	0	0	0.671	8966	7611.3	7434.6	13915	10615.64	-9317.3	1774.916	3770.2	-
	Maximum	-	1	2	1.246	17213	19098.5	11734.9	19099	15462.24	8477.519	9317.296	10250.2	-
a33	Mean	-	0.64	0.04	0.777	12041.22	12741.72	9568.52	15148.18	12066.35	1059.092	5617.945	5579.672	-
	SD	-	0.749	0.198	0.353	2724.789	3485.699	1257.698	3155.372	1965.981	7238.495	4618.979	2892.576	-
	Minimum	-	0	0	0.233	8023	6513.6	6513.6	8023	7227.696	-12008.7	282.4717	345	-
	Maximum	-	3	1	1.981	19504	19286.2	13410.4	19581	15546.45	24214.53	24214.53	11282.9	-
a34	Mean	-	0.64	0.06	0.604	11370.24	12275.76	9153.11	14721.28	12028.07	1474.651	8157.566	5568.212	-
	SD	-	1.083	0.240	0.343	3548.107	3329.548	1823.229	3026.189	1825.647	10275.824	6317.248	3383.955	-
	Minimum	-	0	0	0.083	5818	6566	5703.4	8857	7836.643	-20309.2	171.2713	230	-
	Maximum	-	5	1	1.685	18354	20941.7	12258.8	21079	16905.28	24141.29	24141.29	13283.2	-
a35	Mean	-	0.25	0	0.339	11173.25	16694.75	11173.25	17004.75	14614.89	18071.9	18071.9	5831.525	-
	SD	-	0.500	0	0.092	853.196	2261.854	853.057	2455.611	2231.894	8851.146	8851.146	1761.970	-

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	Minimum	-	0	0	0.240	10228	13358.2	10228.4	13417	11885.83	6775.012	6775.012	3188.9	-
	Maximum	-	1	0	0.462	12059	18377.8	12059.1	18732	16871.9	28024.28	28024.28	6732.1	-
a36	Mean	-	0.6	0.1	0.568	12647.18	10346.5	8980.012	13814.12	11302.21	-4951.22	8313.589	4834.106	-
	SD	-	1.030	0.364	0.315	3031.488	3074.570	2134.837	2709.551	1847.945	9509.699	6702.470	3179.231	-
	Minimum	-	0	0	0.072	7630	4086.9	4086.9	8398	7846.584	-29753.9	189.2224	413.4	-
	Maximum	-	5	2	1.312	19441	17728.2	15307	19441	15962.48	15114.05	29753.94	13582.3	-
a37	Mean	-	0.714	0	0.748	13493.14	12059.07	10329.64	14547.57	12101.14	-2176.96	2746.839	4218.086	-
	SD	-	0.756	0	0.254	2423.284	1560.901	1642.087	2822.771	1430.006	3091.986	2507.336	3223.831	-
	Minimum	-	0	0	0.393	8634	9637.9	7984.4	11291	10499.51	-7196.88	215.9296	590.5	-
	Maximum	-	2	0	1.041	15425	14007.8	12177.2	20031	14788.27	1994.578	7196.877	9566.6	-
a38	Mean	-	0.66	0.04	0.635	12358.62	11721.39	9428.204	14604.9	11822.79	-1988.2	6767.247	5176.71	-
	SD	-	0.717	0.198	0.289	2948.995	2884.474	1710.975	2792.228	1803.476	10992.852	8840.031	3055.657	-
	Minimum	-	0	0	0.088	6122	6122.1	5267.9	9343	7183.682	-52544	0	232.8	-
	Maximum	-	3	1	1.216	19618	18909.2	13476.3	19618	16069.76	13311	52543.97	13560	-
a39	Mean	-	1.824	0.353	0.532	10940.41	11277.47	8647.859	13080.41	10493.93	1793.261	5058.721	4432.471	-
	SD	-	2.430	0.702	0.375	3735.564	3512.032	2350.612	3640.686	2354.853	5916.773	3351.853	3106.312	-
	Minimum	-	0	0	0.057	3555	4145.9	3555.4	5740	4763.285	-11174.5	869.8103	1003.9	-
	Maximum	-	9	2	1.283	16783	17669.1	13358.2	19677	14119.36	12822.7	12822.7	9921	-
a40	Mean	-	0	0	0.373	7305	17078.6	7305.3	17078.5	12434.7	27328.16	27328.16	9773.3	-
	SD	-	0	0.102	793.374	501.056	793.374	501.339	791.062	8255.500	8255.500	292.318		-
	Minimum	-	0	0	0.301	6744	16724.3	6744.3	16724	11875.33	21490.64	21490.64	9566.6	-
	Maximum	-	0	0	0.445	7866	17432.9	7866.3	17433	12994.06	33165.68	33165.68	9980	-
a42	Mean	-	0.7	0.04	0.679	12324.12	11740.72	9144.75	14932.42	11817.73	-205.99	6787.25	5787.718	-
	SD	-	0.814	0.198	0.348	3721.916	2835.559	1956.975	3006.902	1841.987	9364.348	6381.800	3388.365	-
	Minimum	-	0	0	0.093	5933	7442.5	5758.8	8988	7652.018	-26493.6	77.39811	117.2	-
	Maximum	-	3	1	1.562	21408	16960.5	13663.6	21408	15480.47	34262.89	34262.89	12888.7	-
g372	Mean	0.08	0.16	1.96	0.783	10454.38	12427.59	9214.254	13771.44	11471.74	2811.225	5735.022	4557.09	46.267
	SD	0.274	0.370	1.511	0.548	2740.778	2668.175	1828.995	2911.365	2057.339	8308.014	6597.399	2895.304	3.317
	Minimum	0	0	0	0.035	5266	7351.8	5265.8	7352	6936.755	-24391.4	0	469.6	40.395
	Maximum	1	1	5	2.748	18213	19256.9	12616.6	19447	16610.27	28895.38	28895.38	12047.4	54.955
g278	Mean	0.04	0.2	1.62	0.634	12047.06	12855.56	9605.88	14661.24	11992.79	1922.304	6012.995	5055.266	46.080
	SD	0.198	0.452	1.292	0.317	4014.042	3297.766	2364.687	3560.855	2682.627	8774.605	6623.472	2784.828	3.859
	Minimum	0	0	0	0.137	6356	6037	5994.5	8586	7123.615	-14373	136.4819	569.2	38.01
	Maximum	1	2	5	1.768	20459	19770.8	18228	21082	19385.1	43236.73	43236.73	12375.3	58.65
					Н	our (hr) Whi	stle Charao	eteristics						
6:00-6:59	Mean	0.118	0.059	2.235	0.738	11285.312	12758.718	9914.688	13761.500	11722.856	2071.060	3617.388	3846.812	46.537
	SD	0.332	0.243	1.437	0.372	2237.110	2211.431	1917.111	2595.794	2030.506	4389.081	3149.296	2640.360	3.774
	Minimum	0.000	0.000	0.000	0.210	6640.300	8317.600	6640.300	8317.600	7968.775	-8215.196	0.000	670.800	40.395
	Maximum	1.000	1.000	5.000	1.329	15367.600	15708.800	12059.600	19067.200	13947.000	12525.108	12525.108	11004.000	54.955
7:00-7:59	Mean	0.067	0.233	1.600	0.835	10128.110	12509.623	8879.517	14163.087	11561.340	3357.858	7328.705	5283.570	46.033
	SD	0.254	0.430	1.380	0.648	2997.579	2850.761	1733.649	2917.800	2003.962	10236.044	7802.475	2875.621	3.167
	Minimum	0.000	0.000	0.000	0.035	5265.800	7683.800	5265.800	8537.500	7290.110	-24391.429	103.873	469.600	40.410

