USE OF AIR-BASED ECHOLOCATION BY A BOTTLENOSE DOLPHIN (*Tursiops truncatus*)

Jack Kassewitz*
SpeakDolphin.com, Miami, FL 33157

Brandon Cassel
Miami-Dade College, Miami, FL 33132

Michelle Cahill
University of California, Berkeley, CA 94720

Jim McDonough
SpeakDolphin.com, Miami, FL 33157

John Stuart Reid
Sonic Age Ltd, Acoustic Research Laboratory, CA12 4TS, UK

Dr. Michael T. Hyson, Ph.D.
Sirius Institute, Puna, HI 96778

ABSTRACT

This study demonstrates echolocation in the air by a bottlenose dolphin (Tursiops truncatus). The study, conducted in March 2015 in Mexico utilizing a three-year old female dolphin in human care since birth. This dolphin first echolocated underwater on a dolphin trainer's hand. The trainer then moved the target hand from underwater to above water, encouraging the dolphin to also raise her head and rostrum above water and continue to echolocate. The resulting air-based echolocations comprised broadband clicks with an interpulse interval of 25 to 35 microseconds (ms), and a peak power centered at around 8 kHz. We hypothesize that the propagation of dolphin-to-air emissions at frequencies above 8 kHz incurs significantly greater transmission losses than when the dolphin is immersed in water. We recorded an initial, single broadband click at approximately 14 kHz measuring 0.070 ms in width between the first two positive peaks. The click covered a bandwidth between 6 and 45 kHz with additional harmonic content present at higher frequencies including several bands spaced at about 4-5 kHz intervals. This initial click was typical of the click trains subsequently recorded in this study. This study supports the observations of trainers who have felt occurrences of such air-based echolocations.

***Author of record: speakdolphin@mac.com**

Table of Contents

Introduction **3**

Background **4**

Research Equipment and Processing Utilized **5**

Methods Used to Evoke Air-Based Dolphin Echolocation (ABE) **6**

Results **8**

Conclusions **9**

Acknowledgments **10**

Glossary **10**

Endnotes **19**

Bibliography and Works Cited **23**

Appendix 1: General Observations **26**

Appendix 2: Performance Evaluation and Review Technique (PERT) **32**

Introduction

For some time researchers have speculated that dolphins can echolocate on objects and humans above the water. In 2010, the Journal of the Acoustical Society of America published an article, "A method to enable a bottlenose dolphin to echolocate while out of the water"[1] wherein it was reported that "dolphin in-air echolocation behavior, inter-click intervals, and overall performance were analogous to those observed during comparable underwater testing with physical targets, demonstrating that the dolphin was indeed performing an echolocation task while out of water." This study established that dolphins **are capable of** air-based echolocation. The current study however, was designed to show that, in fact, dolphins **do** use air-based echolocation.

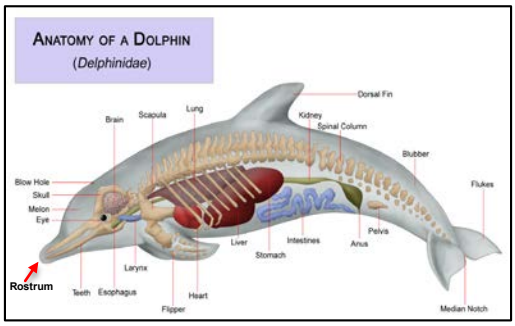


Figure 1 - Anatomy of a dolphin

Anecdotal reports from dolphin trainers indicate that they perceive echolocation on their faces, hands and heads in air. The focus of this investigation is to verify, with air-based ultrasonic recordings, a dolphin echolocating on a trainer with its head and rostrum (See Fig. 1) out of the water.

EQUIPMENT USED

Using a Wildlife Acoustics SM3Bat digital recorder with their SMM-U1 ultrasonic microphone connected to their SMX-Horn, we encouraged a dolphin in human care to follow a trainer's hand and, to continue directed echolocation while transitioning from underwater to air-based echolocation.

Background

Echolocation, also called biosonar, refers to the ability that dolphins and whales and most bats possess enabling them to locate and discriminate objects by projecting high-frequency sound, in the case of dolphins in water, and listening for echoes as the sound waves reflect off objects. Dolphins and whales echolocate by producing clicking sounds and broadcasting them like the light beams from a lighthouse (See Fig. 2) and receiving and interpreting the resulting echoes and as "pictorial" information embedded in the returning signal.

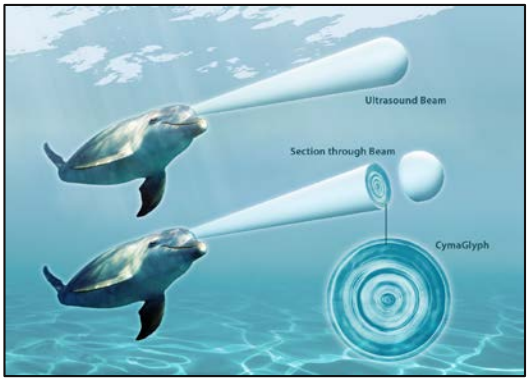


Figure 2. CymaGlyph pattern from the ultrasonic beam of a dolphin

Bottlenose dolphins (*Tursiops truncatus*, Tt) produce directional, broadband clicks in sequence individually or in bursts called click trains. Each click typically lasts about 50 to 128 microseconds. The highest frequencies we have documented are on the order of 300 kHz.

Successive click trains pass through the melon, which consists of special fats that form an acoustic lens. The melon focuses these outgoing click trains into a beam which is projected in front of the dolphin. These sound waves reflect from objects in the water and return to the dolphin in the form of an echo with embedded pictorial information.

Major areas of dolphin sound reception include the fat-filled cavities of the lower mandible. (See Fig. 3) However this model remains incomplete and only partially supported as being the total hearing mechanism of the dolphin. It is commonly thought that the returning signals are received and conducted partially through the

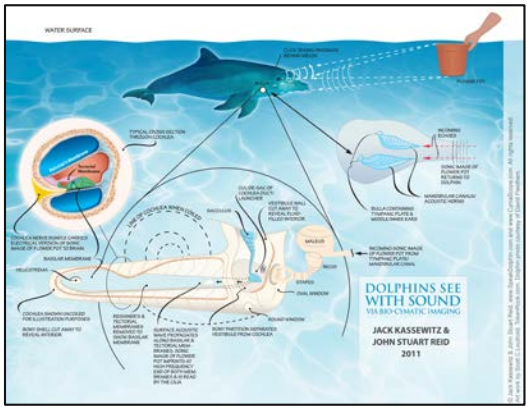


Figure 3. Dolphins see with sound

mandible to the tympanic plates and then to hearing centers in the brain through the dolphin's auditory nerve bundles. There is still much controversy regarding this simplistic model.

The female dolphin Elena (Tt) in this study was born in human care in August of 2012.

Research Equipment and Processing Utilized

Air-based recordings of the dolphin (Tt) used a Wildlife Acoustics SM3BAT digital recorder for the acoustic input/output of the humans (Hs), this dolphin subject (Tt) and the surrounding environment at the zone of encounter. A SM3-1U microphone with an attached SM3 horn was used to improve both directionality of reception and source localization. (See Fig. 4)

Figure 4. SM4BAT, SMM-U1 Ultrasonic microphone, SM3-Horn attachment

1. The SM3BAT is a digital recorder that can simultaneously record in full spectrum at 256 kHz on two channels and has zero crossing on the same channels, resulting in two full spectrum and two zero crossing recorders. At a higher sampling rate, the SM3BAT can sample a full spectrum of up to 384 kHz on one channel. For zero crossing files, the recorder has a zero crossing auto level with division ratios of 4, 8, 12 or 16.
2. The SMM-U1 is a highly sensitive, low noise ultrasonic microphone, designed for recording ultrasound up to 190 kHz.
3. The SM3 Horn Attachment turns the SM3-U1 omnidirectional ultrasonic microphone into a highly directional microphone, while preserving acoustic quality. The attachment is designed

to be used without the standard microphone windscreen and remains weatherproof at angles up to 45-degrees.

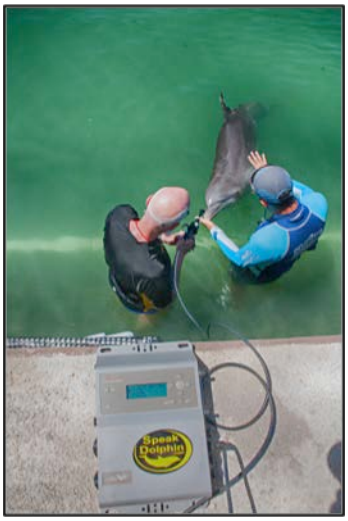
4. The file format used was *.wav and *.wac.
5. Acoustic analysis was performed using Audacity (a software program for the acquisition, visualization, measurement, and analysis of sounds); and Song Scope (a specific bioacoustic software from Wildlife Acoustics).

