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The Effects of White Noise Disturbance on Zebra Finch Behavior; Does Disturbance Predictability Matter?

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THE EFFECTS OF WHITE NOISE DISTURBANCE ON ZEBRA FINCH BEHAVIOR;

DOES DISTURBANCE PREDICTABILITY MATTER?

by

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ABSTRACT

It is undeniable that the progress of human civilization has altered the natural landscape of the world in ways that range from the merely aesthetic to the irreparably destructive. Some impacts are patently obvious. Others may not be as obvious to the casual observer, and yet they can be just as important in terms of truly understanding not only our impact on the world around us, but how we can mitigate this impact.

One of the most far-reaching of these latter impacts is the increased and altered levels of background noise upon the natural acoustic landscape. These changes have the potential to hinder species such as songbirds that rely on acoustic signals as a vital part of many social processes. These impediments have been shown to increase stress levels and levels of predation, erode pair bonds, and decrease the likelihood of survival of populations in the novel acoustic environments we have created. Therefore further study of the effects of noise disturbance on songbird populations and breeding efforts may allow us to create informed conservation strategies to help mitigate these effects. While the effects of masking noise on various species of birds have been studied before, this is the first study designed to understand what effect the predictability of such noise disturbances may have on zebra finch (*Taeniopygia guttata*) behavior. The results pointed towards the predictability of the disturbance not having a significant effect on initiation or time spent vocalizing after the end of a disturbance block.

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INTRODUCTION

The zebra finch (*Taeniopygia guttata*) is a passerine in the family Estrildidae. There are two subspecies of zebra finches, one native to the Lesser Sundas Islands and the surrounding area (*Taeniopygia guttata guttata*), and one native to mainland Australia (*T. g. castanotis*). Throughout most of their range, the climate is very dry, punctuated with short, unpredictable periods of heavy rain from monsoons and cyclones. Because of this, the birds are adapted towards drought conditions for the majority of the year a very limited water supply. They excrete as little water as possible, can drink from a water source that is only as deep as the tip of their bill without having to then tilt their heads back (making otherwise undrinkable water accessible), and can even go without drinking for extended periods of time if necessary (Zann, 1996).

Zebra finches are highly social and live in large flocks that experience a high level of both male and female immigration and emigration and which may shrink significantly during the breeding season (reviewed by Zann, 1996). Because of their highly social lifestyle, zebra finches have developed a variety of calls and songs that they use to communicate with their mates, offspring, intra-colony group, and colony as a whole. The three most common call types are the "tet", "stack" and "distance" calls (Zann, 1996). These calls and others serve many different functions, from assessing the location of others, to warning calls, to territorial defense of their mate or nest. Members of both sexes perform contact calls, but only the males sing as female members of the species only develop the part of the brain responsible for song recognition (Nottebohm & Arnold, 1976).

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Because the zebra finch is a desert species in the wild and has evolved to be able to breed as soon as conditions are right, many of the same traits that make them ideally suited to the dry Australian climate also make them ideal for use in laboratory studies. As the "lab rat of ornithology" (Buchanan, et al., 2010), they are hardy and easy to keep in captivity. In addition, they readily and quickly breed when given conditions similar to those that stimulate breeding in their natural environment.

The zebra finch has become such an important study species that it was the second species of bird to have its genome mapped. It has been used for studies across a wide range of fields, from neuroscience (Amin et al., 2004) and cognition (Healy et al., 2010), to genetics (Forstmeier et al., 2007), mate selection as a result of song production (Burley, 2006 & 1988), and the role of contact calls in keeping track of the location of specific individuals in a colony (Menardy et al., 2012). They have also been used to investigate the effects of anthropogenic noise disturbance (Swaddle & Page, 2007) on bird behavior, which is the focus of this study.

We change the environments we inhabit radically, and these changes comprise both alterations to existing natural landscapes and the creation of completely new urban environments. Wild animals are forced to adapt, leave, or face extinction. These problems have been present to some extent for much of our history. However, ever increasing human populations and urban sprawl, as well as increasing use of disruptive technologies (noise from cars and lights, for example) that have only recently become widespread, have made this a fairly novel problem in terms of both extent and intensity of impact. As our population continues to increase, trying to mitigate these impacts is only going to

become a more important management and conservation goal over time (Slabbekoorn & Ripmeester, 2008).

Conservation efforts can be difficult because of variation among species in response to human disturbances. However there are some trends in response that can help mitigate our impacts. For instance nocturnal animals that use moonlight to guide particular behaviors, such as species of moths (Hausmann, 1992) and sea turtles (Bourgeois et al., 2009), are generally impacted more negatively by light pollution, and so conservation efforts should focus on reducing the negative influences of this form of disturbance. Similarly noise disturbance poses a challenge to passerine birds, because they rely on being able to send and receive vocal signals effectively in order to achieve many biological goals, such as mate acquisition, territory defense, alarm calls upon sighting a predator, and keeping track of other members of a flock.