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	Maximum	1.000	1.000	5.000	2.748	18213.400	19256.900	12616.600	19446.600	16610.265	28895.385	28895.385	12047.400	52.015
8:00-8:59	Mean	-	0.242	0.500	0.583	12535.518	12807.725	10569.596	14458.770	12364.159	1535.380	5862.229	3889.174	-
	SD	-	0.468	1.184	0.284	3153.187	3110.675	1592.682	3072.349	1938.078	8886.884	6814.958	2737.265	-
	Minimum	-	0.000	0.000	0.139	6972.300	7328.763	6782.600	7351.800	6936.755	-14373.003	0.000	284.796	-
	Maximum	-	2.000	5.000	1.371	20459.000	21281.011	14933.400	21281.011	16720.195	43236.735	43236.735	10018.575	-
9:00-9:59	Mean	-	0.578	0.478	0.648	12198.254	11929.244	9589.632	14731.401	12021.479	231.352	6748.425	5141.769	-
	SD	-	0.904	0.915	0.340	3285.437	3423.238	2337.130	3004.907	2230.120	8994.263	5937.797	3106.354	-
	Minimum	-	0.000	0.000	0.068	4779.000	4071.189	4071.189	7245.000	6560.286	-29753.940	0.000	0.000	-
	Maximum	-	5.000	4.000	1.768	20174.665	20924.702	18883.929	21465.402	20376.617	34932.770	34932.770	14382.494	-
10:00-10:59	Mean	-	0.563	0.648	0.608	11510.967	11773.118	9085.566	14061.175	11320.831	-169.692	6037.492	4975.609	-
	SD	-	0.838	1.118	0.370	3296.524	3443.310	2121.404	3450.523	2308.591	7829.372	4961.676	3296.669	-
	Minimum	-	0.000	0.000	0.068	5209.943	4145.000	3370.000	6258.000	4447.850	-28455.687	0.000	0.000	-
	Maximum	-	4.000	4.000	1.752	20679.556	20792.654	16724.878	22795.252	18407.982	22551.563	28455.687	17147.241	-
11:00-11:59	Mean	-	0.200	0.000	0.559	9920.989	12791.733	9795.678	14124.579	11796.339	5402.279	5713.548	4328.901	-
	SD	-	0.447	0.000	0.197	1844.371	2538.554	1716.071	3060.571	1609.952	5341.091	4919.576	3330.288	-
	Minimum	-	0.000	0.000	0.301	7870.457	10832.336	7870.457	10832.336	9373.095	-778.174	778.174	854.388	-
	Maximum	-	1.000	0.000	0.805	11800.643	17097.850	11800.643	17667.442	13814.468	13094.864	13094.864	8885.638	-
12:00-12:59	Mean	-	0.667	0.035	0.648	12497.982	11762.856	9538.905	14597.895	11856.972	-2011.382	6273.512	5058.990	-
	SD	-	0.715	0.186	0.285	2894.803	2748.409	1714.503	2770.578	1753.155	10332.747	8415.687	3063.371	-
	Minimum	-	0.000	0.000	0.088	6122.056	6122.056	5267.923	9342.601	7183.682	-52543.973	0.000	232.790	-
	Maximum	-	3.000	1.000	1.216	19617.877	18909.237	13476.333	20031.250	16069.757	13311.005	52543.973	13560.009	-
13:00-13:59	Mean	-	0.548	0.143	0.728	12627.245	12440.676	9511.728	15325.646	11994.328	-1234.820	6776.003	5813.919	-
	SD	-	0.832	0.472	0.251	3745.684	3557.068	1861.938	3090.068	1792.686	9209.774	6272.785	3396.194	-
	Minimum	-	0.000	0.000	0.161	6390.387	6329.079	6267.772	7984.375	7820.067	-38708.485	239.797	369.726	-
	Maximum	-	3.000	2.000	1.246	20904.212	20534.487	12831.881	20904.212	16328.294	14595.798	38708.485	12077.529	-
14:00-14:59	Mean	-	0.711	0.763	0.503	11354.314	12346.914	9974.164	13577.005	11651.040	3474.788	6660.027	3602.841	-
	SD	-	1.468	1.696	0.328	3265.460	3334.054	2718.268	3299.094	2627.897	8401.697	6154.371	2836.550	-
	Minimum	-	0.000	0.000	0.017	3555.377	4145.910	3555.377	5740.349	4763.285	-15749.775	0.000	296.721	-
	Maximum	-	9.000	7.000	1.316	17933.535	19203.602	16826.000	19676.930	17793.850	32923.980	32923.980	9920.956	-
15:00-15:59	Mean	-	0.396	0.072	0.534	11756.177	12186.377	10023.951	14020.551	11829.241	2346.661	7171.382	3996.599	-
	SD	-	0.633	0.333	0.293	3166.962	2753.863	2182.976	2802.327	2072.831	10562.726	8081.862	2797.981	-
	Minimum	-	0.000	0.000	0.075	4867.771	5768.858	4867.771	7751.585	6896.186	-26082.752	0.000	232.790	-
10.00 10.70	Maximum	-	3.000	3.000	1.274	20308.190	19791.511	19491.838	20990.205	19731.577	54534.668	54534.668	14776.709	-
16:00-16:59	Mean	-	0.789	0.082	0.665	12075.073	12103.413	9599.203	14945.345	12091.123	522.597	6816.560	5346.142	-
	SD	-	1.064	0.275	0.374	3109.568	3225.250	1822.809	3266.057	2034.799	9557.232	6698.998	3257.932	-
	Minimum	-	0.000	0.000	0.051	6152.686	6354.846	5644.562	7344.203	7185.483	-28863.644	0.000	239.739	-
15:00 15:50	Maximum	-	7.000	1.000	2.017	21087.993	20211.054	19185.855	21087.993	19806.353	43867.813	43867.813	11867.071	-
17:00-17:59	Mean	-	0.642	0.276	0.608	11983.763	11944.555	9043.037	14720.575	11718.714	205.557	8003.582	5677.538	-
	SD	-	0.959	0.631	0.344	3905.926	3515.477	2245.724	3414.520	2289.987	10411.823	6623.162	3394.112	-
	Minimum	-	0.000	0.000	0.056	4673.246	4461.897	4461.897	7420.779	5811.562	-33016.449	171.271	230.012	-
10:00 10:50	Maximum	-	5.000	4.000	1.685	23460.811	20941.714	18376.000	23460.811	19046.260	34154.312	34154.312	13283.189	-
18:00-18:59	Mean	-	0.491	1.719	0.614	12968.642	12172.673	10215.999	14848.177	12287.560	-619.844	8232.013	4632.178	-

