EFFECTS OF THE LUNAR CYCLE AND WEATHER ON THE BEHAVIOR OF THE FERAL CHICKEN ON MO'OREA

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Abstract. The descendants of Red Junglefowls, *Gallus gallus*, are globally widespread organisms that are abundant on Mo'orea, French Polynesia. It is important to gain a better understanding of chickens, especially their behaviors, due to their close proximity to humans and intense crowing throughout the night. This study focused on the effects of the lunar cycle and weather on the territorial and predawn crowing behaviors of *G. gallus*. The territorial behavior was assessed by studying two factors—how much the chickens responded to the playback under different weather conditions, and how the crows of different roosters differed in terms of rates, duration, and intervals. The predawn crowing behavior was assessed by investigating the differences and relationships in crow counts among the moon phases, rain variables, brightness of the sky, wind velocity, and cloud cover. It was found that *G. gallus* response rate was significantly different between rain variables and between wind velocity variables, but not between cloud variables. There was no significant difference in crow rates, duration, and intervals among different rooster groups. I also found a significant difference in the crow counts among different moon phases and between rain variables. In addition, cloud cover affects the crowing but brightness of the sky and wind velocity do not. These findings imply that *G. gallus* (1) exhibit little territoriality with conspecifics, although there was a weak sign of territoriality under certain weather conditions, and (2) follow a clear crowing pattern under different environmental conditions, crowing more during full moon with lower cloud cover percentage and less during new moon with higher cloud cover percentage.

Key words: chickens; Gallus gallus; *red junglefowls; lunar cycle; weather effects; territorial behavior; crowing behavior; Moorea, French Polynesia*

INTRODUCTION

The origin of domestic chickens has been disputed among scientists for a long time and still remains unresolved. Darwin (1868) first suggested that all species of domestic chickens are direct descendants of Red Junglefowls (*Gallus gallus*) commonly found in Southeast Asia. The earliest archeological remains of chicken bones dating back 10,000 years were excavated in northern China (Xiang et al. 2014). The earliest evidence of domestication of chickens found in the Indus Valley suggests that domestication started 8,000 years ago (Sawai et al. 2010). These chickens subsequently spread to the Near East and Europe 5,000 and 2,000 years ago, respectively (Perry-Gal et al. 2015). While some scientists found that a single domestication occurred in the Indus Valley and then the chickens were diffused throughout the world (Zeuner 1963, Carter 1971, Thesing 1977, Fumihito et al. 1996), other scientists have challenged this idea and instead suggest that an independent domestication occurred in multiple regions after the chickens reached their new destinations (West and Zhou 1988, Crawford 1990, Moiseyeva 1998, Liu et al. 2006). For a long time, the chickens have been valuable and multipurpose resource for humans. Human's familiarity with the chickens over the millennia has contributed better cuisine, science, and art. However, this familiarity has also led to unawareness of all the benefits chickens bring to the world and the chickens have received little attention in the scientific community.

Chickens were first introduced to French Polynesia by Polynesians on their ocean-going canoes from Southeast Asia—where Red Junglefowls, the ancestor of modern chickens on Mo'orea, originate—via Fiji, Samoa, and Tonga (Halloran and Halloran 1970). The chickens, called *moas* by Tahitians, are ubiquitous on Mo'orea and now a natural part of the ecosystem (Appendix B). Once domesticated chickens escaped human captivity and went feral to expand their territories into the higher regions of the islands and form a large population (Halloran and Halloran 1970). Taxonomically, the chickens on Mo'orea and the Red Junglefowls are the same species, *Gallus gallus* (Dawkins 1989). However, these chickens are now distantly related to the Red Junglefowls due to constant interbreeding between domestic and feral chickens (Halloran and Halloran 1970). With no known natural predators and competitors on Mo'orea, the chickens thrive as generalists and forage food resources successfully (Klasing 2005).

Gallus gallus is a crepuscular species, meaning that it is active at dawn and dusk and inactive between those periods (Collias and Collias 1967). In many cultures, a rooster is a symbol of the break of dawn (Ito et al. 2017). There are two possible reasons many domesticated roosters crow intensely at dawn. First, in response to other roosters to reinforce their dominance and protect their territories (Collias and Collias 1967) and second, in response to their circadian clock. Due to their resemblance to modern gamecocks, it is believed that the chickens on Mo'orea were brought for cockfighting rather than for consumption (Ball 1933). Male gamecocks, known for their aggressiveness, are known to be territorial (Fennell 1945), but it is unknown whether the roosters on Mo'orea behave similarly and crow as a sign of warning (Salomon 1966). Moreover, Shimmura and Yoshimura (2013) discovered that predawn crowing is a result of circadian clock that tells the roosters when to crow regardless of external stimuli. Many studies have explored the involvement of circadian clock in predawn crowing of domestic roosters and suggest that the roosters do in fact exhibit circadian rhythms (Shimmura et al. 2015). Nonetheless, the roosters on Mo'orea crow throughout the day and night at seemingly random times; thus, it is not clear whether the circadian clock is the main contributor to their predawn crowing.