Noise itself is a part of all environments, and it can be defined as virtually any type of sound that degrades the ease of acoustic signal transmission (Brumm & Slabbekoorn, 2005). In many situations the loudest level of masking noise could come from vocal signals created by other species of birds, or from members of an individual's own species or flock. Because of this variation in the degree of masking noise and physical buffers found naturally in most ecosystems (Planque & Slabbekoorn, 2008), most species of passerines are not completely without defenses against the new sources we have created. Changes in pitch or amplitude in relation to the pitch of noise disturbance (Slabbekoorn & den Boer-Visser, 2006; Brumm, 2004) are both common methods of circumventing the effects of masking noise, as are changes in the peak time in

which songs or calls are produced to avoid the noise altogether (Brumm & Slabbekoorn, 2005; Slabbekoorn & Ripmeester, 2008).

Nevertheless, anthropogenic noise may threaten avian populations when we start to add to what is naturally there in a way that is difficult or impossible for them to adjust to, given the physical or environmental constraints of a species. Many urban areas have experienced a decrease in species richness that is at least partially explained by amplified background noise levels (González-Oreja et al., 2012). This decrease in species richness is understandable given the many negative consequences of such disturbance. Noise disturbance not only interferes with communication, but also erodes pair bonds (Swaddle & Page, 2007), increases the risk of predation (due to the decreased ability to hear predators or the alarm calls of other birds), and increases stress levels as a result of the interference it causes (Crino et al., 2011).

Many biotic and abiotic factors can affect the frequency, intensity and duration of stress responses in animals. The stress response can be helpful in specific situations over the short term (for example being chased by a predator), but the long term effects of heightened stress levels can have a variety of negative effects. For instance, other studies of zebra finches have documented reduced lifespan and increased risk of disease to both an individual and its mated partner (Monaghan et al., 2012), and reduced reproductive effort and investment in offspring (Salvante & Williams, 2003).

Rates of extinction have increased in ecological communities around the world, and low levels of species richness in environments that have been highly altered by human influence pose a significant problem. It is likely that these environments will only become more widespread with time. Thus, attempts to understand exactly why habitats

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with a high degree of human influence often experience such a reduction in the number of species that inhabit them are important. Without such understanding we cannot hope to mitigate our impact. Yet until now, no other studies have investigated how the predictability of human-generated noise disturbances might affect the ability of bird species such as the zebra finch to communicate, breed, or carry out other necessary behaviors.

Some anthropogenic noise may occur more "regularly", such as the increase in noise generated by "rush-hour" traffic, and there is already evidence that birds may adjust their vocalizations in response (Brumm, 2004). However other sources of noise occur less predictably (noise from construction, sirens, and airplanes for example), and may be more disturbing or make it harder for animals to adapt. If so, it is possible that decreases in the ability to adapt could cost an animal more in energetic resources as it tries to do so, or increase stress levels as a result of greater disturbance. As mentioned above, a number of studies have revealed that birds also often use a variety of adaptations to help mitigate the effects of noise disturbances, including changing temporal aspects of their calls. If the predictability of anthropogenic noise disturbance helps in forming such a strategy, I predicted that birds exposed to predictable disturbances might exhibit vocalizations that were timed differently from birds exposed to less predictable noise disturbances, or might change the duration of time spent calling in an attempt to be more energetically efficient.

METHODS

Study Population The zebra finches used in this study were obtained approximately one month before the start of the experiment from a variety of pet stores

and private breeders on the North Island of New Zealand. Whenever possible the breeding history of the birds was obtained. However to a large extent their heritage and age was unknown, and therefore the study probably held individuals from a wide age range, as well as number of generations since their ancestors were first captured from the wild. Although this arrangement was not ideal, it was tolerated as it most likely had a negligible effect on study results. Previous studies have shown that the effects of age on reproductive performance in captive populations are minimal, and much more greatly impacted by quality of nutrition (Williams & Christians, 2003).

However, there was still the potential of genetics, color morph, and prior interaction influencing my experiment. To control for this I allocated the finches in such a way that the colonies in each room had a similar composition of morphs and sources, and each finch was paired with a mate with which it had no known prior interaction. While I tried to obtain as many "natural" (the closest domestic morph to the wild morph) color morphs as possible, due to limitations in the number of finches available to me it was necessary to obtain some of the more common domestic color morphs as well. I also paired morphs with each other. Because juvenile zebra finches become imprinted on the morphology of their parents, female receptiveness to a male can depend on the morphs she was exposed to at an early age (Burley, 2006), and thus influence her selection. Finally, Burley (1988) noted that band color had an effect on the reproductive success of individual finches. Leg bands are often used on birds as a method of identification, but specific band colors can increase or decrease a finch's perceived attractiveness, and the effect of each color differs between the sexes. About 15% of my study populations had

metal bands that were not practical to remove, so to account for this I distributed banded individuals evenly among the study rooms.

Cage Set-up Both quarantine and experimental cages were Hoei brand cages that consisted of a metal wire top (30x40x30 cm), a plastic bottom, and removable plastic trays. Cages were the same for both the holding and experimental stages (see below), with the exception of two larger cages that were both used solely in the quarantine rooms.

Holding cages were set up with one food dish filled with finch seed *ad libitum* and one water bottle, to which Ornithon Vitamin Supplement was added. In addition to the finch seed, their diet was supplemented with washed spinach and grass grown in the university greenhouse, as well as frozen spinach and cuttlebone. The males were separated from the females into two different quarantine rooms.