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	SD	-	0.909	2.396	0.357	4170.294	2536.700	2410.979	3184.377	2206.071	12482.821	9340.014	3218.121	-
	Minimum	-	0.000	0.000	0.055	5343.000	7468.080	5343.000	8795.000	7338.108	-53261.300	77.398	117.244	-
	Maximum	-	4.000	10.000	1.299	21408.036	18094.000	16474.000	21408.036	17762.730	34262.887	53261.340	12563.170	-
19:00-19:59	Mean	-	0.350	1.075	0.599	11687.360	12297.585	9741.266	14744.258	12194.196	1597.951	7720.323	5002.991	-
	SD	-	0.960	1.286	0.335	3708.915	3224.257	2492.482	2899.545	2218.910	11140.219	8166.744	2998.661	
	Minimum	-	0.000	0.000	0.051	4629.799	5906.000	4629.799	9006.000	7522.556	-30093.500	0.000	71.000	
	Maximum	-	7.000	5.000	1.945	23218.097	20909.360	17864.000	23218.097	18532.690	72372.245	72372.245	14089.220	-
20:00-29:59	Mean	-	0.000	5.000	0.877	10344.500	7949.500	7843.500	10344.500	8643.957	-2710.570	2710.569	2501.000	-
	SD	-	0.000	0.000	0.116	697.914	99.702	149.200	697.914	448.287	324.477	324.479	548.715	
	Minimum	-	0.000	5.000	0.795	9851.000	7879.000	7738.000	9851.000	8326.970	-2940.010	2481.127	2113.000	-
	Maximum	-	0.000	5.000	0.959	10838.000	8020.000	7949.000	10838.000	8960.944	-2481.130	2940.010	2889.000	-
21:00-21:59	Mean	-	0.780	0.120	0.724	12528.672	11427.909	9263.410	14854.124	11928.181	-385.975	5813.382	5590.714	
	SD	-	0.932	0.385	0.344	3667.850	2847.935	1414.118	3223.916	1794.589	7354.704	4445.062	3286.512	-
	Minimum	-	0.000	0.000	0.074	7022.196	7257.832	7022.196	8259.283	7833.830	-19865.947	0.000	589.089	-
	Maximum	-	4.000	2.000	1.460	21337.064	19843.788	12559.635	21337.064	16119.671	13488.166	19865.947	12842.145	-
22:00-22:59	Mean	-	0.111	1.556	0.556	10947.222	11925.667	9851.222	13373.667	11715.303	3084.433	6136.035	3522.444	-
	SD	-	0.333	1.667	0.263	3375.425	2344.913	1149.207	3360.084	2305.633	6686.898	3613.892	2505.404	-
	Minimum	-	0.000	0.000	0.194	8301.000	8724.000	8301.000	9499.000	8594.211	-10774.200	1222.718	775.000	
	Maximum	-	1.000	5.000	0.837	19503.000	15276.000	11472.000	19714.000	15365.520	11643.710	11643.710	9229.000	
						Year Whistl	e Characte	ristics						
2004	Mean	_	0.12121	1.7917	0.49398	11894.30682	11903.583	10223.545	13862.773	11983.362	899.2733525	7242.3723	3639.23	
	SD	_	0.12121	1.7917	0.49598	4779	4145	10225.545 3370	13862.775 6258	4447.85	-53261.3	1242.3123	3639.23 0	
	SD Minimum	_	4	0 10	1.9446	4779 20560	4145 20066	18376	6258 20701	4447.85 19046.26	$^{-55261.5}$ 34932.77	53261.34	10709	
	Maximum	_	0.445	1.717	0.336	20560 3358.345	3131.291	2604.867	3069.952	19046.26 2580.179	9926.256	6833.077	2611.196	
2005	Maximum Mean	_	0.445	0.116	0.336 0.647945	12045.43	12072.49	2604.867 9483.413	14724.1	2580.179 11909	548.093	6855.077 6870.829	5240.669	-
2000	SD		0.082	0.116	0.33353	3404.85	3240.291	2062.097	3106.687	2040.16	9663.341	6813.866	3240.003 3219.937	
	SD Minimum	_	0.997	0.376	0.0506	3555	4071.2	2082.097 3555.4	5106.687	4763.285	-52544	0013.000	5219.957 117.2	
	Maximum	_	9	3	2.0173	23461	4071.2 21281	19491.8	23461	4765.265 20376.62	-52544 72372.24	72372.24	117.2 17147.2	_
2009	Maximum Mean	0.06	9 0.18	3 1.79	2.0175	11250.72	12641.58	9410.067	14216.34	20376.62 11732.27	2366.765	5874.009	4806.178	46.173
2005	SD	0.239	0.18	1.409	0.70871 0.452022	3511.901	2992.086	2112.363	3266.643	2392.781	2500.705 8512.959	6578.46	2837.286	40.175 3.581
	SD Minimum	0.239	0.411	1.409	0.452022	5511.901 5266	2992.086 6037	5265.8	5266.645 7352	2392.781 6936.755	-24391.4	0578.46	2037.200 469.6	3.581 38.01
	Maximum	1	0 2	5	2.748	20459	19770.8	18228	21082	19385.1	43236.73	43236.73	469.6 12375.3	58.65
	Maximum	1	2	5		lumn Depth				15565.1	45250.75	43230.73	12375.5	00.00
001-100	Mean		0.416	$0.833 \\ 1.3917$	0.605	11895.932	12110.950	9741.882	14333.751	11923.532	986.036	6952.0562	4591.869	
	SD		0.890	1.3917 13193	0.352	3446.810132	3137.1584 34	2245.8368 7	3104.9155 63	2212.9663 86	9680.2542	6803.73565	3080.0891 72	
	Minimum		0	0	0.0171	3555.3768	4086.8566	3370	5740.3493	4447.85	-53261.3 72372.2448	0	0	
	Maximum		9	10	2.748	23218.097	21281.011	18376	23218.097	19385.095	8	72372.245	14776.709	
101-200	Mean		0.715	0.148	0.649	12051.079	12041.413	9444.118	14792.812	11892.917	410.556	6760.744	5348.694	
	SD		0.934	0.462	0.343	3355.627	3297.479	2109.327	3141.311	2120.647	9589.321	6807.534	3192.930	
	Minimum		0.000	0.000	0.051	4673.246	4071.189	4071.189	7316.741	5811.562	-52543.973	0.000	117.244	