Methods Used to Evoke Air-Based Dolphin Echolocation (ABE)

The steps, or *"Subroutines"* utilized, were as follows:

Subroutine 1: ABE **(Picture 1)**

A trainer (HmT), standing on a submerged platform (zone of encounter), attracted and greeted Tt in her lagoon with a vocal acknowledgment. At this point, an investigator (HmI) entered into the zone of encounter directly to the left of HmT. At the zone of encounter, HmI held a shock-mounted *Wildlife Acoustics* SMM-U1 ultrasonic microphone directed at the melon of Tt at a range of 16 - 24 inches. The SMM-U1 was connected by an audio cable to the SM3BAT digital recorder onshore, which was controlled by a observer (HmO1). The SM3BAT was pre-set to record between 8 kHz to 384 kHz at 0 dB. Additionally, there was another observer (HmO2) who, after video confirmation of the event, later completed a pre-designed form. See Appendix 1 – General Observations, which can also be seen online here:



Picture 1.
Subroutine 1: **ABE**

https://speakdolphincom.formstack.com/forms/general_observations

Additionally there were at least 5 project interns were observing, with several of them also filming.

Subroutine 2: ABE

Tt came close and placed her rostrum in the submerged, open hands of HmT. (See Pic. 2)

Picture 2.
***Subroutine 2:* ABE**

Subroutine 3: ABE

HmT then performed a gestural cue to encourage Tt to target HmT's left hand. After initial desensitization of Tt to HmT's hand, HmT slowly began to move his target hand up and away from the water and into the air.

Subroutine 4: ABE

This gesture by HmT encouraged Tt to completely move her head and rostrum out of the water. See Picture 2. Interestingly, both HmI and HmT were able to hear audible air-based echolocation at the zone of encounter, which was the first confirmation that our study had met its goal. This specific interaction – HmT's moving his submerged left hand into the air; followed by the Tt's complete head and rostrum - was repeated four times.

Picture 3. Wildlife Acoustics SM3BAT

Further, we noticed that Tt no longer needed to be cued by HmT for Tt to produce her echolocation, and was, in fact, spontaneously using air-based echolocation. HmO1 stopped and re-started the digital recorder after each of the four interactions, creating individual .wav files corresponding to each trial, for later review and analysis. (See Pic. 3)

Results

A young, 3-year old, female bottlenose dolphin (Tt) named Elena had been previously trained to target echolocate on HmT's hand. After re-establishing this water-based behavior, Tt then successfully followed HmT's targeted hand while continuing to echolocate, until her head and rostrum were completely above water – thereby demonstrating – "air-based echolocation".

The resulting air-based echolocations were broadband clicks with an inter-pulse interval of 25 to 35 ms, and with peak power centered at around 8 kHz. We hypothesize that dolphin-to-air propagation of frequencies above 8 kHz involves significant transmission losses that are far less when the dolphin is immersed in water. We recorded an initial, single broadband click at approximately 14 kHz measuring 0.070 ms in interval between the first two positive peaks. The click covered a bandwidth between 6 kHz and 45 kHz with some higher harmonic bands spaced at about 4-5 kHz intervals. This click was typical of the click trains subsequently recorded in this study. The spectrogram in Figure 5, water-based echolocation, is provided for comparison with the air-based spectrogram in Figure 6 with Tt, which was recorded contemporaneously.

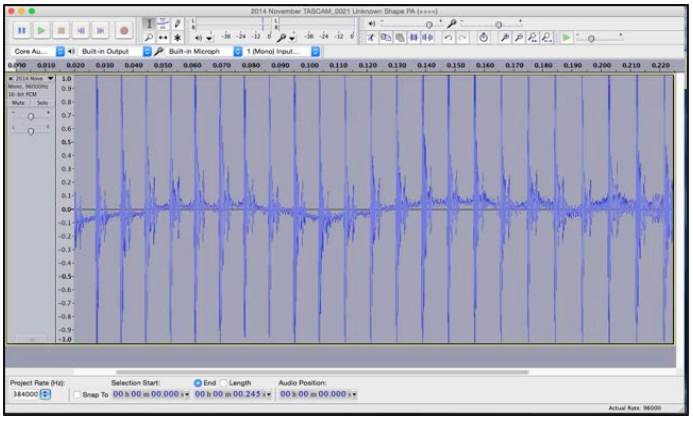


Figure 5. Water-based echolocation. This spectrogram is provided for comparison with the air-based spectrogram in Figure 6 below.

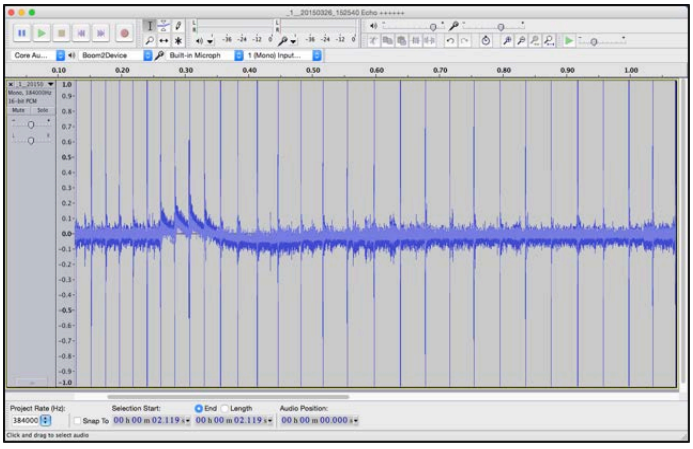


Figure 6. Air-based, broadband click train as described in "Results".

Conclusions

In contrast to the study previously cited, it was possible for HmT to encourage Tt to demonstrate naturally, and even spontaneously, air-based echolocation.

This conclusion is based upon the fact that after Tt showed air-based echolocation one time, it became simple for HmT to request of Tt to demonstrate this behavior. Karen Pryor calls it "one-trial learning".[2] The air-based echolocation was so clear that attending interns observed it acoustically.

Further research will utilize the capabilities of the SM3BAT to record two-channels out to 256 kHz with two ultrasonic microphones. This should allow us to determine if additional information about the structure of outgoing and incoming signals from such air-based echolocation may have been under-represented.

Also, these ultrasonic microphones have an 8 kHz, 4-pole high pass filter that would attenuate sounds below 8 kHz. Further measurements may reveal that there is more energy at lower frequencies which may also be under-represented in our current recordings.

It is also important to measure the sound pressure levels of the reflected sounds that the dolphin receives when it performs an air-based echolocation utilizing a second matched ultrasound microphone placed adjacent to the dolphin. Since high frequency air-based sounds undergo greater diffraction than water-based, it is suggested that the air-based reflected click trains would carry far less energy than similar click trains propagated in water.

We intend during our next expedition to compare the structure of the air-based echolocation clicks with their water-based counterparts.

Acknowledgments

The authors wish to thank Dolphin Discovery, Mexico for the generous use of its facilities; Wildlife Acoustics, USA for loaning us their ultrasonic microphone; and Jonathan Jordan of Dolphin Discovery, Mexico for his dolphin training expertise and advice. The Shoong Foundation, USA and Global Heart, Inc. USA provided financial support.

Glossary

Acoustic following:	The ability of an organism to follow the acoustic bursts initiated by another organism or source.
Acoustic lens (acoustic mirror):	"A dolphin is one of the best animals to explain the ideal acoustic transducer systems. Dolphins and whales do not have vocal chords, but a breathing hole on the head…. By breathing strongly through this hole, a dolphin can generate sound like a human whistle. Though this breathing hole is a point sound source, because of additional physical structures, the sound beam can be focused quite sharply toward the front direction. The cranium shape seems to be a parabola antenna, which reflects the radial propagating sound into a rather parallel frontward beam. Further, 'melon' made of soft tissue like paraffin (with a sound velocity lower than water) behaves as a convex acoustic lens, and focuses the sound beam more sharply. It is notable that if we use a glass lens with a sound velocity higher than water, a convex shape acoustic lens diverges the sound beam (like an optical concave lens). This is the initial sound transmitting process. In order to receive the returned sound signal reflected from some object, if the strong original transmitting signal transfers directly to the receiving organ (ear), a serious blackout problem occurs. In order to overcome this problem, the dolphin has an acoustic impedance mismatch layer (air), which behaves like a double-glazed window for shutting out the noise. The dolphin's receiver is its bottom jaws, through which the sound is transferred to the ear. Notice that the highly sensitive ear is isolated from the cranium bones to protect it from direct sound penetration. This situation is rather different from the human ear, which is connected directly to the bones (in fact, we have a head set that uses direct bone transmission of sound for a hearing aid). Since the dolphin has completely separated right and left jaws, the two ears can detect the right and left sound signals independently, like a 3D stereo system." [3]