Experimental cages were set up similarly to quarantine cages, with a few notable changes. In addition to the diet they received in the quarantine cages a dish was added containing bird grit, and the amount of cuttlebone available was increased in anticipation of the increased calcium needs of breeding female birds. One major addition to the cages was a wooden nesting box placed outside the back upper-right corner of the cage, with the entrance and outside perch facing into the cage itself. In the bottom of the cage were placed a variety of nesting materials that the birds could use for nest construction.

Quarantine Rooms The finches were placed into windowless quarantine rooms for roughly one month so I could assess their general health and to adjust them all to the same diet, cages, temperature, and photoperiod that they would experience during the experiment. Two rooms were used as quarantine rooms; one for the male zebra finches and one for the females. The number of hours of "daylight" was increased incrementally

during the quarantine period to gradually achieve and then maintain a 14 hour light to 10 hour dark cycle. Although zebra finches are opportunistic breeders, an increased photoperiod can help facilitate reproduction.

Experimental Rooms Six windowless rooms were used for the experiment itself. This allowed me to maintain the desired photoperiod as well as to standardize the lighting between rooms. Because the finches were blocked from natural sunlight, full spectrum lights were used in addition to standard incandescent bulbs. Day began at 0500 hours and ended at 2100h. All rooms were ventilated and kept at 22° Celsius. "Colonies" consisted of 6 pairs of birds, with a pair to a cage. Cages were placed approximately 0.3 meters away from each other on one wall of each room, and boards were placed between the cages to prevent visual contact with all other members of a colony save for an individual's mate. This was done so that vocalizations would be the only means of communication between colony members available to the birds.

Pairs were introduced into the experimental rooms every other day, until all pairs were in place. Each cage was given an ID that included which individuals were in each cage as well as pair number with respect to date of introduction. For instance, pairs introduced on the first day were regarded as "pair 1" for each study room. The day that each individual was introduced into the experiment was also the first day it was exposed to its mate, to prevent pre-exposure bias. Although the results are not included here, this was originally done in order be able to measure synchrony of nesting and egg laying attempts later (Waas et al., 2005). Each new pair was introduced after the noise disturbance treatment for that day had ended; therefore the first day that each new pair

was exposed to the noise disturbance treatments was the day after introduction into the experiment.

Sound System Setup The speakers through which the treatments were played were placed one to each room, facing the cages and about a meter off the ground, as well as a meter away from the centermost cage in the colony. Decibel levels were measured routinely to check for any accidental changes in white noise disturbance amplitude, and also to check that all members of the colony experienced the same conditions. Noise disturbance treatments were originally set to broadcast at 90 dB, but were lowered to 82 dB before the start of the experiment out of concern that the noise would be too loud. The noise levels experienced decreased by a couple of decibels between the cages in the center and edge of the colony (a distance of about 2-3 meters). This change in amplitude experienced could have potentially caused a meaningful difference in behavior, and to help mitigate this cages were moved a set time before the video recording of a pair (see below), and thus no one cage was permanently at the edge or in the center of the colony. An "iPod Nano" (© 2012 Apple Inc.) was connected to each sound system, and held playlists customized for each treatment and set to an alarm. The speaker system as a whole was connected to a timer to remotely turn the treatments on and off every day. The system was set up so that the timer controlling the speakers would turn on just before the alarm on the iPods went off. Disturbance began at 0600h (an hour after lights had been turned on for the day), and continued until 0900h. This time frame was chosen to cover the period of highest song production in adult zebra finches (Johnson et al., 2002; Zann, 1996).

Treatments Three treatments were used in this experiment: an "unpredictable" noise treatment, a "predictable" noise treatment, and a control treatment. Two rooms (and therefore two colonies) were exposed to the control treatment, two were exposed to the predictable treatment, and two to the unpredictable treatment. The predictable treatment type played 180 one-minute tracks, set up to deliver a total of 90 minutes of silence and 90 minutes of masking white noise that covered the zebra finch's natural vocal frequency range (16 Hz to 8 kHz) and amplitude (0 to 76 dB- for both see Brumm, 2009). The noise treatment was delivered once daily and the tracks played in this treatment alternated in a potentially predictable fashion between one minute silent and one minute noise block tracks. The unpredictable noise treatment was set up in exactly the same fashion as the control and predictable noise treatments, and featured 180 one-minute tracks set up to deliver a total of 90 minutes of silence, and 90 minutes of white noise. The iPods for this treatment were set on "shuffle" (an Apple application term for a software technique where a "playlist" or group of songs is played through once in as random an order as possible through the capabilities of the software) for the duration of the three hours, which resulted in a random sequence of silence and noise blocks. The two zebra finch colonies in the control experiment again received the same feeding and care schedule as the other two treatment types, and the set up of the rooms remained the same including the placement of a decoy sound system, camera and speakers. This system was turned on and played daily with the other two treatment types, but the iPods used in the control contained only silent tracks.