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mea Powe (dB)
	Maximum		7.000	5.000	2.017	23460.811	20924.702	19491.838	23460.811	20376.617	54534.668	54534.668	17147.241	
						The Eastern	-							
						Whistle Typ								
А	Mean	0.095	0.139	2.821	0.445	11253.440	11218.232	9583.959	12649.650	10932.421	2620.016	9147.402	3065.692	49.
	SD	0.341	0.388	1.236	0.336	3584.877	3515.995	3117.820	3685.842	3254.329	43162.203	42258.504	2668.445	20.
	Minimum	0.000	0.000	0.000	0.022	3665.400	4105.300	3665.400	5503.800	4545.115	-98732.323	0.000	274.200	17.
D	Maximum	2.000	2.000	6.000	1.850	22932.300	30075.200	22368.400	31203.000	28684.210	589540.909	589540.91	14849.600	86
В	Mean	0.301	0.151	1.835	0.560	10548.096	15182.514	9136.035	15956.363	12226.109	12523.567	14275.497	6820.328	49
	SD	0.768	0.411	1.424	0.360	3840.380	4840.702	3270.060	4536.255	3434.322	17440.241	16033.573	3620.078	19
	Minimum	0.000	0.000	0.000	0.015	3516.500	5498.100	3203.000	6344.800	4784.930	-50975.141	0.000	538.900	18
C	Maximum	7.000	3.000	6.000	2.017	25563.900	44282.700	24436.100	44282.700	29760.885	128538.235	128538.24	23076.900	96
С	Mean	0.194	0.184	1.587	0.508	14724.867	10451.092	9392.624	15712.643	12036.983	-12420.875	13532.032	6320.019	48
	SD	0.610	0.426	1.331	0.321	4393.948	3270.670	3017.282	4113.166	3099.313	15203.374	14218.190	3686.304	21
	Minimum	0.000	0.000	0.000	0.048	4793.200	3455.800	3190.000	6860.900	6033.840	-102528.283	0.000	660.700	18
D	Maximum	5.000	2.000	7.000	1.491	32962.900	22180.500	22180.500	32962.900	26038.535	35841.949	102528.28	20112.800	97
D	Mean	0.349	0.174	1.256	0.643	10572.736	10520.244	8915.373	15172.955	12061.205	-648.036	3949.787	6257.581	49
	SD	0.589	0.411	1.065	0.351	3753.520	3063.482	2802.070	3785.319	2917.814	5953.573	4481.692	3156.205	19
	Minimum	0.000	0.000	0.000	0.104	3947.400	4646.600	3947.400	6860.900	6339.285	-33452.542	0.000	638.700	18
Ð	Maximum	2.000	2.000	4.000	1.382	28091.300	21379.100	21379.100	28091.300	25398.140	11251.643	33452.542	16776.300	85
Ε	Mean	0.363	0.220	1.264	0.686	13185.058	12981.632	8454.548	14571.692	10967.941	-891.135	4430.598	6117.144	52
	SD	1.017	0.490	1.172	0.442	3984.260	3969.636	2127.384	3969.641	2349.309	6087.984	4244.784	3599.138	21
	Minimum	0.000	0.000	0.000	0.057	5639.100	5512.500	5007.500	8107.200	6367.650	-16781.159	0.000	1594.900	20
Б	Maximum	6.000	2.000	5.000	2.087	30827.100	24456.300	16917.300	30827.100	17937.025	15037.548	16781.159	22368.500	87
\mathbf{F}	Mean	0.495	0.806	0.989	0.965	12186.795	13030.062	8398.662	16408.457	11958.465	2187.513	5338.870	8009.795	45
	SD	0.802	1.271	1.118	0.382	4472.372	4184.080	2357.586	3613.764	2625.418	8854.400	7377.280	2948.814	16
	Minimum	0.000	0.000	0.000	0.148	3383.500	7142.900	3383.500	8773.000	6562.510	-12030.000	0.000	2067.700	16
	Maximum	5.000	7.000	5.000	1.754	25375.900 ncounter Wh	25375.900	15977.400	27255.600	22189.850	54041.875	54041.875	16917.300	84
s334	M	0.015	0.000	1 000					1 4990 0	0500.004	10500.05	10040.00	0054.0	
3004	Mean SD	0.917	0.083 0.289	1.083 0.900	0.928	8438.25	13042.48	5354.6	14330.9	8588.894	10783.87	16648.93	8976.3	86
		0.900			0.464	6088.856	3226.555	1286.234	3619.529	1640.178	32702.060	29898.213	2822.444	18
	Minimum Maximum	$0 \\ 2$	0 1	0	$0.114 \\ 1.493$	3517 18651	8302.8 19728.4	3516.5 7515.2	9482.4 19728.4	6154.955 11014.1	-29670.4 108945.6	2516.458 108945.6	4757.4 12447.5	97
s381	Maximum Mean	0.06	0.32	3 0.6	0.517	12019.16	19728.4 11664.76	7515.2 8713.93	19728.4 14309.77	11014.1 11208.65	242.834	9821.154	12447.5 5595.836	97 71
5001	SD	0.08	0.52	0.8	0.317	3574.296	3628.639	2489.513	3571.951	2790.056	242.854 16107.754	9821.134 12692.375	2857.151	5
	SD Minimum	0.240	0.655	0.990	0.373	5574.296 5287	5626.659 5404.8	2489.515 4151.5	5571.951 5796.4	2790.056 4545.115	-63475	345.4145	2857.151 364.1	5
			0	4									11553.7	
s546	Maximum Maan	1	3 0.224		1.654	18251 10757 61	21171.5	14177.8	21171.5	17703.83	49428.97 1627 564	63475 4857.579		79
5040	Mean SD	$0.082 \\ 0.275$	0.224 0.509	$2.020 \\ 1.457$	$0.605 \\ 0.381$	10757.61 2957.958	11633.46 3288.145	9310.563 2186.745	12565.91 3383.944	10860.51 2439.543	1637.564 7606.922	4857.579 5830.158	3255.349 2918.166	78 10
	SD Minimum	0.275	0.509	1.457	0.381 0.075	2957.958 5522	5288.145 5326.5	4856.5	5583.944 5522.3	2439.543 5185.475	-11112.1	5830.158 0	2918.166 274.2	7
	Minimum Maximum	0	0 2	5	0.075 1.554	5522 19426	5326.5 18681.8	4856.5 13707.8	5522.3 19425.9	5185.475 14751.57	-11112.1 24804.55	24804.55	274.2 11827.9	8
s558	Maximum Mean	1 0.02	2 0.38	э 1.38	$1.554 \\ 0.598$	19426 11004.2	18681.8	13707.8 8773.29	19425.9 13105.82	14751.57 10773.19	24804.55 42.70666	24804.55 5429.971	4332.528	8 78
3000	Mean SD	0.02	0.38	1.38	0.598 0.289	11004.2 2431.701	10988.11 2795.794	8773.29 2065.835	13105.82 2210.857	10773.19 1903.638	42.70666 6795.835	5429.971 4012.344	4332.528 2319.110	78