Allophone: [4]	In phonology, one of a set of multiple possible spoken sounds (or phones) used to pronounce a single phoneme in a particular language.
Approximation:	The method used in our programs to create behavioral steps and may also be called differential reinforcement of successive approximations. It is a map to reaching the final behavioral goal ending in a bridge. The legend in this behavioral map is the agreements and rules. When a desired behavior is not attained the human has the option to step back one or more components of the desired behavior. (See PERT) The operator will then work forward to the desired behavioral response and initiate a bridge. The reward is not a bridge, but a post behavioral incentive.
Behavioral Steps:	The individual components of a behavior as defined by the operators predetermined preferences They are then broken down into modules or individual behavioral steps for training purposes.
Biosonar (echolocation):	The biological sonar used by several kinds of animals including dolphins and whales. Echolocating animals emit calls out to the environment and listen to the echoes of those calls that return from various objects near them.
Bridge:	A signal that the desired behavior has been fulfilled to completion and can be stopped and is many times a trainer's whistle.
Broadband clicks:	"When echolocating, dolphins typically emit a single short duration, high-frequency, broadband "click," then wait for the echo to return before emitting another click. However, previous studies have shown that dolphins and belugas performing long-range echolocation tasks may instead emit a burst, or "packet," of several clicks, then waits for the packet of echoes to return before emitting another packet of clicks. The exact reasons for the use of packets, rather than individual clicks, are unknown. In this study, the use of packets by dolphins was examined by having trained bottlenose dolphins perform long-range echolocation tasks. The tasks featured the use of "phantom" echoes produced by capturing the dolphin's outgoing echolocation clicks, convolving the clicks with the impulse response of a physical target to create an echo waveform, then broadcasting the delayed, scaled echo waveform back to the dolphin. Dolphins were trained to report the presence of phantom echoes or a change in phantom echoes. At ranges below 75 m, the dolphins rarely used packets of clicks. For ranges greater than 75 m, the likelihood of packet use was related to both target range and echo strength." [5] A click, which is narrow in time i.e., very short. Approximates a Dirac Delta function, which is an infinitely narrow pulse. Such a function has all frequencies with equal power. Its Fourier transform is a horizontal

	line at some amplitude and therefore is very broadband. So a broadband click is a narrow click, or short time click. (Hyson's note)
Bursts:	See "Train of bursts".
Click train:	See "Train of bursts".
Consonant:	A speech sound that is articulated with complete or partial closure of the vocal tract. Examples are [p], pronounced with the lips; [t], pronounced with the front of the tongue; [k], pronounced with the back of the tongue; [h], pronounced in the throat; [f] and [s], pronounced by forcing air through a narrow channel (fricatives); and [m] and [n], which have air flowing through the nose (nasals). Contrasting with consonants are vowels.
Desensitization: [6]	Animals are very aware of their environment and changes within that environment. As a basic part of training, trainers work with the animals to help them learn to accept unusual or unexpected changes in their environment. When animals become used to changes in the environment, it is known as *desensitization*.
Dialect: [7]	A form of a language that is spoken in a particular area and that uses some of its own words, grammar, and pronunciations.
Diphthong (gliding vowel):	Two adjacent vowel sounds occurring within the same syllable. A diphthong is a vowel with two different targets: that is, the tongue (and/or other parts of the speech apparatus) moves during the pronunciation of the vowel. In most dialects of English, the phrase no highway cowboys has five distinct diphthongs, one in every syllable.
Echolocation (see also, biosonar):	The biological sonar used by several kinds of animals including dolphins and whales. Echolocating animals emit calls out to the environment and listen to the echoes of those calls that return from various objects near them.
Ethogram: [8] [9] [10] [11]	A catalogue or inventory of observable behaviors or actions exhibited by an animal used in ethology. The behaviors in an ethogram are usually defined to be mutually exclusive and objective, avoiding subjectivity and functional inference as to their possible purpose.
Focal (or continuous) ethogram sampling:	Our investigator/observer identifies the target individual (dolphin) in the program and records behaviors for a set period of time (usually half an hour). Using a timer, the investigator can determine the amount of time spent doing specific behaviors and begin to predict those behaviors. We are looking for changes in performance that might indicate a increased awareness of the Study goal to communicate. (See Appendix 2

	for our ethogram.) This will begin 10 minutes before the program and continue 10 minutes after the program.
Fricatives (frictives):	Consonants produced by forcing air through a narrow channel made by placing two articulators close together.
Game:	A structured participation, usually undertaken for amusement and sometimes used as an educational tool. It has agreements and rules (implied or identified) for the participants. These agreements or rules may not be mutually agreeable or acceptable to all the participants therefore the results may reflect the attitude of the participants. The rules or agreements may sometimes change as the game progresses and in some cases this aspect of changing rules or agreements is encouraged and considered in the results.
Hand signal (or gesture):	Must be included at the very start of the program to denote that particular behavior identified by the specific signal has begun. Every requested behavior must include a separate signal so as not to confound the dolphin or human with an already established primary gestural indicator.
Language:	The ability to acquire and use complex systems of communication, and a language is any specific example of such a system. The scientific study of language is called linguistics. The use of the above ability is having a language.
Lexicon (in linguistics):	A language's inventory of lexemes. A lexeme is a unit of lexical meaning that exists regardless of the number of inflectional endings it may have or the number of words it may contain. It is a basic unit of meaning, and the headwords of a dictionary are all lexemes. [12]
Melon: [13] [14]	The mass of adipose tissue found in the forehead of all toothed whales. It focuses and modulates the animal's vocalizations and acts as a sound lens. It is thus a key organ involved in communication and echolocation.
Modeling (observational learning):	In "Social foundation of thought and action: A social cognitive theory", Albert Bandura suggested that modeling is the basis for an assortment of a child's behaviors. Children and animals develop many positive and negative responses by observation. I have a young dog that opens the doors to the house on his own. He learned this from one the older dogs strictly by observation. "Of the many cues that influence behavior, at any point in time, none is more common than the actions of others." [15] Many of the collaborative vocal and tactile games we play with dolphins are initiated by the modeling of the predetermined rules by two or more Hm's. Note: We have observed that the inclusion of an emotional component during modeling seems to encourage the respondent to action; i.e., Clapping or verbally praising each participant.

Morpheme (in linguistics):	The smallest grammatical unit in a language. In other words, it is the smallest meaningful unit of a language. The field of study dedicated to morphemes is called morphology. A morpheme is not identical to a word, and the principal difference between the two is that a morpheme may or may not stand alone, whereas a word, by definition, is freestanding. When it stands by itself, it is considered a root because it has a meaning of its own (e.g. the morpheme cat) and when it depends on another morpheme to express an idea, it is an affix because it has a grammatical function (e.g. the –s in cats to specify that it is plural). [16] Every word comprises one or more morphemes. The more combinations a morpheme is found in, the more productive it is said to be.[17] **Bound morpheme** A morpheme that appears only as part of a larger word; a free or unbound morpheme is one that can stand alone. [18] A bound morpheme is also known as a bound form, and similarly a free morpheme is a free form.[19]
Operant: [20]	An item of behavior that is initially spontaneous, rather than a response to a prior stimulus, but whose consequences may reinforce or inhibit recurrence of that behavior.
Phoneme:	A basic unit of a language's phonology, which is combined with other phonemes to form meaningful units such as words or morphemes. The phoneme can be described as "The smallest contrastive linguistic unit which may bring about a change of meaning." [21]
Phonetics:	A branch of linguistics that comprises the study of the sounds of human speech, or—in the case of sign languages—the equivalent aspects of sign.[22] It is concerned with the physical properties of speech sounds or signs (phones): their physiological production, acoustic properties, auditory perception, and neurophysiological status. Phonology, on the other hand, is concerned with the abstract, grammatical characterization of systems of sounds or signs. The field of phonetics is a multilayered subject of linguistics that focuses on speech. In the case of oral languages there are three basic areas of study: 1. Articulatory phonetics: The study of the production of speech sounds by the articulatory and vocal tract by the speaker. 2. Acoustic phonetics: The study of the physical transmission of speech sounds from the speaker to the listener. 3. Auditory phonetics: The study of the reception and perception of speech sounds by the listener.

	These areas are inter-connected through the common mechanism of sound, such as wavelength (pitch), amplitude, and harmonics.
Phonology:	A branch of linguistics concerned with the systematic organization of sounds in languages. It has traditionally focused largely on the study of the systems of phonemes in particular languages but it may also cover any linguistic analysis either at a level beneath the word or at all levels of language where sound is considered to be structured for conveying linguistic meaning.
Pidgin (Or pidgin language): [23]	A simplified version of a language that develops as a means of communication between two or more groups that do not have a language in common. It is most commonly employed in situations such as trade, or where both groups speak languages different from the language of the country in which they reside (but where there is no common language between the groups). Fundamentally, a pidgin is a simplified means of linguistic communication, as it is constructed impromptu, or by convention, between individuals or groups of people. A pidgin is not the native language of any speech community, but is instead learned as a second language.[24] [25]
Program: [26]	"A set of detailed instructions (expressed or implicit) transmitted by one biocomputer and received by another/ or by both in interlock relationships. A program includes guidelines as to expected recordable and analyzable behavioral performances, vocal and nonvocal. A program defines values of time intervals between events, their amplitude, phases, durations, frequency ranges and modes of transmission, conduction, and reception. When possible, an attempt to measure the accuracy of the transmission and reception of a given program is made. "In a program, a 'burst' is defined as a physical entity: a continuous series of pressure variations in a gas, liquid, or solid, the amplitude of which remains above an arbitrarily chosen threshold value for a minimum period of time, and of which the waveform frequencies and group repetition rates remain above a given value for the same period of time. For the purpose of this discussion, the burst source is either dolphin or a human. For psychophysical experiments, the chosen amplitude, repetition rates, and minimum time duration are a function of the source's previous programing, hearing curve, frequency difference limens, and time functions (man, woman, or dolphin). "The determinants of the 'burst' for physical recording and displays are a function of the instrumental modifications of the original waveforms (the overall instrumental transforms) of the sequence of the original pressure variations. Such variables as frequency passbands, impulse responses, differential phase shifts, intermodulation, rectification, and time transforms determine the definition of the burst in the program.