Recording System Setup In order to record the zebra finches' behaviors as they were being exposed to the noise disturbance treatments, cameras with audio and black

and white video were attached to tripods, at a similar height to each other and one to a room. Audio-visual input cables were connected to VCRs located outside of the experimental rooms, that were set to record the 20 minutes immediately before and the first 20 minutes of the treatments. After being set up and focused, the cameras and tripods were not moved for the remainder of the experiment. Although the audio captured the vocalizations of the colony as a whole, the video itself focused on one cage per video. To cover all cages equally, the cages were rotated into position in front of the camera well before each cage was recorded on a schedule. Each pair was videotaped three times, on the third, eighth and fifteenth days of noise treatment exposure for each pair. This was done with the intent of testing for differences in behaviors on an individual/ pair-wise level as a response to treatment type, and so standardize days of exposure to the treatment types for each set (1, 2 and 3) of videos. Because the original goal of my experiment was to also measure potential changes in the synchrony of nest building and egg laying dates between the three treatment types, the introduction dates of pairs into the colonies were staggered. However this may have had an adverse effect on the first round of video and audio recordings. Because the whole colony had not yet been introduced for five out of the six first videos of each pair of birds, there may have been a difference in the patterns and frequency of vocalizations of the birds as a result of varying numbers in the colony. This could have affected my results, and thus I did not use the first set of videos to test my hypotheses.

Goals and Experimental Hypotheses Initially I had wanted to look at the responses of undirected song with respect to treatment at the level of individual males, as well as counting out instances of a few of the various types of colony-wide contact calls

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specifically with respect to treatment. However, during the data analysis, I found that there was really no good way to separate out male undirected and directed song and the many different types of contact calls that both sexes routinely make, as most of the time vocalizations overlapped too intensely. Additionally, because zebra finches are such social animals, and because undirected song often serves a territorial purpose, the frequency and timing of an individual male's song might not be completely independent from those of other singing males in the colony, and thus pseudoreplication might be a real issue.

Instead, I observed vocal responses to treatment type on a colony-wide basis. I believe that this measure is reasonable because zebra finches, as a social colony-breeder, utilize many of the various types of contact calls and undirected song to communicate with other colony members, and thus this method would help to measure attempts at communication between members of the colony, who each could not see any member of the colony other than their own mates.

I selected my two main experimental hypotheses in order to help determine if there were any differences in how the zebra finches were vocalizing on a colony-wide scale among treatment types. The first hypothesis deals with whether or not there is any difference between treatments in the average time in seconds it takes before the start of the first colony-wide vocalization bout in the minute immediately following the cessation of a white noise disturbance block. I measured this because I predicted that, if the unpredictable treatment was truly less predictable than the predictable treatment type, there might be a significantly longer length of silence before the first colony-wide vocal bout. This might be a difference caused by the zebra finches being able to anticipate the

end of a white noise block in the predictable treatment, in which case they might exhibit an earlier first colony-wide vocal bout.

The second hypothesis addresses any potential changes in the mean total duration of all colony-wide vocalization bouts that occurred in the minute immediately following the end of a white noise disturbance block with respect to treatment. In other words, I wanted to know whether they were spending time vocalizing for a greater or lesser proportion of the sample minute depending on treatment. If, again, the unpredictable treatment was truly less predictable than the predictable treatment type, the zebra finches might vocalize more, in an attempt to communicate as much as possible with other colony members before the onset of the next noise disturbance block that they were unable to anticipate.

Criteria for counting colony-wide vocal bouts Because I could not count bouts of vocalizations accurately from listening to the videos alone, I created spectrograms from the separated audio in a digital audio editor called Audacity® (fig. 1). From these audio files I collected information that addressed two hypotheses pertaining to the relative initiation and duration of colony-wide vocalizations in response to noise disturbance treatment.
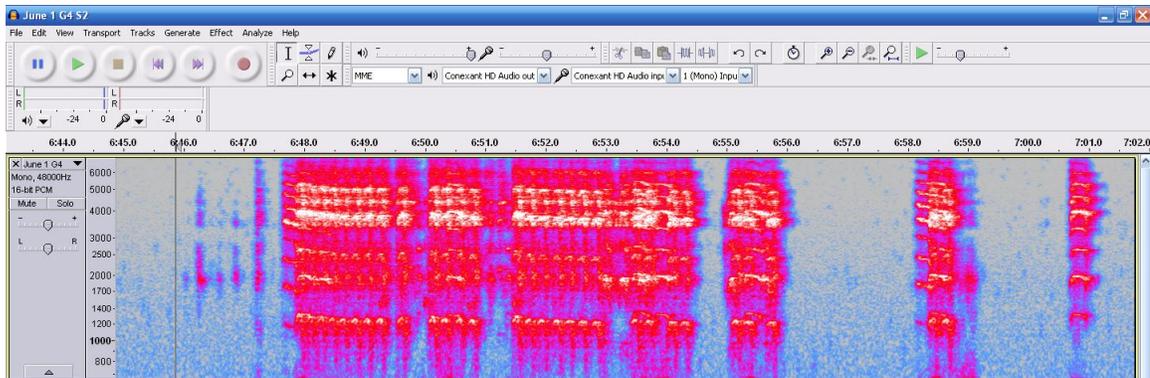
Figure 1. An example of the spectrogram created in Audacity® (©1999-2012 Audacity Team) from the original video recordings. On the horizontal axis is time in seconds, and on the vertical axis is the frequency in Hertz.

Because I was trying to discover whether there were differences in duration and patterning of response in the advent of a block of silence immediately following a noise disturbance block, I focused specifically on counting vocalization bouts in the minute immediately after a noise disturbance block ended (see figure 2). As often as possible, four counts were collected pertaining to each hypothesis per video. In other words, I collected data in the minute immediately following the cessation of four separate white noise disturbance blocks. I tried to make sure that the minutes from which data were gathered were as temporally close across treatments as possible. Even though I could not always match them exactly, the fact that all four sample minutes were taken during the same 15 minute block of time each day means that any potential time effect was kept to a minimum. These minutes became available for sampling after each colony had been exposed to the first four minutes of treatment for the day, to allow the finches to calm down from any potential non-experimental source of disturbance during the couple times when I had to enter the room to manually start the treatment, and also to allow exposure to a couple of noise blocks to occur before measurement of response began.