The purpose of this paper is twofold, all under different environmental conditions: firstly, to evaluate the rooster's territorial behavior by quantifying the individual variation in the call sequences of roosters; secondly, to analyze the predawn crowing behavior. I will investigate how different external conditions—lunar cycle and weather—affect the territorial and predawn crowing behavior of the feral chickens on Mo'orea.

METHODS

Study site

This study took place on the island of Mo'orea, French Polynesia. The primary study site was on the UC Gump Research Station, including observations from the balcony of Totara and Nohu bungalows (17º49'S, 149º83'W) (Fig. 1).

Study organisms

Commonly seen and heard, *Gallus gallus* is an abundant species with a significantly small biomass per individual on Mo'orea. Red Junglefowls are social birds and the flock structure usually contains one rooster and multiple hens, occupying a regular home range (McBride et al. 1969). They also eat a ton of insects and control invertebrate populations (Savory 1978).

A group of nine *G. gallus* individuals—three roosters, five hens, and one chick—that reside in the woods behind the bungalows was the test subject for the playback experiment under territorial behavior studies described below. All *G. gallus* heard from the balcony of Totara and Nohu bungalows were recorded and analyzed as part of the territorial behavior and predawn crowing behavior studies (also described below).

Territorial behavior

I collected data on territorial behavior of *G. gallus* from October 21 to November 7 to study their territorial behavior. There were two components to this study: the playback experiment and analysis of the rates, duration, and intervals of crowing.

Playback experiment.—To observe the effects of weather on the territorial behavior of *G. gallus* on Mo'orea, I used a playback of *G. gallus* crowing recorded from Southeast Asia found on YouTube. Since *G. gallus* are naturally territorial and crow as a warning signal to other roosters (Collias and Collias 1967), how the test subjects react to the playback will assess their territoriality. This experiment was conducted for the two-hour period spanning sunrise (Kimball 1949). The playback was repeated ten times during this period, and any kind of response or interest from the group of *G. gallus* was marked to calculate the response rate. This experiment was repeated under different weather conditions, e.g., cloud cover (> or ≤50%), wind velocity (> or ≤29km/h), and precipitation (rain or no rain), to explore the influences of those factors on the response rate. In order to determine how much each weather variable—cloud cover, wind velocity, and rain—affected the response rate or the territorial behavior of *G. gallus*, I used the χ^2 goodness of fit test to compare the differences within each weather variable.

Rates, duration, and intervals of crowing.—Rates, duration, and intervals of crowing were recorded to quantify the territorial behavior. Since male *G. gallus* crow to show dominance, the rate determines whether they do crow in response to other roosters and whether hierarchy exists within the group (Collias and Collias 1967). Dominant roosters crow more frequently and longer than the subsequent roosters (Leonard and Horn 1994). Therefore, differences in all three mean that hierarchy exists and they are indeed territorial. All crows of *G. gallus* heard from the observation site were recorded for the two-hour period spanning sunrise (Kimball 1949). Crows were distinguished, categorized, and identified as Rooster 1, Rooster 2, Rooster 3, and Rooster 4. Rooster 1, Rooster 2, and Rooster 3 are distinct calls that were easily identifiable in terms of directions each call originated from (Fig. 1). Rooster 4 includes the faint and distant crows coming from all directions, and potentially represents multiple individuals. The crow rates, duration, and intervals were analyzed using a sound analysis software RavenLite (Bioacoustics Research Program 2014). To test the differences in the crow rates of various rooster groups, I used the χ^2 goodness of fit test for each twenty-minute time slice. Then, I used the Kruskal-Wallis test to determine significant differences in the mean number of crows, duration, and intervals among the rooster groups.