	"In the sequence of such bursts, the period of time between the instant of the end of one burst (below the threshold instant) and the beginning of the next (above threshold instant) is defined as the '*interburst silent interval*' or '*interburst silence*'. The duration of the interburst silent interval is the time measured from the 'below-threshold instant' of burst one to the 'above-threshold instant' of the next burst in sequence."
Rostrum: [27]	In anatomy, the term **rostrum** (from the Latin *rostrum* meaning *beak*) is used for a number of phylogenetically unrelated structures in different groups of animals. The beak or snout of a vertebrate may also be referred to as the rostrum. Toothed whales, such as dolphins[6] and beaked whales, have rostrums (beaks), which evolved from their jawbones. The narwhale possesses a large rostrum (tusk), which evolved from a protruding canine tooth.
Reward:	Can be food, a novel object, focused and directed attention, or some kind of emotional energetic response for the human or dolphin. Many times the human operators forget they are also in the mix of the research and their bias may be bridged by the interactions of the dolphins.
Station (see Picture 1b):	A holding pattern or place for the dolphin or human to remain stationary until another action is requested by one of them.
Train of bursts: [28]	"A sequence of bursts in time in which the burst repetition rate and interburst silence maximum durations are programmatically (i.e., by the imposed program and/or given programs in the man or dolphin) defined within a certain range of values and within a certain frequency-of-occurrence distribution. "The time interval between individual separate trains is defined either in the program, or is to be determined experimentally. "In dolphin-human experiments, the human programming is specified by programs arbitrarily assigned by the operator, by those already exiting below levels of awareness in the operator, and by those developed between the operator and the dolphin in the experiments. In the case of the dolphin, similar programming exists. Some human and some dolphin programs are already present, others can be created and certain behavioral parts are both recorded experimentally by the objective methods."
Transformational Interlock (in our programs): [29]	"A system ontology that the one system, as it provides form and realization of the entities of that other system, results in a "transformational interlock." This is seen as a knowing between our Hs an Tt that some acoustic interplay is moving back and forth in an acoustic recognitions and exchanges and can measured and documented as well

	as predicted. Linguistically this may be a proto-pidgin, as it becomes a more robust acoustic exchange.
***Tursiops truncatus* (common bottlenose dolphin):** [30]	*Tursiops truncatus,* commonly known as the common bottlenose dolphin or the Atlantic bottlenose dolphin (and in older literature simply as the bottlenose dolphin, a term now applied to the genus), is the most well-known species from the family Delphinidae. Common bottlenose dolphins are the most familiar dolphins due to the wide exposure they receive in captivity in marine parks and dolphinaria, and in movies and television programs.[31] *T. truncatus* is the largest species of the beaked dolphins.[32] They inhabit temperate and tropical oceans throughout the world, and are absent only from polar waters.[33] [34] [35] [36] [37] All bottlenose dolphins were previously known as *T. truncatus*, but recently the genus has been split into three species, *T. truncatus*, *T. aduncus* (Indo-Pacific bottlenose dolphin)[38] [39] and *T. australis* (Burrunan dolphin). Although *T. truncatus* has been traditionally called the bottlenose dolphin,[40] [41] many authors have used the name common bottlenose dolphin for this species since two other species of bottlenose dolphins were described.[42] [43] [44] The dolphins inhabit warm and temperate seas worldwide. Considerable genetic variation has been described among members of this species, even between neighboring populations, and so many experts believe multiple species may be included within *T. truncatus*.[45] [46]
Ultrasound (ultrasonic): [47]	**Ultrasound** is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range. Ultrasound is thus not separated from 'normal' (audible) sound by differences in physical properties, only by the fact that humans cannot hear it. Although this limit varies from person to person, it is approximately 20 kilohertz (20,000 hertz) in healthy, young adults. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.
Unvoiced / Voicelessness (in linguistics):	The property of sounds being pronounced without the larynx vibrating. Phonologically, this is a type of phonation, which contrasts with other states of the larynx, but some object that the word "phonation" implies voicing, and that voicelessness is the lack of phonation.
Vocalization and Gestural String(s): [48]	A sequence of vowels, consonants, sounds, gestures, or word-constructs indicating a complete behavior structure. It may be either as a literal behavior like (1) stop; or as some kind of variant of a behavior, as in (1) the fish (2) is (3) over there. The latter may allow its vocal or gestural elements to be mutated and the length changed, or it may be fixed after it has been established as a recurring signal or cue. A vocalization or gestural string is a finite

	sequence of sounds or gesture that are chosen from a set established by the operator.
Voice (or Voicing):	A term used in phonetics and phonology to characterize speech sounds, with sounds described as either voiceless (unvoiced) or voiced. The term, however, is used to refer to two separate concepts. 1. Voicing can refer to the articulatory process in which the vocal cords vibrate. This is its primary use in phonetics to describe phones, which are particular speech sounds. 2. It can also refer to a classification of speech sounds that tend to be associated with vocal cord vibration but need not actually be voiced at the articulatory level. This is the term's primary use in phonology when describing phonemes, or in phonetics when describing phones.
Vowel: **(in phonetics)**	A sound in spoken language, such as an English ah! /ɑː/ or oh! /oʊ/, pronounced with an open vocal tract so that there is no build-up of air pressure at any point above the glottis. This contrasts with consonants, such as English sh!, which have a constriction or closure at some point along the vocal tract.
Whistle:	An auditory cue that tells the animal when it has done a behavior correctly. **Signature whistles**[49] are a form of dolphin vocalization emitted by bottlenose dolphins (*Tursiops truncatus*). [50] They are used in communication within the species and have specialized functions and properties.[51] Researchers define it as a whistle with a unique frequency curve that dominates in the repertoire of a dolphin.[52] Each dolphin has a distinct signature whistle that no other dolphin has developed. They are typically used for locational purposes, however they also provide dolphins with identity information and behavioral context.[53] [54] Signature whistles also play an important role in group cohesion and social interaction.
Zone of encounter:	A particular kind of meeting place. It must be mutually beneficial to both organisms for the purpose of the meeting. A zone of encounter is a place of mutual trust and reciprocal rewards, a place of safety to experience co-evolving sets of experiences, a place to learn compromises that benefit each other. (Author's description)

Endnotes

1 James Finneran et al., "A Method to Enable a Bottlenose Dolphin (Tursiops Truncatus) to Echolocate While out of Water," *The Journal of the Acoustical Society of America* 128, no. 3 (September 3, 2010): 1483–89, doi:http://dx.doi.org/10.1121/1.3471915.

2 Karen Pryor, *Reaching the Animal Mind: Clicker Training and What It Teaches Us About All Animals*, 1st ed. (Scribner, 2010), http://www.clickertraining.com/.

3 Kenji Uchino, ed., "15.3.1 Acoustic Lens and Horn," in *Advanced Piezoelectric Materials*, Science and Technology (Pennsylvania State University, USA: Woodhead Publishing, 2010), 547, https://www.elsevier.com/books/advanced-piezoelectric-materials/uchino/978-1-84569-534-7.

4 Roman Jakobson, ed., "Structure of Language and Its Mathematical Aspects," in *Symposia in Applied Mathematics*, vol. XII (New York City: American Mathematical Society, 1980). "... An allophone is the set of phones contained in the intersection of a maximal set of phonetically similar phones and a primary phonetically related set of phones..."

5 James Finneran, "Dolphins Use 'packets' of Broadband Clicks during Long Range Echolocation Tasks," *The Journal of the Acoustical Society of America* 132, no. 3 (2012): 1884.

6 Anonymous, "Desensitization," *SeaWorld*, Challenges of Animal Training, n.d., http://seaworld.org/animal-info/animal-infobooks/animal-training/challenges-of-animal-training/.

7 "Dialect," *Merriam-Webster Free Online Dictionary*, 2005.

8 J. Hans F. Abeelen, "Mouse Mutants Studied by Means of Ethological Methods," *Genetica* 34 (1963): 79–94.

9 Daniel R. MacNulty, David L. Mech, and Douglas W. Smith, "A Proposed Ethogram of Large-Carnivore Predatory Behavior, Exemplified by the Wolf," *Journal of Mammology* 88, no. 3 (2007): 595–605.

10 M. Wilkinson, C. Stirton, and A. McConnachie, "Behavioral Observations of Singly-Housed Grey Short-Tailed Opossums (Monodelphis Domestica) in Standard and Enriched Environments," *Laboratory Animals* 44, no. 4 (October 2010): 364–69.

11 N. Greenberg, "Anolis Ethogram," *Physiology & Behavior* 79 (2003): 429–40.

12 David Crystal, "Lexicon," *The Cambridge Encyclopedia of The English Language* (Cambridge: Cambridge University Press, 1995).

13 Ted W. Cranford, Mats Amundin, and Kenneth S. Norris, "Functional Morphology and Homology in the Odontocete Nasal Complex: Implications for Sound Generation," *Journal of Morphology* 288, no. 3 (June 1996): 223–85.

14 C. J. Harper et al., "Morphology of the Melon and Its Tendinous Connections to the Facial Muscles in Bottlenose Dolphins (Tursiops Truncatus)," *Journal of Morphology* 269, no. 7 (July 2008): 820–39.

15 Albert Bandura, *Social Foundation of Thought and Action: A Social Cognitive Theory*, Social Learning Theory (New Jersey: Prentice Hall, 1986).

16 Suzanne Kemmer, *Words in English: Structure* (Rice University, 2015).

17 Martin Packer, "Morphology" (Duquesne University, 2001).

18 Paul Kroeger, *Analyzing Grammar: An Introduction* (Cambridge: Cambridge University Press, 2005), 13.

19 Benjamin F. Elson and Velma Pickett, *Beginning Morphology and Syntax* (Dallas: Summer Institute of Linguistics, 1988).