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	Minimum	0	0	0	0.067	5626	5126.9	4283.6	8870.7	6803.075	-17606	321.2389	638.7	70.7
	Maximum	1	2	6	1.250	15948	18238.9	13997.4	18238.9	14451.26	11278.59	17605.97	9611.9	85.2
s559	Mean	0.059	0.255	1.255	0.415	10465.73	10785.48	8621.775	12582.6	10222.88	3014.611	9594.389	3960.829	76.22
	SD	0.240	0.476	1.226	0.302	2381.626	2462.139	1429.576	2125.147	1251.406	14075.802	10679.059	2643.141	2.94
	Minimum	0	0	0	0.064	6259	6921.7	6258.6	8662.5	7829.41	-31763.6	515.3641	290.2	71.
	Maximum	1	2	4	1.392	17947	19273	12268.4	19273	13394.92	51350.44	51350.44	12682.9	85.
s565	Mean	0.1	0.18	0.96	0.596	11109.98	11392.2	8707.418	13465.04	10881.68	1196.231	6675.192	4757.626	76.4
	SD	0.303	0.482	1.212	0.328	2918.470	3305.227	2085.872	2581.975	2090.794	8877.037	5898.679	2257.149	4.4
	Minimum	0	0	0	0.075	4556	5503.8	4556.4	5503.8	5127.065	-14993.3	41.52457	497.4	63.7
	Maximum	1	2	5	1.708	16241	20120.3	13849.6	20120.3	15133.08	32926.17	32926.17	9574.3	86.7
s621	Mean	0.4	0.34	0.96	0.668	10626.62	11062.11	7335.116	13845.55	10363.79	922.8298	8202.645	6510.436	69.1
	SD	0.571	0.745	1.124	0.385	4180.342	3940.314	2531.069	3295.851	2478.674	9923.240	5539.234	3304.625	6.7
	Minimum	0	0	0	0.061	3699	4105.3	3203	6812	4982.71	-22310.9	946.7996	541.4	53.3
	Maximum	2	3	4	1.510	20120	18541.4	15383.5	20120.3	16896.99	20285.91	22310.87	14571.4	81.
s48	Mean	0.32	0.2	1.52	0.629	11486.96	12332.71	8758.928	16032.21	11976.23	1202.103	10977.92	7273.282	44.8
	SD	0.621	0.452	1.359	0.333	4584.911	3262.775	2742.341	3504.774	2584.906	16801.924	12680.883	3332.350	5.2
	Minimum	0	0	0	0.121	4370	6907.9	4370.3	8458.6	7718.515	-52946.2	203.17	1691.7	34.4
	Maximum	2	2	6	1.300	24107	20723.7	19877.8	24107.1	22309.67	40684.56	52946.15	16776.3	58.0
s282	Mean	0.06	0.1	2.1	0.419	10242.72	11052.64	7480.272	13575.35	9952.697	5962.575	16763.38	6095.08	23.0
	SD	0.240	0.303	1.329	0.329	3116.117	3585.871	2253.912	3209.789	2188.419	27524.431	22519.468	3413.869	3.8
	Minimum	0	0	0	0.068	3384	4511.3	3383.5	8176.7	6033.84	-38568.9	0	986.8	16.5
	Maximum	1	1	5	1.459	17622	20300.8	13674.8	24248.1	15451.12	128538.2	128538.2	19595.8	30.7
s302	Mean	0.14	0.12	2.18	0.551	13275.5	13327.9	10055.6	15869.44	12523.61	497.7466	10721.94	5813.836	31.3
	SD	0.495	0.328	1.320	0.374	5000.034	4818.539	3756.322	4435.569	3453.216	16817.002	12874.716	3314.431	5.3
	Minimum	0	0	0	0.040	5916	3455.8	3190	9586.5	7240.545	-59197.5	0	939.9	22.
	Maximum	2	1	5	1.850	32963	28195.5	24436.1	32962.9	25676.7	56390	59197.48	15789.4	48.8
s303	Mean	0	0.5	1.98	0.384	11045.78	12413.72	8481.618	14336.66	11246.47	2282.232	17978.43	5855.04	27.2
	SD	0	1.266	1.220	0.272	3941.871	3816.188	2560.080	3583.527	2551.594	28627.965	22249.833	3135.051	3.4
	Minimum	0	0	0	0.021	3665	5639.1	3665.4	6203	5479.335	-98732.3	0	1127.8	20.
010	Maximum	0	7	4	1.035	22556	24624.1	15977.4	24624.1	20084.59	70968.37	98732.32	13721.8	35.8
s313	Mean	0.06	0.28	2.5	0.466	12377.24	12784.97	9727.588	15337.1	12215.11	10884.07	21328.37	5609.51	33.4
	SD	0.240	0.497	1.147	0.290	3793.642	4039.160	2805.951	4108.178	3523.818	85351.585	83316.217	3492.573	4.4
	Minimum	0	0	0	0.022	6579	6578.9	5451.1	7800.8	7349.63	-102528	0	376	24.
0.10	Maximum	1	2	5	1.382	22556	30075.2	22368.4	31203	28684.21	589540.9	589540.9	14285.7	46.3
s346	Mean	0.16	0.22	2.38	0.619	12791.66	13758.4	10014.39	16267.08	12856.69	1513.81	7898.206	6252.69	35.2
	SD	0.422	0.465	1.469	0.436	4643.205	4306.844	3674.662	4392.391	3572.784	10451.630	6922.441	3963.061	6.6
	Minimum	0	0	0	0.109	4887	6203	4887.2	9210.5	7189.85	-22377.4	0	563.9	21.7
. 9.00	Maximum	2	2	5	2.087	23659	29135.3	23120.3	29135.3	26137.22	35841.95	35841.95	16481.4	47.
s368	Mean	0.92	0.1	2.26	0.774	12389.6	13483.56	8955.512	16652.5	12103.1	1490.521	9447.588	7696.992	54.4
	SD	1.027	0.364	1.382	0.344	4914.936	5305.053	3132.703	5083.536	3525.106	14485.447	11000.757	4276.028	11.4
	Minimum	0	0	0	0.152	5075	5545.1	4917.8	7518.8	5383.065	-32663.6	0	1315.8	30.3
	Maximum	3	2	6	1.653	27444	35526.3	18076.4	35526.3	20902.25	62295.39	62295.39	21616.5	71.8

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
s374	Mean	0.4	0.24	2.52	0.628	13599.4	15267.56	10465.99	17480.64	13401.82	3195.036	9399.61	7014.652	35.422
	SD	0.857	0.517	1.474	0.388	5249.538	5134.226	3649.582	4670.774	3244.305	12119.873	8194.638	4594.204	8.267
	Minimum	0	0	0	0.089	3947	6954.9	3947.4	8270.7	7753.75	-35586.4	0	939.9	20.46
	Maximum	4	2	6	1.754	30827	28195.5	21992.5	30827.1	24464.29	27195.74	35586.41	22368.5	57.285
s375	Mean	0.82	0.26	1.92	0.871	13658.9	15216.77	9791.682	18241.7	13415.71	2379.871	10136.95	8450.022	45.630
	SD	1.044	0.803	1.368	0.434	5275.328	7430.160	3810.175	6310.202	4626.022	17205.540	14034.075	4897.842	9.525
	Minimum	0	0	0	0.154	4990	5405.4	4781.7	8967.5	7359.66	-54710.5	0	831.6	28.915
	Maximum	4	5	6	1.702	25376	44282.7	21621.6	44282.7	29760.89	83469.14	83469.14	23076.9	69.85
s376	Mean	0.3	0.22	2.3	0.425	13751.72	13720.78	10704.07	16840.89	13529.81	-1097.2	14046.05	6136.816	38.406
	SD	0.580	0.648	1.542	0.359	4292.030	4379.354	3316.569	3783.917	3149.982	20090.454	14266.638	3551.251	6.495
	Minimum	0	0	0	0.069	6040	6766.9	4323.3	10526.3	9125.935	-58741	0	939.8	29.155
	Maximum	2	4	6	1.364	30263	25751.9	22180.5	30263.2	26038.54	46568.92	58740.97	16917.3	56.835
s377	Mean	0.1	0.16	2.24	0.678	11711.14	14200.75	9407.496	16049.2	12493.73	4589.496	9653.745	6641.708	36.848
	SD	0.303	0.468	1.479	0.401	3852.545	3500.759	2238.321	2917.048	2114.100	13260.873	10111.746	2748.321	5.538
	Minimum	0	0	0	0.138	5921	7310.3	5050.8	11164.8	8458.645	-37563	0	1594.9	25.46
	Maximum	1	2	7	2.032	21993	20488.7	15789.5	21992.5	17796.06	52414.42	52414.42	11748.1	53.57
s378	Mean	0.34	0.14	1.62	0.701	13487.04	12554.62	9065.89	15687.33	11862.35	-2046.34	6404.029	6621.438	36.461
	SD	0.717	0.495	1.159	0.432	4061.464	4295.395	1991.111	3896.308	2078.901	8232.527	5495.362	4068.472	5.696
	Minimum	0	0	0	0.077	5981	5582.4	5582.4	8506.5	6472.945	-18124.7	0	469.9	27.905
	Maximum	4	2	4	2.017	22932	23120.3	13157.9	24624.1	16090.23	19675	19675	16917.3	51.925
s515	Mean	0.08	0.14	2.28	0.385	9983.48	10146.63	8485.362	12302.79	10407.78	973.0601	8473.294	3817.43	34.028
	SD	0.274	0.495	1.310	0.332	3904.097	3741.637	2964.983	4365.780	3292.688	16417.629	14044.318	3266.900	5.736
	Minimum	0	0	0	0.015	4323	5169.2	4323.3	6579.3	6339.285	-40279	0	398.8	25.475
	Maximum	1	3	6	1.192	19079	18985	16071.4	20958.6	18515.03	81453.33	81453.33	12781.9	44.1
s561	Mean	0.76	0.12	1.3	0.649	12788.74	15881.86	10600.65	17694.41	14098.77	8088.111	11205.75	7093.756	44.659
	SD	1.685	0.385	1.233	0.381	5041.819	5395.596	4157.248	5152.631	4241.903	17045.184	15138.006	3724.191	13.379
	Minimum	0	0	0	0.067	4253	6645.7	3987.4	6645.7	4784.93	-15688.9	0	563.9	28.76
	Maximum	7	2	4	1.574	28091	33834.6	21379.1	33834.6	26024.44	99189.55	99189.55	19454.9	76.73
	1				Н	our (hr) Whi	stle Charao	cteristics						
6:00-6:59	Mean	0.078	0.216	2.020	0.593	10704.273	11643.392	9310.984	12548.490	10851.985	1940.377	5034.116	3237.506	78.210
	SD	0.272	0.503	1.435	0.381	2816.911	3104.605	2022.961	3161.315	2258.253	7447.297	5783.893	2889.806	3.510
	Minimum	0.000	0.000	0.000	0.075	5522.300	5326.500	4856.500	5522.300	5185.475	-11112.093	0.000	274.200	66.535
	Maximum	1.000	2.000	5.000	1.554	19425.900	18681.800	13707.800	19425.900	14751.570	24804.545	24804.545	11827.900	86.850
7:00-7:59	Mean	0.148	0.247	1.745	0.573	11269.857	12250.556	8887.189	14600.381	11396.753	4255.020	11629.664	5713.191	55.489
	SD	0.433	0.482	1.376	0.352	3729.671	3461.780	2420.745	3391.676	2574.135	39434.293	37914.014	3240.423	20.772
	Minimum	0.000	0.000	0.000	0.022	3516.500	5126.900	3516.500	7800.800	6154.955	-102528.283	0.000	290.200	24.730
0.00.0.80	Maximum	2.000	2.000	7.000	2.032	24107.100	30075.200	22368.400	31203.000	28684.210	589540.909	589540.91	16776.300	97.875
8:00-8:59	Mean	0.250	0.180	2.000	0.660	13139.318	13156.509	9540.141	15977.205	12359.521	-266.268	7151.117	6437.064	35.835
	SD	0.592	0.479	1.371	0.434	4354.005	4321.890	2978.724	4141.005	2950.709	9529.546	6263.292	4000.072	6.196
	Minimum	0.000	0.000	0.000	0.077	4887.200	5582.400	4887.200	8506.500	6472.945	-22377.381	0.000	469.900	21.775
	Maximum	4.000	2.000	5.000	2.087	23658.800	29135.300	23120.300	29135.300	26137.215	35841.949	35841.949	16917.300	51.925
10:00-10:59	Mean	0.107	0.147	1.807	0.511	11456.274	11622.245	9082.793	13879.091	11271.021	889.013	8623.474	4796.297	47.264