Predawn crowing behavior

The effects of the lunar cycle and weather on the predawn crowing behavior of *G. gallus* were observed from October 7 to November 7 to complete one full lunar cycle. Moon phase, brightness of the sky, wind velocity, cloud cover, and precipitation were recorded at the start of the observation and every thirty minutes until sunrise, with an additional hour after sunrise. The observation began when the first crow broke the dormancy. The brightness of the sky was recorded at the start, and the total crow counts through the end of the experiment were counted. This data was used to test whether or not the lunar cycle and

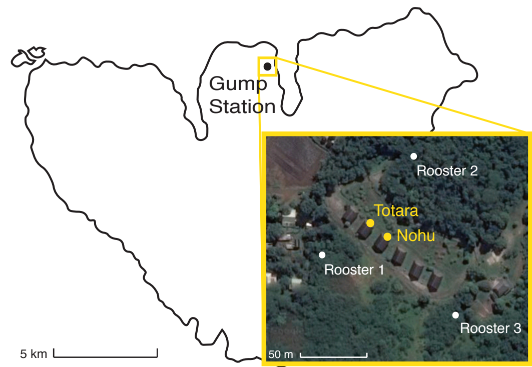

FIG. 1. Map of Mo'orea, French Polynesia. The Gump Station is located on the northwest area of the Cook's Bay, indicated by a black dot. Totara and Nohu bungalows are indicated by yellow dots on the inset image. Approximate distance and direction of Rooster 1, Rooster 2, and Rooster 3 are indicated by white dots on the inset image.

different weather conditions affected the predawn crowing behavior of *G. gallus*.

Lunar cycle.—Four days of data were gathered per moon phase to observe whether the crowing behavior is different during each moon phase. The data was not collected if there was rain or the wind velocity was over 25 km/h (Kimball 1949). For each thirty-minute time slice, the crows were counted, and the average in each time slice over four days of one moon phase was calculated. The brightness of the sky, which is a cloud-modulated version of the lunar cycle (Zou et al. 2010), was also evaluated using a phone app called Dark Sky Meter. This app measures the brightness of a specific location in terms of the Bortle scale (Bortle 2001, Table 1). In order to assess how much differences there are among the moon phases, I used the χ^2 goodness of fit test for each thirty-minute time slice. A total of fourteen χ^2 tests were performed. The relationship between the crow counts and brightness of the sky was determined using a simple linear regression analysis.

Weather.—I used a wind meter to measure the wind velocity and data from windy.com, a weather forecast that gives information of a specific location at a specific time, to find the cloud cover percentage. For precipitation, I recorded a binary response of yes (raining) or

TABLE 1. The Bortle Scale measures the brightness of the night sky of a specific location in SQM. SQM = Sky Quality Meters in mag/arcsec^2.

Class	Title	Approx. SQM	Description
1	Excellent dark sky	21.7-22.0	Zodiacal light and band, milky way, gegenschein visible
2	Typical truly dark	21.5-21.7	Surroundings not visible
3	Rural sky	21.3-21.5	Surroundings slightly visible
4	Rural/suburban transition	20.4-21.3	Surroundings clearly visible
5	Suburban sky	19.1-20.4	Weak milky way, light pollution
6	Bright suburban sky	18.0-19.1	Zodiacal light invisible
7	Suburban/urban transition	18.0-19.1	Milky way invisible
8	City sky	<18.0	Sky is light grey
9	Inner-city sky	<18.0	Sky is very lit

no (not raining) based on my own observations. The average number of crows in a thirty-minute time slice of the same weather variable was calculated. The relationship between the crow counts and wind velocity was analyzed using a simple linear regression analysis for each time slice. Similarly, the same test was used to identify any relationships occurring between crow counts and cloud cover for each time slice. A significant difference between the presence and absence of rain was determined using a χ^2 goodness of fit test for each time slice.

Statistical analyses

Since I treated multiple individual that are not independent of one another as replicates, my results may be weaker. All statistical analyses for χ^2 goodness of fit test were done in Microsoft Excel. Linear regressions and the Kruskal-Wallis tests were done using the software PAST (Hammer et al. 2001).

RESULTS

Territorial behavior

Rain and cloud cover significantly affected the response rates of *G. gallus* for the playback experiment, while the cloud cover did not (Table 1; Appendix A, Fig. 2). For rain and wind velocity, the response rates differed significantly between rain and no rain (χ^2=6.76, $p<0.05$) and between wind velocity >29km/h and wind velocity ≤29km/h (χ^2=4.74, $p<0.05$), respectively. For cloud cover, there was no significant difference between cloud cover >50% and cloud cover ≤50% (χ^2=0.19, $p>0.05$).