20 Michael Domjan, ed., *The Principles of Learning and Behavior*, 5th ed. (California: Thomson/Wadsworth, 2003), http://www.amazon.com/Principles-Learning-Behavior-Michael-Domjan/dp/053456156X/ref=sr_1_1?s=books&ie=UTF8&qid=1425332271&sr=1-1&keywords=the+principles+of+learning+and+behavior+5th+edition.

21 Noam Chomsky and Morris Halle, *The Sound Pattern of English* (New York, Cambridge, MA: Harper and Row, The MIT Press, 1968).

22 William O'Grady, *How Children Learn Language*, (Cambridge: Cambridge University Press, 2005), 15.

23 Various, "Pidgin," *Wikipedia*, 2015, Wikipedia.

24 Loreto Todd, *Pigeons and Creoles*, 2nd ed. (Routledge, 1990), http://www.gettextbooks.com/isbn/9780415053112.

25 Sarah Grey Thomason and Terrance Kaufman, *Language Contact, Creolization, and Genetic Linguistics* (Berkeley: University of California Press, 1988), https://archive.org/details/rosettaproject_afr_detail-2.

26 Lilly, John C. Lilly, Alice M. Miller, and Henry M. Truby, "Reprogramming the Sonic Output of the Dolphin: Sonic Burst Count Matching," *The Journal of the Acoustical Society of America (JASA)* 43, no. 6 (June 1968): 1412–14.

27 "Rostrum," *Wikipedia*, n.d., http://en.wikipedia.org/wiki/Rostrum_%28anatomy%29. Anatomy, "Rostrum," n.d.

28 Lilly, Miller, and Truby, "Reprogramming the Sonic Output of the Dolphin: Sonic Burst Count Matching."

29 John C. Lilly, "Vocal Mimicry in Tursiops. Ability to Match Numbers and Duration of Human Vocal Bursts," *Science* 147 (1965): 300–301.

30 Various, "Common Bottlenose Dolphin," *Wikipedia*, 2015, http://en.wikipedia.org/wiki/Common_bottlenose_dolphin.

31 S. Leatherwood and R. Reeves, eds., *The Bottlenose Dolphin* (San Diego: Academic Press, Inc., 1989).

32 Jessica Jenkins, "Tursiops Truncatus Bottlenosed Dolphin," *Animal Diversity Web*, 2009.

33 Ibid.

34 Leatherwood and Reeves, *The Bottlenose Dolphin*.

35 Anonymous, "Bottlenose Dolphins," *SeaWorld Parks & Entertainment*, 2015, http://seaworld.org/en/animal-info/animal-infobooks/bottlenose-dolphins/.

36 P. Hammond et al., "Tursiops Truncatus," *IUCN Red List of Threatened Species*, 2015.

37 Margaret Klinowska, *Dolphins, Porpoises, and Whales of the World: The IUCN Red Data Book*, (Gland, Switzerland, Cambridge UK: IUCN, 1991).

38 Ibid.

39 Hammond et al., "Tursiops Truncatus."

40 Lilly, "Vocal Mimicry."

41 Anonymous, "Bottlenose Dolphin," *American Cetacean Society*, 2015.

42 R. Wells and M. Scott, "Bottlenose Dolphins," ed. W. Perrin, B. Wursig, and J. Thewissen, *Encyclopedia of Marine Mammals* (London: Academic Press, Inc., 2002).

43 R. Reeves et al., *National Audubon Society Guide to Marine Mammals of the World*, 1st ed., National Audubon Society Field Guide (A. A. Knopf, 2002),.

44 H. Shirihai and B. Jarrett, *Whales, Dolphins, and Other Marine Mammals of the World*, Princeton Field Guides (Princeton: Princeton University Press, 2006).

45 Ibid.

46 James G. Mead and Robert L. Brownell, Jr., "Order Cetacea," in *Mammal Species of the World. A Taxonomic and Geographic Reference*, ed. Don E. Wilson and DeeAnn M. Reeder, 3rd ed. (Baltimore: Johns Hopkins University Press, 2005), 2142.

47 Various, "Ultrasound (ultrasonic)," *Wikipedia*, n.d., http://en.wikipedia.org/wiki/Ultrasound.

48 Jack Kassewitz and Michael Hyson, *Private, Personal Communication between Authors Kassewitz and Hyson* (Skype, 2015).

49 Various, "Signature Whistles," *Wikipedia*, 2015.

50 Vincent M. Janik, "Chapter 4 Acoustic Communication in Delphinids," *Advances in the Study of Behavior* 40 (August 6, 2009): 123–57.

51 Ibid.

52 A. Agafonov and E. Panova, "Individual Patterns of Tonal (whistling) Signals of Bottlenose Dolphins (Tursiops Truncates) Kept in Relative Isolation," *Biology Bulletin* 39, no. 5 (September 2002): 430–40.

53 Bruno Diaz Lopez, "Whistle Characteristics in Free-Ranging Bottlenose Dolphins (Tursiops Truncatus) in the Mediterranean Sea: Influence of Behaviour," *Mammalian Biology* 76, no. 2 (March 2011): 180–89.

54 Vincent M. Janik, "Whistle Matching in Wild Bottlenose Dolphins," *Science* 289, no. 5483 (August 25, 2000): 1355–57.

Bibliography and Works Cited

Abeelen, J. Hans F. "Mouse Mutants Studied by Means of Ethological Methods." *Genetica* 34 (1963): 79–94.

Agafonov, A., and E. Panova. "Individual Patterns of Tonal (whistling) Signals of Bottlenose Dolphins (Tursiops Truncates) Kept in Relative Isolation." *Biology Bulletin* 39, no. 5 (September 2002): 430–40.

Anatomy. "Rostrum," n.d.

Anonymous. "Bottlenose Dolphin." *American Cetacean Society*, 2015. http://acsonline.org/fact-sheets/bottlenose-dolphin/.

———. "Bottlenose Dolphins." *SeaWorld Parks & Entertainment*, 2015. http://seaworld.org/en/animal-info/animal-infobooks/bottlenose-dolphins/.

———. "Desensitization." *SeaWorld*. Challenges of Animal Training, n.d. http://seaworld.org/animal-info/animal-infobooks/animal-training/challenges-of-animal-training/.

Bandura, Albert. *Social Foundation of Thought and Action: A Social Cognitive Theory*. Social Learning Theory. New Jersey: Prentice Hall, 1986. http://psycnet.apa.org/index.cfm?fa=search.displayRecord&uid=1985-98423-000.

Chomsky, Noam, and Morris Halle. *The Sound Pattern of English*. New York, Cambridge, MA: Harper and Row, The MIT Press, 1968.

Cranford, Ted W., Mats Amundin, and Kenneth S. Norris. "Functional Morphology and Homology in the Odontocete Nasal Complex: Implications for Sound Generation." *Journal of Morphology* 288, no. 3 (June 1996): 223–85.

Crystal, David. "Lexicon." *The Cambridge Encyclopedia of The English Language*. Cambridge: Cambridge University Press, 1995. http://www.cambridge.org/us/academic/subjects/languages-linguistics/english-language-and-linguistics-general-interest/cambridge-encyclopedia-english-language-2nd-edition?format=PB.

"Dialect." *Merriam-Webster Free Online Dictionary*, 2005. http://www.merriam-webster.com/dictionary/dialect.

Domjan, Michael, ed. *The Principles of Learning and Behavior*. 5th ed. California: Thomson/Wadsworth, 2003. http://www.amazon.com/Principles-Learning-Behavior-Michael-Domjan/dp/053456156X/ref=sr_1_1?s=books&ie=UTF8&qid=1425332271&sr=1-1&keywords=the+principles+of+learning+and+behavior+5th+edition.

Elson, Benjamin F., and Velma Pickett. *Beginning Morphology and Syntax*. Dallas: Summer Institute of Linguistics, 1988. https://openlibrary.org/books/OL8179585M/Beginning_Morphology_and_Syntax.

Finneran, James. "Dolphins Use 'packets' of Broadband Clicks during Long Range Echolocation Tasks." *The Journal of the Acoustical Society of America* 132, no. 3 (2012): 1884.

Finneran, James, Dorian Houser, Patrick Moore, Brian Branstetter, Jennifer Trickey, and Sam Ridgway. "A Method to Enable a Bottlenose Dolphin (Tursiops Truncatus) to Echolocate While out of Water." *The Journal of the Acoustical Society of America* 128, no. 3 (September 3, 2010): 1483–89. doi:http://dx.doi.org/10.1121/1.3471915.

Greenberg, N. "Anolis Ethogram." *Physiology & Behavior* 79 (2003): 429–40.

Hammond, P., G. Bearzi, A. Bjørge, K. Forney, L. Karczmarski, T. Kasuya, and et al. "Tursiops Truncatus." *IUCN Red List of Threatened Species*, 2015. http://www.iucnredlist.org/details/22563/0.

Harper, C. J., W. A. McLellan, S. A. Rommel, D. M. Gay, R. M. Dillaman, and D. A. Pabst. "Morphology of the Melon and Its Tendinous Connections to the Facial Muscles in Bottlenose Dolphins (Tursiops Truncatus)." *Journal of Morphology* 269, no. 7 (July 2008): 820–39. doi:10.1002/jmor.10628.

Jakobson, Roman, ed. "Structure of Language and Its Mathematical Aspects." In *Symposia in Applied Mathematics*, Vol. XII. New York City: American Mathematical Society, 1980. http://www.ams.org/books/psapm/012/psapm012-endmatter.pdf.

Janik, Vincent M. "Chapter 4 Acoustic Communication in Delphinids." *Advances in the Study of Behavior* 40 (August 6, 2009): 123–57.