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Minutes sampled in control treatments obviously did not immediately follow a white-noise block, but were useful precisely because they did not. This way I could see if there was a significant difference not only between the predictable and unpredictable treatments, but whether or not there was a difference between instances of colony-wide vocalization bouts in the two types of treatment rooms from the way they would "naturally" vocalize without exposure to these treatments. Because the predictable and unpredictable minutes could not be exactly the same, control values were obtained from minutes that were as close to the unpredictable and predictable treatment sampling minutes as possible.
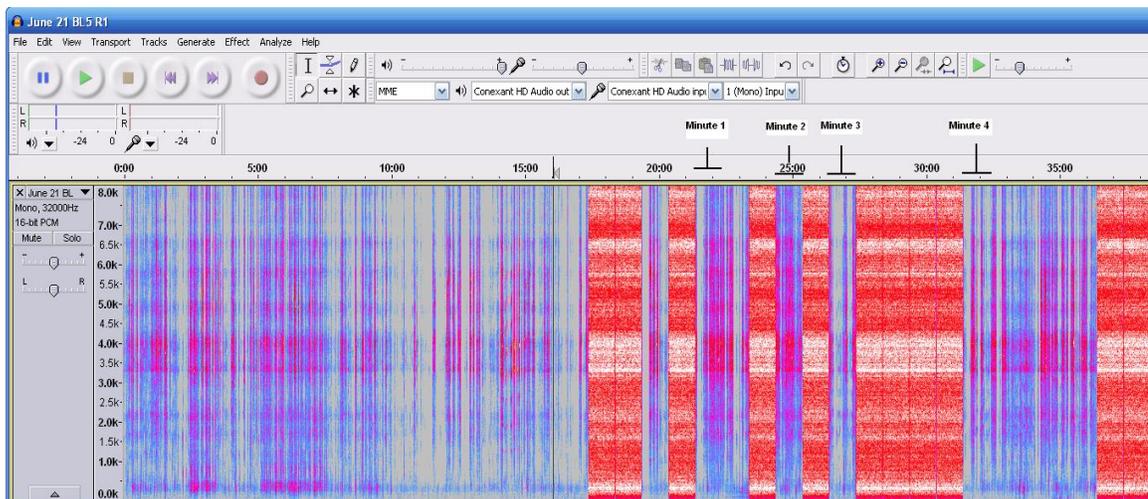
Figure 2. Visual of how the four sampling minutes were selected, again from Audacity ®. Pictured is the spectrogram data for the unpredictable treatment room 1, taken on June 21st, 2011. The red vertically-oriented rectangles in the second half of the spectrogram are the 1-minute white noise disturbance blocks, and the black lines on the horizontal axis depict an example of the minutes from which the vocalization data were gathered.

During the minutes that were sampled, I established the following criteria that had to be met before a set of vocalizations would be counted as a "colony-wide vocalization bout" (defined for this experiment of a string of vocalizations between all the birds in a study room). First, clusters of the louder categories of calls and song were counted as one

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colony-wide vocal bout only if they were longer than one second in duration. The designation as one bout continued until one full second of silence had passed between calls, and from this the bout duration was counted, to the nearest half second. There is some precedence for using this method (Johnson et al., 2002). When appropriate (Hypothesis 1), the number of seconds into the observation minute when the bout began was recorded, also to the nearest half second. Second, I selected what specific kinds of vocalizations would be counted. Individual tet calls were not counted: they were too quiet to show up consistently between videos, as well as equally for all members of the entire colony, especially for members whose cages were positioned farthest away from the video system. Individual stack, distance, and other calls were also not counted, because they did not qualify as a string of calls. However, stack calls numbering more than three that lasted for the duration of a second were counted, and continued to be counted as long as they fell within this criterion. Distance calls, given their nature in keeping track of visually isolated members of the colony (Menardy et al., 2012; Zann, 1996), were counted where they occurred in numbers of two or more.

Statistical Analyses Both of my hypotheses were analyzed using the Kruskal-Wallis test. This test was used because the Kruskal-Wallis test is one of the best ways of comparing data across multiple treatments when it is likely that the data do not follow a normal distribution, and are unlikely to be improved through transformation. In this case, because each room was looked at as a colony my maximum sample size per treatment could only be two, which is too low to assume a normal distribution.

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RESULTS

Hypothesis One. To determine if there was a statistically significant difference among the treatments in the length of time in seconds between the end of a noise disturbance block and the initiation of a first colony-wide vocal bout, I used a Kruskal-Wallis test, with the calculations involved shown below in Table 1. The first row is the treatment type, and the second and third rows are the means of each of the two rooms exposed to that treatment, and their corresponding standard deviations. Means could have ranged from 0 seconds (no time between end of disturbance treatment and start of vocalization) to 59 seconds (Did not begin a colony-wide vocal bout until the last second of the sample minute). The final three rows show the calculations involved in the Kruskal-Wallis test. To compare among multiple treatments with data that do not follow a normal distribution, Kruskal-Wallis tests assign a "rank" to each mean, with the lowest rank (1) corresponding to the mean with the lowest value, and so on. These ranks are then added together for each treatment and divided by the number of samples in the treatment, to create values that are then used to calculate the test statistic. Row four is the within-group sample size (   ),   in row five is the sum of the ranks generated from the means in each treatment, and   in row six is the mean created from dividing the summed ranks by n.   was set at 0.10, N was 6 and k (number of treatments) was 3.