While the playback experiment showed the influence of weather on the territorial behavior, there was no significant difference in the crow rates among Rooster 1, Rooster 2, Rooster 3, and Rooster 4 in all the twenty-minute time slices, from -60 to 60 minutes from sunrise (Table 2; Appendix A, Fig. 3). Moreover, there was no significant difference in the mean number of crows between Rooster 1, Rooster 2, Rooster 3, and Rooster 4 ($p>0.05$), as well as the difference between the mean call durations given by the roosters ($p>0.05$). Again, there was no significant difference between the mean intervals between crows given by Rooster 1, Rooster 2, Rooster 3, and Rooster 4 ($p>0.05$). The spectrogram (Fig. 1; Appendix A) produced from RavenLite visualizes the crows of Rooster 1, Rooster 2, and Rooster 3 in a waveform.

Predawn crowing behavior

The lunar cycle had a strong effect on the predawn crowing behavior of *G. gallus*. Crow counts during different moon phases in all the time slices, except at 90, 150, 210, and 360 minutes from midnight, differed significantly ($p<0.05$, Table 3; Appendix A). At peak crowing time, four to five hours after midnight, crow counts were highest during full moon, lower during first and third quarter, and lowest during new moon (Fig. 4).

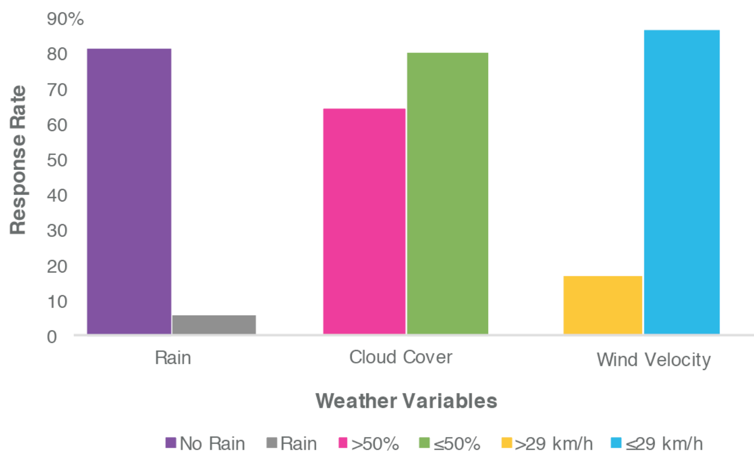

FIG. 2. A summary of the response rates of *G. gallus* under different weather variables. Significant differences were found between rain and no rain and between wind velocity >29km/h and ≤29km/h. No significant differences were found between cloud cover >50% and ≤50%.

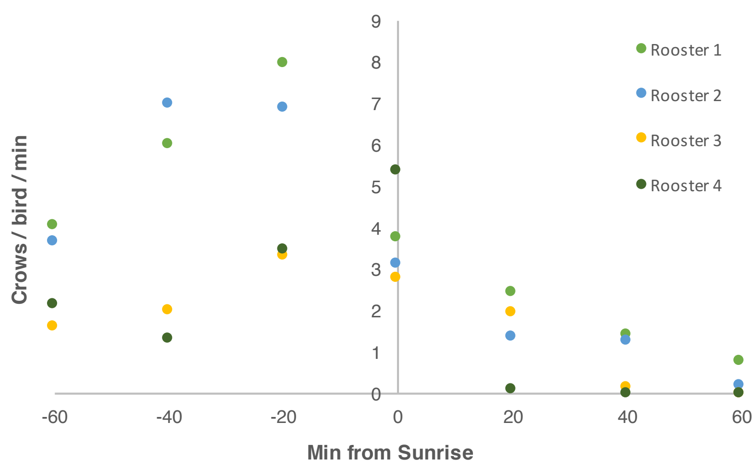

FIG. 3. Crow rates of Rooster 1, Rooster 2, Rooster 3, and Rooster 4. Dots represent means (15 days of observations) of crow rates for each rooster individual. Sunrise is 0 on the x-axis.