———. "Whistle Matching in Wild Bottlenose Dolphins." *Science* 289, no. 5483 (August 25, 2000): 1355–57. doi:10.1126/science.289.5483.1355.

Jenkins, Jessica. "Tursiops Truncatus Bottlenosed Dolphin." *Animal Diversity Web*, 2009. http://animaldiversity.org/accounts/Tursiops_truncatus/.

Kassewitz, Jack, and Michael Hyson. *Private, Personal Communication between Authors Kassewitz and Hyson*. Skype, 2015.

Kemmer, Suzanne. *Words in English: Structure*. Rice University, 2015. http://www.ruf.rice.edu/~kemmer/Words04/structure/.

Klinowska, Margaret. *Dolphins, Porpoises, and Whales of the World: The IUCN Red Data Book*. Gland, Switzerland, Cambridge UK: IUCN, 1991. https://openlibrary.org/books/OL1461924M/Dolphins_porpoises_and_whales_of_the_world.

Kroeger, Paul. *Analyzing Grammar: An Introduction*. Cambridge: Cambridge University Press, 2005.

Leatherwood, S., and R. Reeves, eds. *The Bottlenose Dolphin*. San Diego: Academic Press, Inc., 1989. http://store.elsevier.com/product.jsp?isbn=9780323139618&pagename=search.

Lilly, John C. "Vocal Mimicry in Tursiops. Ability to Match Numbers and Duration of Human Vocal Bursts." *Science* 147 (1965): 300–301.

Lilly, Lilly, John C., Alice M. Miller, and Henry M. Truby. "Reprogramming the Sonic Output of the Dolphin: Sonic Burst Count Matching." *The Journal of the Acoustical Society of America (JASA)* 43, no. 6 (June 1968): 1412–14.

Lopez, Bruno Diaz. "Whistle Characteristics in Free-Ranging Bottlenose Dolphins (Tursiops Truncatus) in the Mediterranean Sea: Influence of Behaviour." *Mammalian Biology* 76, no. 2 (March 2011): 180–89.

MacNulty, Daniel R., David L. Mech, and Douglas W. Smith. "A Proposed Ethogram of Large-Carnivore Predatory Behavior, Exemplified by the Wolf." *Journal of Mammology* 88, no. 3 (2007): 595–605.

Mead, James G., and Robert L. Brownell, Jr. "Order Cetacea." In *Mammal Species of the World. A Taxonomic and Geographic Reference*, edited by Don E. Wilson and DeeAnn M. Reeder, 3rd ed., 2142. Baltimore: Johns Hopkins University Press, 2005. https://jhupbooks.press.jhu.edu/content/mammal-species-world.

O'Grady, William. *How Children Learn Language*. Cambridge: Cambridge University Press, 2005. http://www.cambridge.org/us/academic/subjects/languages-linguistics/psycholinguistics-and-neurolinguistics/how-children-learn-language.

Packer, Martin. "Morphology." Duquesne University, 2001. http://www.mathcs.duq.edu/~packer/Courses/Psy598/Ling-Morphology.pdf.

Pryor, Karen. *Reaching the Animal Mind: Clicker Training and What It Teaches Us About All Animals*. 1st ed. Scribner, 2010. http://www.clickertraining.com/.

Reeves, R., B. Stewart, P. Clapham, and Powell, J. *National Audubon Society Guide to Marine Mammals of the World*. 1st ed. National Audubon Society Field Guide. A. A. Knopf, 2002. http://knopfdoubleday.com/book/119980/national-audubon-society-guide-to-marine-mammals-of-the-world/.

Shirihai, H., and B. Jarrett. *Whales, Dolphins, and Other Marine Mammals of the World*. Princeton Field Guides. Princeton: Princeton University Press, 2006. http://press.princeton.edu/titles/8250.html.

Thomason, Sarah Grey, and Terrance Kaufman. *Language Contact, Creolization, and Genetic Linguistics*. Berkeley: University of California Press, 1988. https://archive.org/details/rosettaproject_afr_detail-2.

Todd, Loreto. *Pigeons and Creoles*. 2nd ed. Routledge, 1990. http://www.gettextbooks.com/isbn/9780415053112.

Uchino, Kenji, ed. "15.3.1 Acoustic Lens and Horn." In *Advanced Piezoelectric Materials*, 547. Science and Technology. Pennsylvania State University, USA: Woodhead Publishing, 2010. https://www.elsevier.com/books/advanced-piezoelectric-materials/uchino/978-1-84569-534-7.

Various. "Common Bottlenose Dolphin." *Wikipedia*, 2015. http://en.wikipedia.org/wiki/Common_bottlenose_dolphin.

———. "Pidgin." *Wikipedia*, 2015. Wikipedia, https://en.wikipedia.org/wiki/Pidgin.

———. "Rostrum." *Wikipedia*, n.d. http://en.wikipedia.org/wiki/Rostrum_%28anatomy%29.

———. "Signature Whistles." *Wikipedia*, 2015. http://en.wikipedia.org/wiki/Signature_whistles.

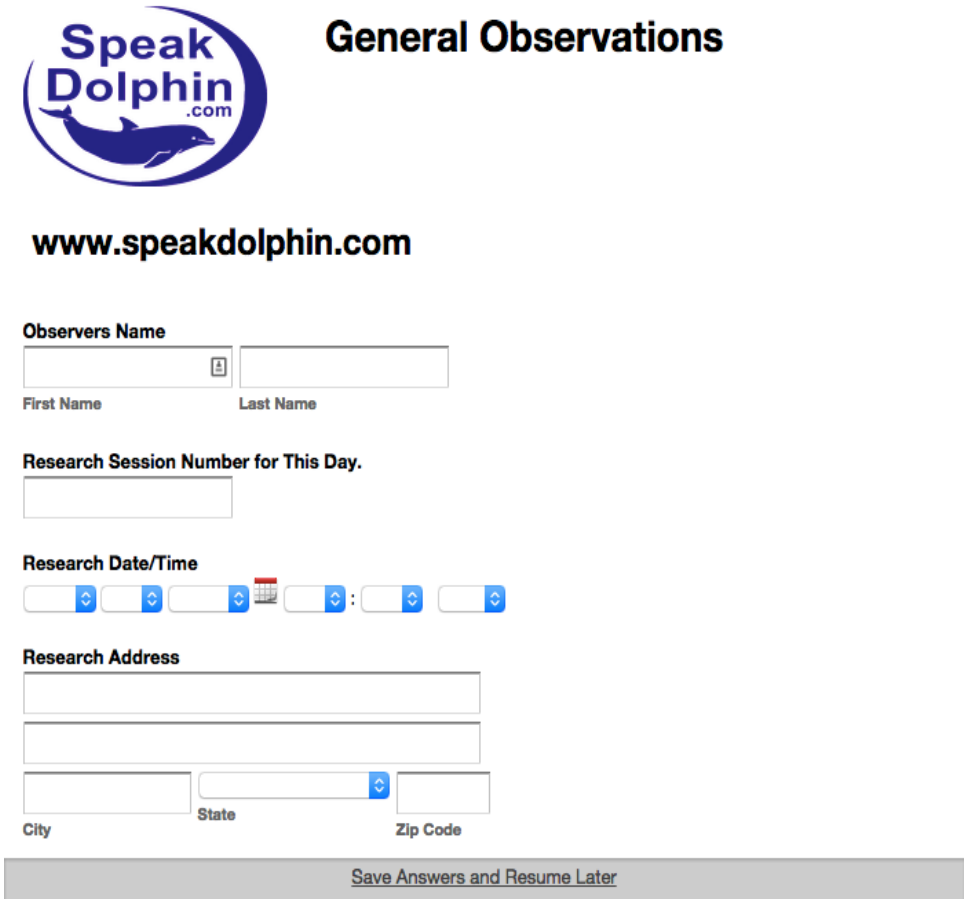
———. "Ultrasound (ultrasonic)." *Wikipedia*, n.d. http://en.wikipedia.org/wiki/Ultrasound.

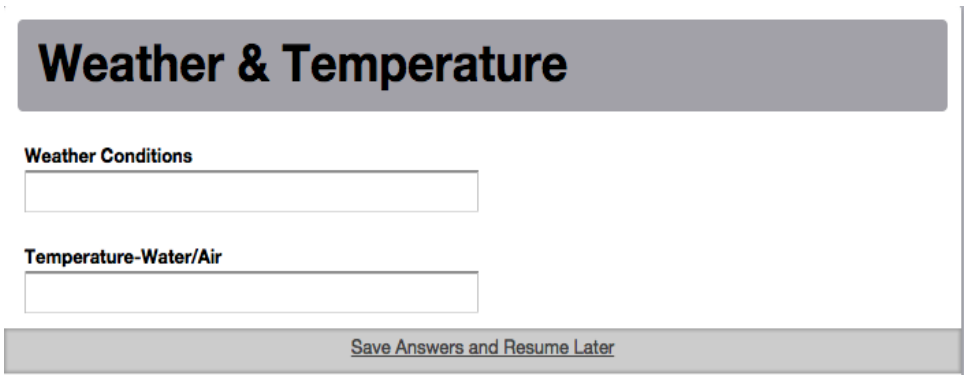
Wells, R., and M. Scott. "Bottlenose Dolphins." Edited by W. Perrin, B. Wursig, and J. Thewissen. *Encyclopedia of Marine Mammals*. London: Academic Press, Inc., 2002. https://openlibrary.org/works/OL16967695W/Encyclopedia_of_marine_mammals.