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	SD	0.369	0.439	1.408	0.355	4232.472	4190.092	3073.544	4141.398	3122.815	14409.908	11557.583	3076.912	21.374
	Minimum	0.000	0.000	0.000	0.015	4323.300	3455.800	3190.000	5503.800	5127.065	-59197.479	0.000	398.800	22.380
	Maximum	2.000	3.000	6.000	1.850	32962.900	28195.500	24436.100	32962.900	25676.695	81453.333	81453.333	15789.400	86.765
11:00-11:59	Mean	0.400	0.240	2.520	0.628	13599.390	15267.560	10465.990	17480.642	13401.814	3195.038	9399.610	7014.652	35.422
	SD	0.857	0.517	1.474	0.388	5249.510	5134.226	3649.582	4670.774	3244.305	12119.871	8194.638	4594.204	8.267
	Minimum	0.000	0.000	0.000	0.089	3947.400	6954.900	3947.400	8270.700	7753.750	-35586.408	0.000	939.900	20.460
	Maximum	4.000	2.000	6.000	1.754	30827.100	28195.500	21992.500	30827.100	24464.290	27195.745	35586.408	22368.500	57.285
13:00-13:59	Mean	0.580	0.287	2.053	0.676	12364.720	13704.685	9076.271	16410.289	12255.092	2050.874	12520.989	7334.018	42.440
	SD	0.936	0.900	1.325	0.412	4832.378	5791.621	3232.987	5329.583	3750.515	20881.472	16806.035	4281.393	14.357
	Minimum	0.000	0.000	0.000	0.021	3665.400	5405.400	3665.400	6203.000	5383.065	-98732.323	0.000	831.600	20.570
	Maximum	4.000	7.000	6.000	1.702	27443.600	44282.700	21621.600	44282.700	29760.885	83469.145	98732.323	23076.900	71.835
14:00-14:59	Mean	0.300	0.220	2.300	0.425	13751.690	13720.778	10704.072	16840.888	13529.803	-1097.197	14046.050	6136.816	38.406
	SD	0.580	0.648	1.542	0.359	4292.028	4379.354	3316.569	3783.917	3149.981	20090.456	14266.638	3551.251	6.495
	Minimum	0.000	0.000	0.000	0.069	6040.300	6766.900	4323.300	10526.300	9125.935	-58740.972	0.000	939.800	29.155
	Maximum	2.000	4.000	6.000	1.364	30263.200	25751.900	22180.500	30263.200	26038.535	46568.919	58740.972	16917.300	56.835
15:00-15:59	Mean	0.400	0.340	0.960	0.668	10626.540	11062.110	7335.116	13845.552	10363.790	922.832	8202.644	6510.436	69.147
	SD	0.571	0.745	1.124	0.385	4180.333	3940.314	2531.069	3295.851	2478.673	9923.236	5539.234	3304.625	6.741
	Minimum	0.000	0.000	0.000	0.061	3699.200	4105.300	3203.000	6812.000	4982.710	-22310.870	946.800	541.400	53.325
	Maximum	2.000	3.000	4.000	1.510	20120.300	18541.400	15383.500	20120.300	16896.985	20285.906	22310.870	14571.400	81.970
16:00-16:59	Mean	0.760	0.120	1.300	0.649	12788.674	15881.858	10600.654	17694.410	14098.771	8088.113	11205.755	7093.756	44.659
	SD	1.685	0.385	1.233	0.381	5041.826	5395.595	4157.248	5152.631	4241.903	17045.181	15138.006	3724.191	13.379
	Minimum	0.000	0.000	0.000	0.067	4253.300	6645.700	3987.400	6645.700	4784.930	-15688.859	0.000	563.900	28.760
	Maximum	7.000	2.000	4.000	1.574	28091.300	33834.600	21379.100	33834.600	26024.440	99189.552	99189.552	19454.900	76.730
18:00-18:59	Mean	0.061	0.214	1.337	0.471	11166.223	11347.922	8072.117	13979.720	10579.399	2975.019	13372.529	5907.603	46.800
	SD	0.241	0.523	1.399	0.356	3457.463	3617.298	2427.713	3396.857	2545.313	22827.301	18691.163	3143.218	24.811
	Minimum	0.000	0.000	0.000	0.032	3383.500	4511.300	3383.500	5796.400	4545.115	-63475.000	0.000	364.100	16.595
	Maximum	1.000	3.000	5.000	1.654	18251.000	21171.500	14177.800	24248.100	17703.825	128538.235	128538.23	19595.800	79.930
1000	1					Year Whistl								
1998	Mean	0.151	0.276	1.189	0.580	10897.86	11320.41	8450.869	13351.74	10634.5	1550.072	7799.905	4900.805	75.431
	SD	0.409	0.568	1.280	0.36223	3309.39	3254.986	2252.766	2953.514	2193.549	12585.29	9988.289	3023.965	6.507
	Minimum	0	0	0	0.032	3517	4105.3	3203	5504	4545.115	-63475	0	274.2	53.325
2000	Maximum	2	3	6	1.708	20120	21171.5	15383.5	21172	17703.83	108945.6	108945.6	14571.4	97.875
2000	Mean	0.319	0.2	2.079	0.584024	12327.85	13295.92	9428.218	15883.45	12291.71	2851.078	11745.38	6455.161	37.222
	SD	0.790	0.588	1.382	0.392697	4572.641	4827.947	3242.621	4563.137	3406.166	28466.87	26083.55	3856.181	10.664
	Minimum	0	0	0	0.015	3384	3455.8	3190	6203	4784.93	-102528	0	376	16.595
	Maximum	7	7	7	2.087	32963	44282.7	24436.1	44283	29760.89	589540.9	589540.9	23076.9	76.73
F00-1000+		0.077	0.4	2.225		umn Depth				10100.15				
500-1000†	Mean	0.920	0.100	2.260	0.774	12389.512	13483.564	8955.512	16652.504	12103.101	1490.521	9447.588	7696.992	54.440
	SD	1.027	0.364	1.382	0.344	4914.914	5305.053	3132.703	5083.536	3525.106	14485.447	11000.757	4276.028	11.449
	Minimum	0.000	0.000	0.000	0.152	5075.200	5545.100	4917.800	7518.800	5383.065	32663.600	0.000	1315.800	30.385
1700-1900	Maximum	3.000	2.000	6.000	1.653	27443.600	35526.300	18076.400	35526.300	20902.250	62295.390	62295.390	21616.500	71.835
1700-1800	Mean	0.220	0.150	1.930	0.689	12599.072	13377.685	9236.693	15868.266	12178.038	1271.575	8028.887	6631.573	36.655