The total number of crows counted was negatively correlated with the brightness of the night sky, recorded at the start of the observation (Fig. 5), but this relationship was not significant in a linear regression ($p=0.06935$, $r^2=0.216$). Similarly, the total number of crows counted in each time slice was also negatively correlated with wind velocity (Fig. 6) without a significance in a linear regression (Table 4; Appendix A). The results concluded that 60, 240, and 360 minutes from midnight were the only time slices that showed that the relationships were significant in a linear regression ($r^2=0.273$, $p<0.05$; $r^2=0.269$, $p<0.05$; $r^2=0.34455$, $p<0.05$; respectively). All other time slices showed no significant relationship between the number of crows and wind velocity (Table 4; Appendix A). On the other hand, the relationships between the number of crows and cloud cover percentage in each thirty-minute time slice,

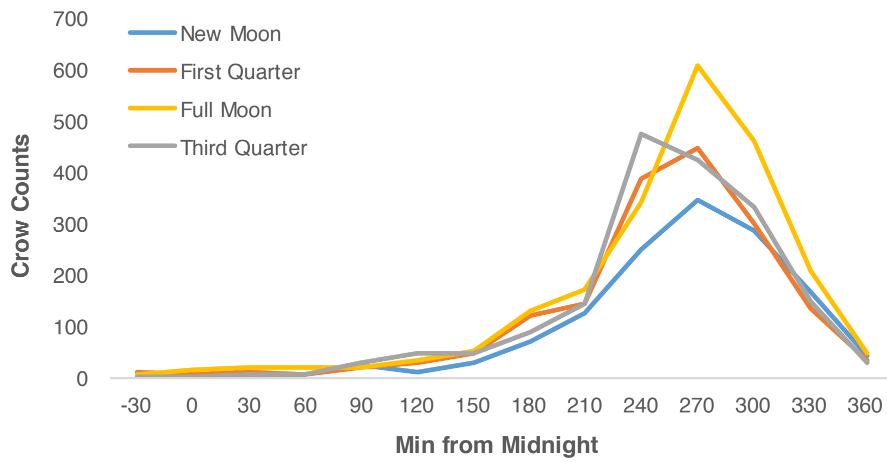

FIG. 4. Lunar trends of predawn crowing of roosters on Mo'orea. Most crowing was done during the full moon, followed by the third quarter, first quarter, then the new moon.

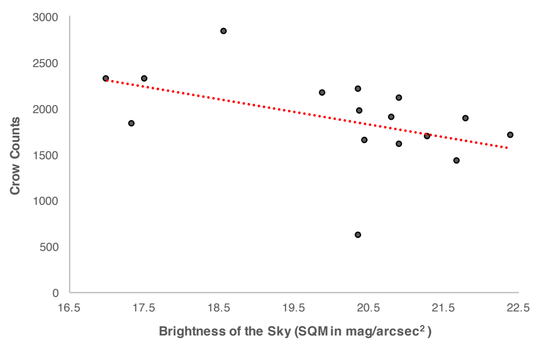

FIG. 5. Correlation between the crow counts and brightness of the sky. Y-axis is the total number of crows throughout the night. Smaller SQM indicates a brighter night sky.

between 150 and 360 minutes from midnight, were significant in a linear regression (Fig. 7, Table 5; Appendix A). The correlation between the crow counts and cloud cover in the time slices before 150 minutes from midnight was not significant in a linear regression (Table 5; Appendix A). It is important to note that *G. gallus* crowed more between 4 to 5 hours after midnight regardless of wind velocity and cloud cover.

Finally, there was a significant difference in the crow counts between rain and no rain (Fig. 8). Under rain, the crow count was always 0, while under no rain, the crow counts varied in different time slices.

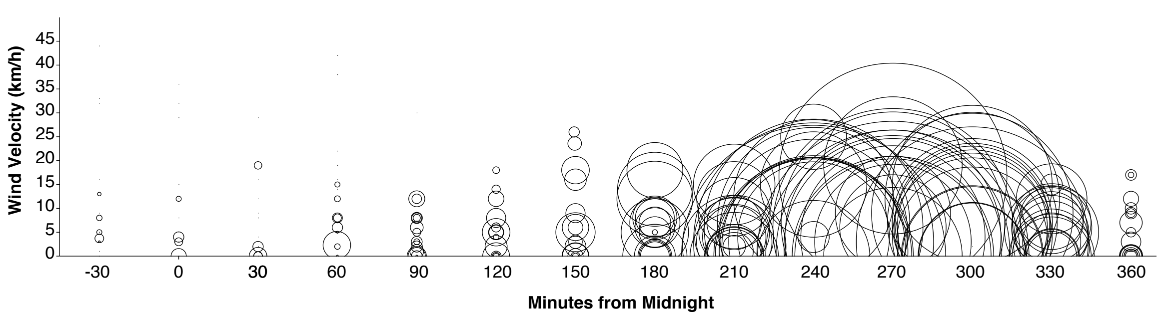

FIG. 6. Bubble chart depicting the relationship between the crow counts and wind velocity. Larger bubbles indicate higher crow counts. Wind velocity is not the only factor that affects the crowing. *G. gallus* crowed more between 4-5 hours regardless of wind velocity.