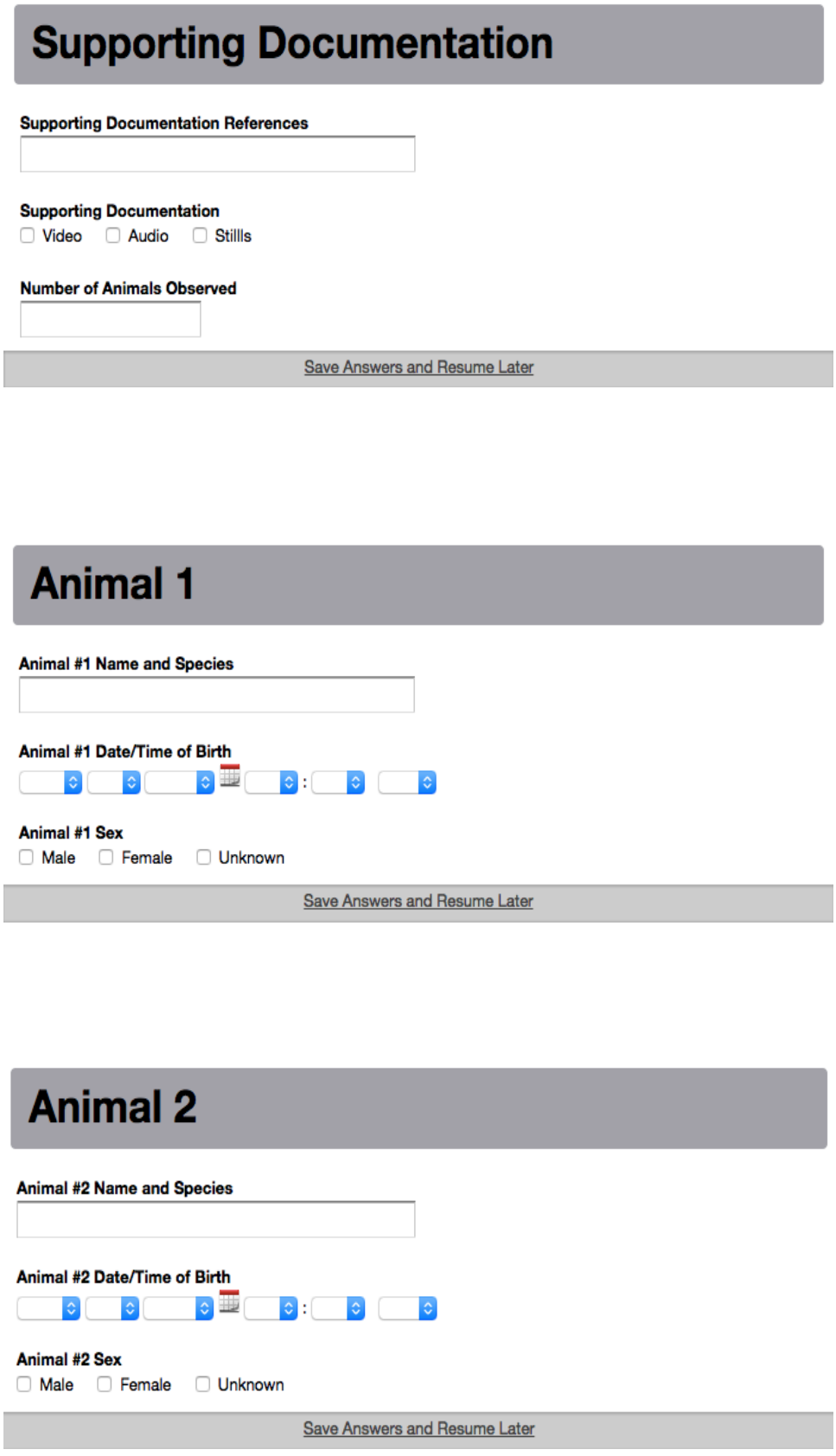
Wilkinson, M., C. Stirton, and A. McConnachie. "Behavioral Observations of Singly-Housed Grey Short-Tailed Opossums (Monodelphis Domestica) in Standard and Enriched Environments." *Laboratory Animals* 44, no. 4 (October 2010): 364–69.