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	SD	0.561	0.479	1.358	0.415	4038.190	3985.232	2114.579	3429.084	2109.950	11476.149	8259.608	3454.160	5.593
	Minimum	0.000	0.000	0.000	0.077	5921.100	5582.400	5050.800	8506.500	6472.945	37563.000	0.000	469.900	25.460
	Maximum	4.000	2.000	7.000	2.032	22932.300	23120.300	15789.500	24624.100	17796.060	52414.420	52414.420	16917.300	53.570
2000-2500†	Mean	0.300	0.220	2.300	0.425	13751.690	13720.778	10704.072	16840.888	13529.806	-1097.197	14046.050	6136.816	38.406
	SD	0.580	0.648	1.542	0.359	4292.028	4379.354	3316.569	3783.917	3149.982	20090.454	14266.638	3551.251	6.495
	Minimum	0.000	0.000	0.000	0.069	6040.300	6766.900	4323.300	10526.300	9125.935	58741.000	0.000	939.800	29.155
	Maximum	2.000	4.000	6.000	1.364	30263.200	25751.900	22180.500	30263.200	26038.540	46568.920	58740.970	16917.300	56.835
$2500 - 3000 \dagger$	Mean	0.820	0.260	1.920	0.871	13658.812	15216.774	9791.682	18241.704	13415.706	2379.871	10136.946	8450.022	45.630
	SD	1.044	0.803	1.368	0.434	5275.304	7430.160	3810.175	6310.202	4626.022	17205.540	14034.075	4897.842	9.525
	Minimum	0.000	0.000	0.000	0.154	4989.600	5405.400	4781.700	8967.500	7359.660	54710.500	0.000	831.600	28.915
	Maximum	4.000	5.000	6.000	1.702	25375.900	44282.700	21621.600	44282.700	29760.890	83469.140	83469.140	23076.900	69.850
3000-3100	Mean	0.040	0.317	1.317	0.505	10732.250	10885.793	8696.782	12841.621	10495.309	1543.371	7532.796	4144.839	77.221
	SD	0.196	0.509	1.256	0.307	2398.622	2651.919	1772.708	2181.954	1626.306	11104.285	8270.459	2469.771	3.331
	Minimum	0.000	0.000	0.000	0.064	5625.900	5126.900	4283.600	8662.500	6803.075	31763.600	321.239	290.200	70.760
	Maximum	1.000	2.000	6.000	1.392	17946.700	19273.000	13997.400	19273.000	14451.260	51350.440	51350.440	12682.900	85.520
3100-3200	Mean	0.400	0.340	0.960	0.668	10626.540	11062.110	7335.116	13845.552	10363.791	922.830	8202.645	6510.436	69.147
	SD	0.571	0.745	1.124	0.385	4180.333	3940.314	2531.069	3295.851	2478.674	9923.240	5539.234	3304.625	6.741
	Minimum	0.000	0.000	0.000	0.061	3699.200	4105.300	3203.000	6812.000	4982.710	22310.900	946.800	541.400	53.325
	Maximum	2.000	3.000	4.000	1.510	20120.300	18541.400	15383.500	20120.300	16896.990	20285.910	22310.870	14571.400	81.970
3300-3400	Mean	0.061	0.327	0.571	0.519	12016.647	11604.680	8643.986	14294.076	11145.062	133.606	9907.402	5650.090	71.423
	SD	0.242	0.658	0.979	0.377	3611.235	3641.031	2465.175	3607.226	2782.118	16255.958	12809.093	2860.619	5.567
	Minimum	0.000	0.000	0.000	0.032	5287.300	5404.800	4151.500	5796.400	4545.115	63475.000	345.415	364.100	59.010
	Maximum	1.000	3.000	4.000	1.654	18251.000	21171.500	14177.800	21171.500	17703.830	49428.970	63475.000	11553.700	79.930
3400 - 3500	Mean	0.060	0.100	2.100	0.419	10242.646	11052.636	7480.272	13575.352	9952.697	5962.575	16763.375	6095.080	23.064
	SD	0.240	0.303	1.329	0.329	3116.151	3585.871	2253.912	3209.789	2188.419	27524.431	22519.468	3413.869	3.876
	Minimum	0.000	0.000	0.000	0.068	3383.500	4511.300	3383.500	8176.700	6033.840	38568.900	0.000	986.800	16.595
	Maximum	1.000	1.000	5.000	1.459	17622.200	20300.800	13674.800	24248.100	15451.120	128538.20	128538.20	19595.800	30.745
3000-3500†	Mean	0.400	0.240	2.520	0.628	13599.390	15267.560	10465.990	17480.642	13401.817	3195.036	9399.610	7014.652	35.422
	SD	0.857	0.517	1.474	0.388	5249.510	5134.226	3649.582	4670.774	3244.305	12119.873	8194.638	4594.204	8.267
	Minimum	0.000	0.000	0.000	0.089	3947.400	6954.900	3947.400	8270.700	7753.750	35586.400	0.000	939.900	20.460
	Maximum	4.000	2.000	6.000	1.754	30827.100	28195.500	21992.500	30827.100	24464.290	27195.740	35586.410	22368.500	57.285
3500-3600	Mean	0.420	0.130	1.790	0.517	11386.056	13014.242	9543.008	14998.601	12253.278	4530.585	9839.524	5455.593	39.344
	SD	1.249	0.442	1.358	0.380	4702.401	5444.694	3746.351	5469.485	4208.609	17029.197	14592.222	3854.588	11.551
	Minimum	0.000	0.000	0.000	0.015	4253.300	5169.200	3987.400	6579.300	4784.930	40279.000	0.000	398.800	25.475
	Maximum	7.000	3.000	6.000	1.574	28091.300	33834.600	21379.100	33834.600	26024.440	99189.550	99189.550	19454.900	76.730
3700-3800	Mean	0.917	0.083	1.083	0.928	8438.067	13042.475	5354.600	14330.900	8588.894	10783.872	16648.930	8976.300	86.105
	SD	0.900	0.289	0.900	0.464	6088.943	3226.555	1286.234	3619.529	1640.178	32702.060	29898.213	2822.444	13.312
	Minimum	0.000	0.000	0.000	0.114	3516.500	8302.800	3516.500	9482.400	6154.955	29670.400	2516.458	4757.400	54.800
4000-4100	Maximum	2.000	1.000	3.000	1.493	18651.000	19728.400	7515.200	19728.400	11014.100	108945.60	108945.60	12447.500	97.875
	Mean	0.100	0.180	0.960	0.596	11109.908	11392.204	8707.418	13465.044	10881.677	1196.231	6675.192	4757.626	76.450
	SD	0.303	0.482	1.212	0.328	2918.445	3305.227	2085.872	2581.975	2090.794	8877.037	5898.679	2257.149	4.431
	Minimum	0.000	0.000	0.000	0.075	4556.400	5503.800	4556.400	5503.800	5127.065	14993.300	41.525	497.400	63.725