Table 1. Mean times in seconds between the end of a noise disturbance block and the initiation of the first colony-wide vocal bout for each treatment, and the calculations used in the Kruskal-Wallis test of Hypothesis One.

Control	Predictable	Unpredictable
0.9 +/- 2.0	3.6 +/-10.1	2.7 +/- 7.0
5.4 +/- 8.4	4.8 +/-10.0	5.2 +/- 8.1
= 2	= 2	= 2
= 7	= 7	= 7
= 3.5	= 3.5	= 3.5

The test statistic (H) was 0. With an alpha level of 0.10 and k=3, the critical value was 4.571. The significantly lower value of H (as low as it is possible to be for this test) in relation to the critical value means that there was no significant effect of treatment on start time of the first colony-wide vocal bout was found between the treatments.

Hypothesis Two. To determine if there was a statistically significant difference among the treatments in the means of the total duration (in seconds) of all colony-wide vocal bouts observed in the 60 seconds immediately following a noise disturbance block, I used a second Kruskal-Wallis test, with the calculations involved shown below in Table 2. Again, the first row is the treatment type, and the second and third rows are the means of each of the two rooms exposed to that treatment, and their corresponding standard deviations. Total duration values ranged from 0 to 60 seconds. The final three rows show the calculations involved in the Kruskal-Wallis test. Row four is the within-group sample size ( ),   in row five is the sum of the ranks generated from the means in each treatment, and   in row six is the mean created from dividing the summed ranks by n. was set at 0.10, N was 6 and k (number of treatments) was 3.

Table 2. Means of total duration in seconds of all colony-wide vocal bouts observed in the minute immediately following a noise disturbance block for each treatment, and the calculations used in the Kruskal-Wallis test of Hypothesis Two.

Control	Predictable	Unpredictable
35.3 +/- 19.6	37.9 +/-15.8	32.8 +/-15.8
28.8 +/- 15.5	25.8 +/-15.7	27.0 +/-13.7
= 2	= 2	= 2
= 8	= 7	= 6
= 4.0	= 3.5	= 3.0

The test statistic (H) was 0.857. With an alpha level of 0.10 and k=3, the critical value was 4.571. The lower value of H in relation to the critical value means that there was no significant effect of treatment on duration of colony-wide vocal bouts.

DISCUSSION

The results revealed no significant differences in mean time in seconds to first colony-wide vocal bout following a white noise disturbance block between any of the treatments. Vocalizations began not only just as quickly after the end of a noise disturbance block between the predictable and unpredictable treatments, but also began just as quickly as the control treatment that did not include white noise disturbance blocks. The results also revealed no significant difference in mean total duration (in seconds) of all colony-wide vocal bouts observed in the 60 seconds immediately following a noise disturbance block between any of the treatments. This suggests that the disturbance treatments may have not have meaningfully affected their vocalizations as they were assessed in this experiment.

There could be a number of biological reasons for this. Because zebra finches are a colonially-breeding species, it could be that in the wild they already experience high

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levels of potentially unpredictable noise generated by the birds themselves. Additionally, while a large part of the zebra finch's range is located in the still relatively wild interior of Australia, where their range does overlap with higher human population levels they have proven to be adaptable to the point of "…breeding in dense shrubs planted in traffic islands…" (Zann, 1996).

However, because the sample size for each treatment was only 2, the power of the test was low, and thus it is not possible to say that zebra finches without doubt do not respond differently depending on the predictability of the disturbance. Increasing the sample size for each treatment would be the obvious answer, but given the work load associated with taking care of the eighty finches necessary for the experimental design I had, establishing a greater number of colonies with a similar number of finches per colony and obtaining more study rooms would not have been possible.

A number of other factors could also have contributed to the observed results. For instance, concerning the first hypothesis, the zebra finches vocalized frequently with averages of the total time spent in colony-wide vocalization bouts for every room ranging between 25.8-37.9 seconds out of the 60 seconds available to them during the sampling minutes. Given the amount of time spent vocalizing regardless of treatment, vocalizations may have been too frequent of an occurrence for changes in timing to be a meaningful strategy for coping with masking noise.

Additionally, the video data revealed that vocal bouts (although seemingly much less frequent) did not stop entirely during the white noise disturbance blocks. If the zebra finches were still communicating during the disturbance blocks it would have made measures of a first vocal bout after the end of a disturbance block less useful as a study

measure, because that measurement was based on the assumption that it was the finch's first chance to communicate effectively after at least one minute of being unable to do so. However it is impossible to say whether or not the occasional vocalizations that were observed during the noise disturbance could be considered effective. Counting or getting an accurate measure of these vocalizations was not an option even with noise removal software, with the majority of the finch vocalizations being removed along with the white noise, and so these vocalizations could represent unsuccessful attempts to communicate during the noise disturbance, or they could represent a failure of the noise disturbance to effectively mask their vocalizations.