Appendix 1: General Observations

https://speakdolphincom.formstack.com/forms/general_observations







Supporting Documentation

Supporting Documentation References

Supporting Documentation

☐ Video ☐ Audio ☐ Stillls

Number of Animals Observed

Save Answers and Resume Later

Animal 1

Animal #1 Name and Species

Animal #1 Date/Time of Birth

Animal #1 Sex

☐ Male ☐ Female ☐ Unknown

Save Answers and Resume Later

Animal 2

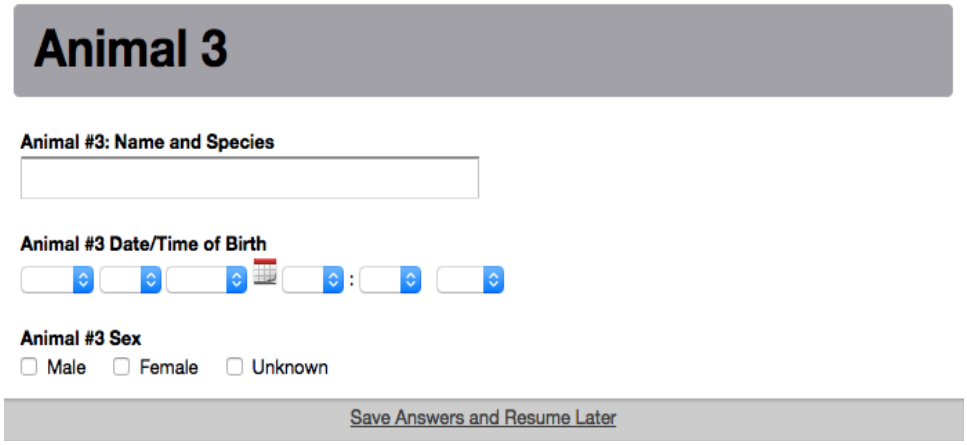
Animal #2 Name and Species

Animal #2 Date/Time of Birth

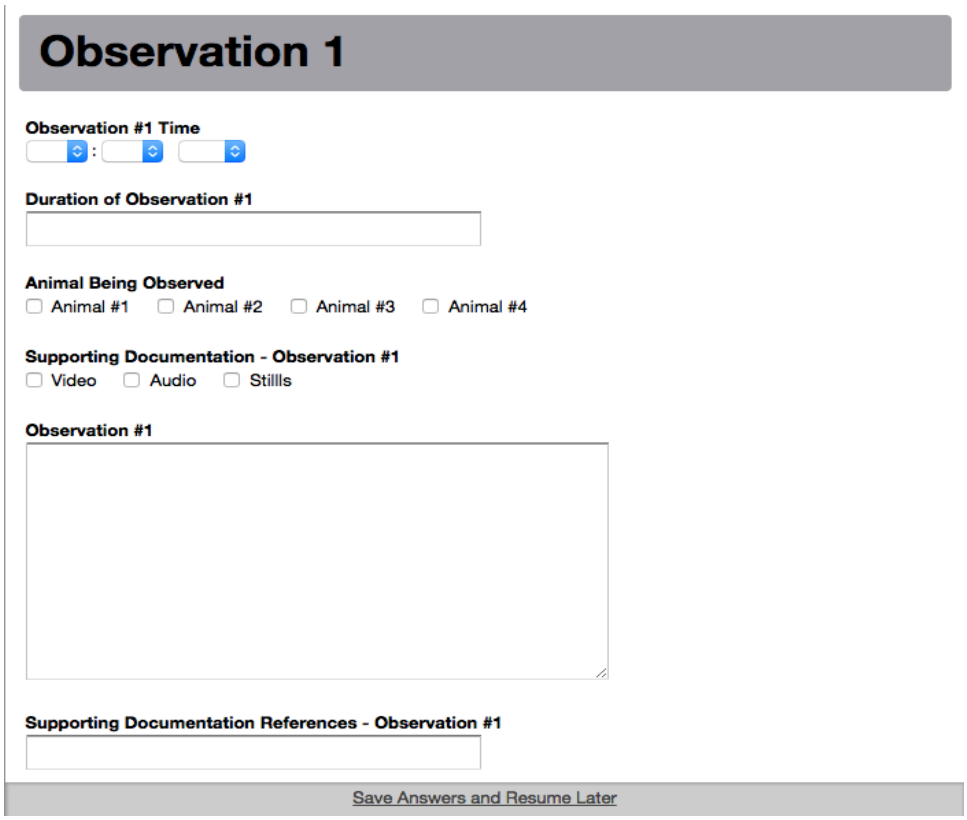
Animal #2 Sex

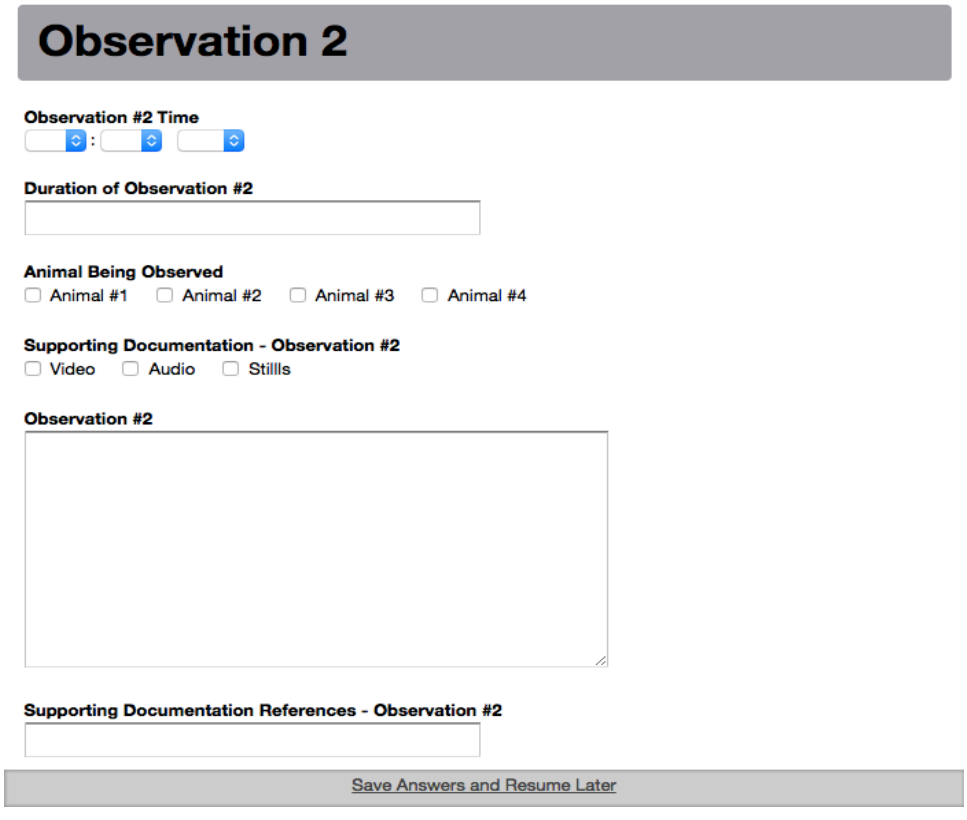
☐ Male ☐ Female ☐ Unknown

Save Answers and Resume Later


Animal 3
Animal #3: Name and Species
Animal #3 Date/Time of Birth
Animal #3 Sex
Male
Female
Unknown
Save Answers and Resume Later


Animal 4
Animal #4 Name and Species
Animal #4 Date/Time of Birth
Animal #4 Sex
Male
Female
Unknown
Save Answers and Resume Later


Observation 1
Observation #1 Time
Duration of Observation #1
Animal Being Observed
Animal #1
Animal #2
Animal #3
Animal #4
Supporting Documentation - Observation #1
Video
Audio
Stillls
Observation #1
Supporting Documentation References - Observation #1
Save Answers and Resume Later


Observation 2
Observation #2 Time
Duration of Observation #2
Animal Being Observed
Animal #1
Animal #2
Animal #3
Animal #4
Supporting Documentation - Observation #2
Video
Audio
Stillls
Observation #2
Supporting Documentation References - Observation #2
Save Answers and Resume Later

Observation 3

Observation #3 Time

:

Duration of Observation #3

Animal Being Observed

☐ Animal #1 ☐ Animal #2 ☐ Animal #3 ☐ Animal #4

Supporting Documentation - Observation #3

☐ Video ☐ Audio ☐ Stillls

Observation #3

Supporting Documentation References - Observation #3

Save Answers and Resume Later

Observation 4

Observation #4 Time

:

Duration of Observation #4

Animal Being Observed

☐ Animal #1 ☐ Animal #2 ☐ Animal #3 ☐ Animal #4

Observation #4

Supporting Documentation - Observation #4

☐ Video ☐ Audio ☐ Stillls

Supporting Documentation References - Observation #4

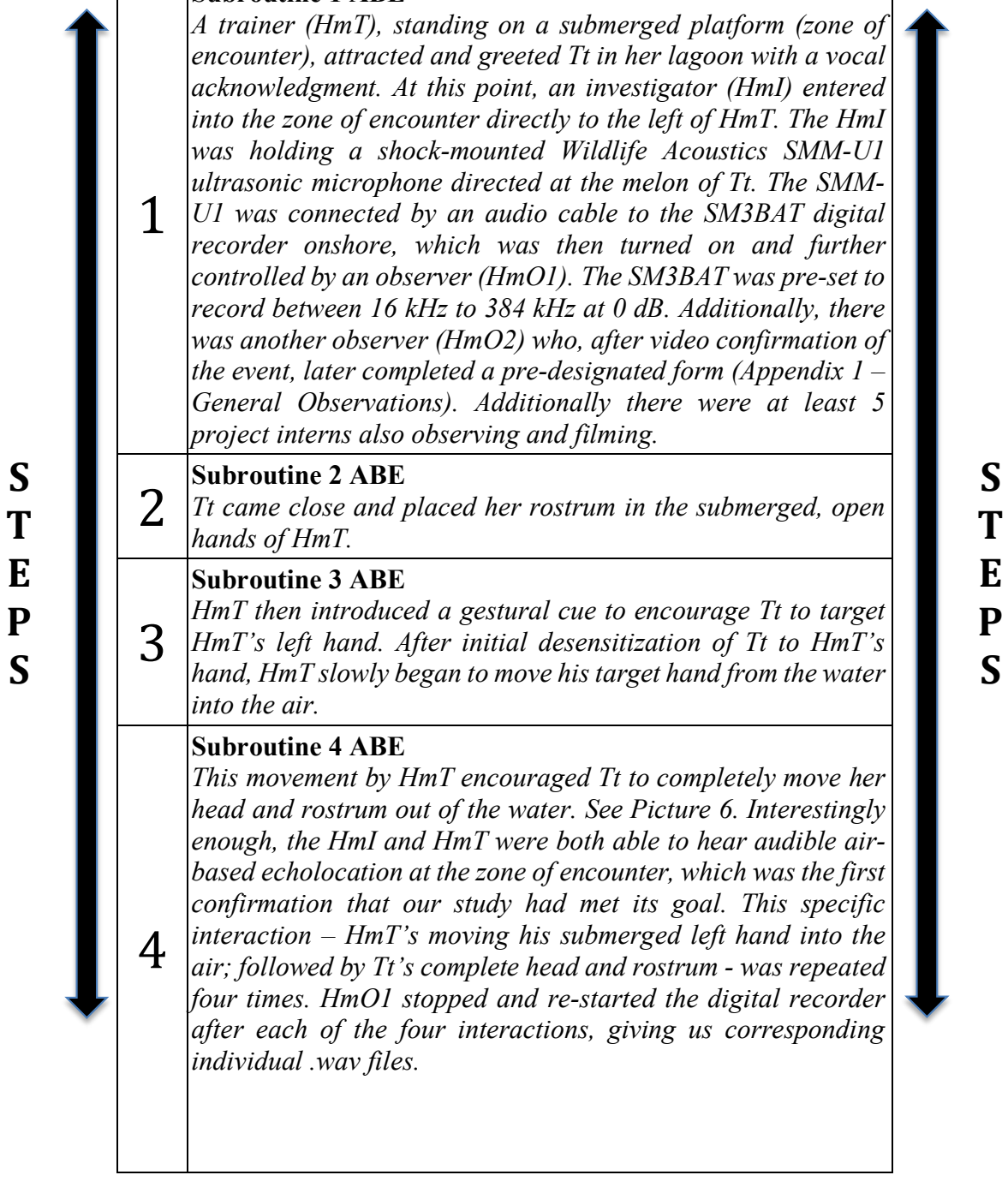
Save Answers and Resume Later


Comments & Signature
Observers Email
Comments
Additional Supporting Material
Choose File
No file chosen
Observers Signature
[clear]
Use your mouse or finger to draw your signature above
Save Answers and Resume Later

Appendix 2: Performance Evaluation and Review Technique (PERT)

This is the Protocol Workflow that the Study Managers used on the dock.

Use of Air-Based Echolocation by a Bottlenose Dolphin



1	**Subroutine 1 ABE** *A trainer (HmT), standing on a submerged platform (zone of encounter), attracted and greeted Tt in her lagoon with a vocal acknowledgment. At this point, an investigator (HmI) entered into the zone of encounter directly to the left of HmT. The HmI was holding a shock-mounted Wildlife Acoustics SMM-U1 ultrasonic microphone directed at the melon of Tt. The SMM-U1 was connected by an audio cable to the SM3BAT digital recorder onshore, which was then turned on and further controlled by an observer (HmO1). The SM3BAT was pre-set to record between 16 kHz to 384 kHz at 0 dB. Additionally, there was another observer (HmO2) who, after video confirmation of the event, later completed a pre-designated form (Appendix 1 – General Observations). Additionally there were at least 5 project interns also observing and filming.*
2	**Subroutine 2 ABE** *Tt came close and placed her rostrum in the submerged, open hands of HmT.*
3	**Subroutine 3 ABE** *HmT then introduced a gestural cue to encourage Tt to target HmT's left hand. After initial desensitization of Tt to HmT's hand, HmT slowly began to move his target hand from the water into the air.*
4	**Subroutine 4 ABE** *This movement by HmT encouraged Tt to completely move her head and rostrum out of the water. See Picture 6. Interestingly enough, the HmI and HmT were both able to hear audible air-based echolocation at the zone of encounter, which was the first confirmation that our study had met its goal. This specific interaction – HmT's moving his submerged left hand into the air; followed by Tt's complete head and rostrum - was repeated four times. HmO1 stopped and re-started the digital recorder after each of the four interactions, giving us corresponding individual .wav files.*