		Harmonics*	Inflections	Steps	Duration (s)	Start Frequency (Hz)	End Frequency (Hz)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	Mean Frequency (Hz)	Frequency Gradient (Hz/s)	Absolute Frequency Gradient (Hz/s)	Frequency Range (Hz)	Mean Power (dB)*
	Maximum	1.000	2.000	5.000	1.708	16240.600	20120.300	13849.600	20120.300	15133.080	32926.170	32926.170	9574.300	86.765
4200-4300	Mean	0.140	0.120	2.180	0.551	13275.476	13327.904	10055.600	15869.436	12523.609	497.747	10721.937	5813.836	31.312
	SD	0.495	0.328	1.320	0.374	5000.090	4818.539	3756.322	4435.569	3453.216	16817.002	12874.716	3314.431	5.389
	Minimum	0.000	0.000	0.000	0.040	5916.000	3455.800	3190.000	9586.500	7240.545	59197.500	0.000	939.900	22.380
	Maximum	2.000	1.000	5.000	1.850	32962.900	28195.500	24436.100	32962.900	25676.700	56390.000	59197.480	15789.400	48.855
4300-4400	Mean	0.000	0.500	1.980	0.384	11045.836	12413.718	8481.618	14336.658	11246.475	2282.232	17978.433	5855.040	27.251
	SD	0.000	1.266	1.220	0.272	3941.972	3816.188	2560.080	3583.527	2551.594	28627.965	22249.833	3135.051	3.496
	Minimum	0.000	0.000	0.000	0.021	3665.400	5639.100	3665.400	6203.000	5479.335	98732.300	0.000	1127.800	20.570
	Maximum	0.000	7.000	4.000	1.035	22556.400	24624.100	15977.400	24624.100	20084.590	70968.370	98732.320	13721.800	35.805
4000-4500†	Mean	0.080	0.220	2.020	0.601	10785.196	11692.966	9367.176	12616.166	10929.794	1716.713	4872.327	3248.990	78.443
	SD	0.274	0.507	1.450	0.380	2784.983	3115.667	2002.890	3155.871	2211.048	7347.841	5724.853	2917.969	3.119
	Minimum	0.000	0.000	0.000	0.075	5522.300	5326.500	4856.500	5522.300	5185.475	11112.100	0.000	274.200	69.025
	Maximum	1.000	2.000	5.000	1.554	19425.900	18681.800	13707.800	19425.900	14751.570	24804.550	24804.550	11827.900	86.850
4700-4800	Mean	0.320	0.200	1.520	0.629	11486.844	12332.706	8758.928	16032.210	11976.230	1202.103	10977.925	7273.282	44.879
	SD	0.621	0.452	1.359	0.333	4584.935	3262.775	2742.341	3504.774	2584.906	16801.924	12680.883	3332.350	5.292
	Minimum	0.000	0.000	0.000	0.121	4370.300	6907.900	4370.300	8458.600	7718.515	52946.200	203.170	1691.700	34.495
	Maximum	2.000	2.000	6.000	1.300	24107.100	20723.700	19877.800	24107.100	22309.670	40684.560	52946.150	16776.300	58.095
4800-4900	Mean	0.060	0.280	2.500	0.466	12377.200	12784.970	9727.588	15337.098	12215.114	10884.074	21328.370	5609.510	33.494
	SD	0.240	0.497	1.147	0.290	3793.696	4039.160	2805.951	4108.178	3523.818	85351.585	83316.217	3492.573	4.438
	Minimum	0.000	0.000	0.000	0.022	6578.900	6578.900	5451.100	7800.800	7349.630	102528.00	0.000	376.000	24.730
	Maximum	1.000	2.000	5.000	1.382	22556.400	30075.200	22368.400	31203.000	28684.210	589540.90	589540.90	14285.700	46.345
$4500 - 5000 \dagger$	Mean	0.160	0.220	2.380	0.619	12791.618	13758.402	10014.392	16267.082	12856.694	1513.810	7898.206	6252.690	35.208
	SD	0.422	0.465	1.469	0.436	4643.226	4306.844	3674.662	4392.391	3572.784	10451.630	6922.441	3963.061	6.657
	Minimum	0.000	0.000	0.000	0.109	4887.200	6203.000	4887.200	9210.500	7189.850	22377.400	0.000	563.900	21.775
	Maximum	2.000	2.000	5.000	2.087	23658.800	29135.300	23120.300	29135.300	26137.220	35841.950	35841.950	16481.400	47.550

* Summaries for Harmonics and Mean Power were only calculated if all whistles in the category had been measured for them.

** Statistically different in all shared whistle parameters excluding Start Frequency † Bathymetric range was in the Peru-Chile Trench.

Appendix 7.2. Mann-Whitney U test results for variety in tow lengths in the Celtic Deep (2004-2005)

	Test Statistics ^a												
	Inflections	Steps	Duration	Start Frequency	End Frequency	Minimum Frequency	Maximum Frequency	Mean Frequency	Frequency Gradient	Absolute Frequency Gradient	Freqency Range		
Mann- Whitney U	233106.000	233966.500	226247.000	238400.000	245150.500	228773.000	224606.000	218223.000	244707.500	245123.500	236281.500		
Wilcoxon W	634066.000	384392.500	376673.000	388826.000	646110.500	379199.000	375032.000	368649.000	395133.500	646083.500	386707.500		
Z	-1.852	-1.891	-2.471	889	010	-2.142	-2.685	-3.515	068	014	-1.165		
Asymp. Sig. (2-tailed)	.064	.059	.013	.374	.992	.032	.007	.000	.946	.989	.244		

a. Grouping Variable: Tow Lengths

Encounter	Date	Time	Latitude	Longitude	Species	Best	High	Low
g372	24/08/2009	06:58:08	51.915170	-5.462400	D. delphis	6	7	5
g278	27/08/2009	09:27:39	51.888893	-5.514747	D. delphis	-	-	-