Another potential influence on the results could have been that there actually was a difference in patterning, initiation or time spent vocalizing as a result of treatment type, but because I did not separately compare data from the beginning and end of the experiment, adjustments in calling or singing behavior could have hidden any initial differences in response. There may also have been a significant difference at a different time scale; for instance if I had selected sample minutes throughout the whole three hours of the daily disturbance treatment instead of only during the very beginning of the disturbance treatment.

Furthermore, there are many different types of contact calls that can vary in amplitude, frequency (of initiation in addition to pitch), duration, and purpose. Even more complex is the fact that the same call can serve different purposes at different times, or depend on context and gender as with distance calls (Zann, 1996). Therefore, the situational and between-sex variability in calling pattern and frequency could have been a significant confounding variable.

It is possible that the finches may respond differently to noise disturbance depending on the type of call or song in terms of volume and frequency, and they may also respond differently to changes in predictability depending on the type of vocalization. Slightly different adjustments in patterns of vocalization depending on predictability of noise disturbance of one type of call could have been hidden by grouping the vocalizations together.

It is also possible that individuals from wild populations of zebra finches would react differently in response to the relative predictability of anthropogenic noise disturbances than the domesticated finches did to the experimental treatments to which they were exposed. Not only are there different environmental variables, but using a domesticated population might yield different responses from a wild population, because some changes in behavior and genetics have occurred with domestication (Griffith & Buchanan, 2010; Forstmeier et al., 2007), although Tschirren et al. (2009) state that differences in response between wild and domesticated populations vary in significance depending on the research question being addressed. However in a field setting the effects of various aspects of noise disturbance are often hard to study, because it is difficult or impossible to control for other factors that may be affecting behaviors. Laboratory studies help reduce these confounding variables, although it does not eliminate them. It is important to keep this in mind when making conclusions about the results.

CONCLUSION

The results indicate that the predictability of the noise disturbance does not have a significant effect on initiation or duration of colony-wide vocal bouts after the end of a noise disturbance block. For a species that vocalizes as frequently as the zebra finch, the relative predictability of the noise disturbance may not 'matter' enough for such a change in behavior to confer any benefit. However the two hypotheses that were tested here were used to address only a small portion of the data that were collected during the actual experiment, and consequently the conclusions drawn here may not be the same as they would be with a more complete picture generated from of all of the data I gathered. Due to the large number of videos taken, counting vocalizations alone represented a significant investment of time, and there was not enough time to analyze the effects of noise disturbance predictability on other behaviors, or on breeding and nesting synchrony.

Although I was not able to test these additional measures of the impact of noise disturbance predictability, I learned a lot through the process of collecting data on and researching how to test these measures, as well as the process of setting up and carrying out an original research project. Knowing what I know now, I might have set up my experiment differently in order to collect data that could have more conclusively answered my research questions. One thing I could have done differently would have been to set up scheduled recordings in an isolated testing chamber divided in half by a partition. One member of a pair would be set on each side of the partition, through which the pair could hear but not see each other, similar to the set-up used in many mate choice studies (Swaddle & Page, 2007). Zebra finches would be pre-exposed and adjusted to

these chambers for a set period of time before starting each trial. Because I was also

collecting data on mating efforts the pairs had to be in the same cage during the

treatments, and thus the implications for some of the types of calls used more specifically

to locate a mate went unaddressed. Not only would this method help me to understand

whether intra-pair communication patterns change as a result of the predictability of noise

disturbance, but the likelihood of being able to count individual vocalizations is much

greater with only two animals calling at a time.

REFERENCES

Amin, N., Grace, J. A., & Theunissen, F. E. (2004). Neural response to bird's own song and tutor song in the zebra finch field l and caudal mesopallium. *Journal of Comparative Physiology A- Neuroethology Sensory Neural and Behavioral Physiology*, *190*(6), 469-489.

Bourgeois, S., Gilot-Fromont, E., Viallefont, A., Boussamba, F., & Deem, S. L. (2009). Influence of artificial lights, logs and erosion on leatherback sea turtle hatchling orientation at pongara national park, gabon. *Biological Conservation*, *142*(1), 85-93.

Brumm, H. (2004). The impact of environmental noise on song amplitude in a territorial bird. *Journal of Animal Ecology*, 73, 434-440.

Brumm, H & H. Slabbekoorn (2005). Acoustic communication in noise. *Advances in the Study of Behavior*, 35, 151-209.

Brumm, H. (2009). Song amplitude and body size in birds. *Behavioral Ecology and Sociobiology*, *63*(8), 1157-1165.

Buchanan, K. L., Griffith, S. C., & Pryke, S. R. (2010). The zebra finch: A synthesis revised. *Emu: Austral Ornithology*, *110*(3), i-ii.

Burley, N. T. (2006). An eye for detail: Selective sexual imprinting in zebra finches. *Evolution, 60*(5), 1076-1085.

Burley, N. T. (1988). Wild zebra finches have band-colour preferences. *Animal Behaviour*, 36, 1235-1237.

Crino, O. L., Van Oorschot, B. K., Johnson, E. E., Malisch, J. L., & Breuner, C. W. (2011). Proximity to a high traffic road: Glucocorticoid and life history consequences for nestling white-crowned sparrows. *General and Comparative Endocrinology*,*173*(2), 323-332.

Forstmeier, W., Segelbacher, G., Mueller, J. C., & Kempanaers, B. (2007). Genetic variation and differentiation in captive and wild zebra finches (*Taeniopygia guttata*). *Molecular Ecology*, *16*(19), 4039-4050.

González-Oreja, J. A., De La Fuente-Diaz-Ordaz, A. A., Hernandez-Santin, L., Bonache-Regidor, C., & Buzo-Franco, D. (2012). Can human disturbance promote nestedness? Songbirds and noise in urban parks as a case study. *Landscape and Urban Planning*, *104*(1), 9-18.

Griffith, S. C., & Buchanan, K. L. (2010). The zebra finch: The ultimate Australian supermodel. *Emu: Austral Ornithology*, *110*(3), v-xii.

Hausmann, A. (1992). Studies of the mass mortality of moths near municipal lights (Lepidoptera, Macroheterocera). *Atalanta*, *23*(3-4), 411-416.

Healy, S. D., Haggis, O., & Clayton, N. S. (2010). Zebra finches and cognition. *Emu: Austral Ornithology*, *110*(3), 242-250.

Johnson, F., Soderstrom, K., & Whitney, O. (2002). Quantifying song bout production during zebra finch sensory-motor learning suggests a sensitive period for vocal practice. *Behavioural Brain Research*,*131*(1-2), 57-65.

Planque, R., & Slabbekoorn, H. (2008). Spectral overlap in songs and temporal avoidance in a peruvian bird assemblage. *Ethology*, *114*(3), 262-271.

Menardy, F., Touiki, K., Dutrieux, G., Bozon, B., Vignal, C., Mathevon, N., & Del

    Negro, C. (2012). Social experience affects neuronal responses to male calls in

    adult female zebra finches. *The European Journal of Neuroscience*, *35*(8), 1322-

    1336.

Monaghan, P., Heidinger, B. J., D'Alba, L., Evans, N. P., & Spencer, K. A. (2012). For

    better or worse: Reduced adult lifespan following early-life stress is transmitted to

    breeding partners. *Proceedings of the Royal Society B-Biological*

    Sciences, *279*(1729), 709-714.

Nottebohm, F., & Arnold, A. P. (1976). Sexual dimorphism in vocal control areas of

    songbird brain. *Science*, *194*(4261), 211-213.

Salvante, K. G., & Williams, T. D. (2003). Effects of corticosterone on the proportion of

    breeding females, reproductive output and yolk precursor levels. *General and*

    Comparative Endocrinology, *130*(3), 205-214.

Slabbekoorn, H., & den Boer-Visser, A. (2006). Cities change the songs of birds. *Current*

    Biology, *16*(23), 2326-2331.

Slabbekoorn, H., & Ripmeester, E. A. P. (2008). Birdsong and anthropogenic noise:

    Implications and applications for conservation. *Molecular Ecology*, *17*(1), 72-83.

Swaddle, J. P., & Page, L. C. (2007). High levels of environmental noise erode pair

    preferences in zebra finches: Implications for noise pollution. *Animal Behaviour*,

    74, 363-368.

Tschirren, B., Rutstein, A. N., Postma, E., Mariette, M., & Griffith, S. C. (2009). Short- and long- term consequences of early developmental conditions: a case study on wild and domesticated zebra finches. *Journal of Evolutionary Biology*, *22*(2), 387-395.

Waas, J. R., Colgan, P. W., & Boag, P. T. (2005). Playback of colony sound alters the breeding schedule and clutch size in zebra finch (*Taeniopygia guttata*) colonies. *Proceedings of the Royal Society B- Biological Sciences*, *272*(1561), 383-388.

Williams, T. D., & Christians, J. K. (2003). Experimental dissociation of the effects of diet, age and breeding experience on primary reproductive effort in zebra finches, *Taeniopygia guttata*. *Journal of Avian Biology*, *34*(4), 379-386.

Zann, R. A. (1996). *The zebra finch: A synthesis of field and laboratory studies*. (pp. 1-300). Oxford, New York: Oxford University Press Inc.

APPENDIX

Prior Approval- Before obtaining the finches and starting the experiment, prior approval of the experimental protocol was obtained on March 18, 2011 from University of Waikato Animal Ethics Committee.

AUTHOR'S BIOGRAPHY

Kathryn Chenard was born in Lebanon, New Hampshire, on April 18th, 1990. She was raised in Sunapee, New Hampshire and Rochester, New York, and graduated from Gates Chili High School in 2008. She has always been fascinated by and enjoyed spending time in the natural world, and majored in Wildlife Ecology with an Individualized Concentration in Animal Behavior at the University of Maine. In particular Kathryn is interested in animal communication and social interactions, and plans to pursue a PhD on the subject. As an undergraduate, Kathryn was active in the University of Maine Student Chapter of the Wildlife Society, including serving one year as its President. She was also a member of the Outing Club, and is a member of Xi Sigma Pi and Phi Beta Kappa. She was also fortunate enough to have had the opportunity to travel extensively during her undergraduate career, taking Tropical Ecology field courses in Peru and in Tanzania, in addition to studying abroad at the University of Waikato in Hamilton, New Zealand, where she carried out the research portion of her Thesis. In her spare time she also paints and creates pen and ink drawings, almost entirely of wildlife.