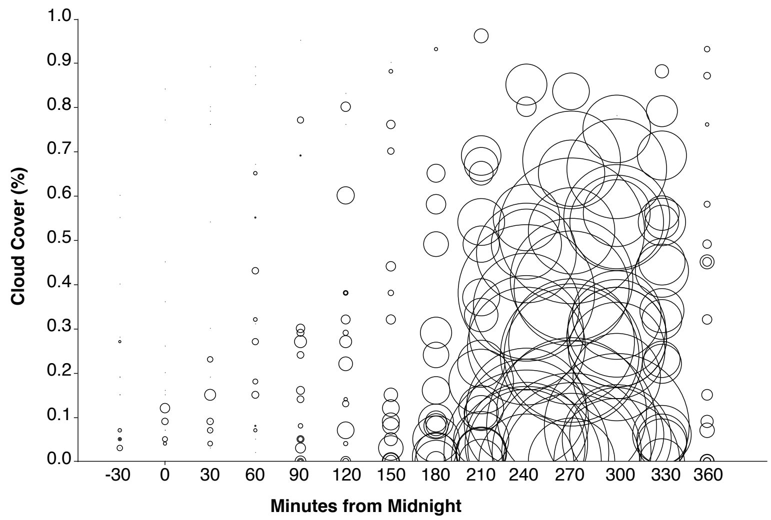

FIG. 7. Bubble chart depicting the relationship between the crow counts and cloud cover. Larger bubbles indicate higher crow counts. Cloud cover is not the only factor that affects the crowing. *G. gallus* crowed more between 4-5 hours regardless of cloud cover. In general, lower cloud cover percentages resulted in more crowing.

DISCUSSION

When the group of nine *G. gallus* was exposed to the playback of another rooster's crow, the response rate was higher when there was no rain and wind velocity was lower. Cloud cover, on the other hand, did not influence the response rates of *G. gallus*. Since roosters react to another rooster's crow as a territorial signal (Leonard and Horn 1994), *G. gallus* exhibited more territoriality when there was no rain and wind velocity was lower. This is consistent with past studies that have focused on relationships between different environmental conditions and the playback response rates of spittle owls, which are in the class Aves, same as *G. gallus* (Carpenter 1987, Ganey 1990, Clark and Anderson 1997). During the playback, the most common behavior of *G. gallus* was walking towards the source of the playback, followed by crowing back to the playback. Only one out of three roosters crowed back. In fact, Leonard and Horn (1995) found that it is always the dominant male rooster that crows back to another group's dominant male rooster. This suggests that some social hierarchy exists in the group of *G. gallus,* as it was always the same rooster that responded to the playback.

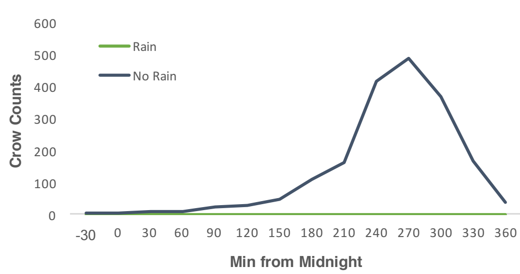

FIG. 8. The effect of rain on the crow counts. Rain resulted in 0 crow.

Meanwhile, a lack of significant difference in crow rates, duration, and intervals among the roosters signifies that they show little territoriality with conspecifics, compared to traditional gamecocks (Ball 1933). Since social dominance is important in the *G. gallus* community, louder, longer, and more frequent crows signify a higher-ranking rooster due to a higher testosterone level (Furlow et al. 1998). Although roosters may exhibit more territoriality under certain weather variables, social hierarchy is still an important factor within the same *G. gallus* group.

The crowing pattern of *G. gallus* exhibited a clear trend in a full lunar cycle. Each moon phase induced first crows at different time slices and had significant differences in crow counts among the moon phases. Roosters crowed the most and earliest around 2300 during the full moon as opposed to the least and latest around 0130 during the new moon. The effects of the lunar cycle on *G. gallus* on Mo'orea appears to be evident. The peak crowing activity occurred twenty minutes before sunrise for all moon phases. In contrast, a study conducted by Luukonen (1997) found the peak crowing activity to be right before sunset. Moreover, the lunar cycle plays an important role on many invertebrate and vertebrate species. Lunar cycle not only induces spawning events of many marine organisms (Naylor 2011), but also affects human behavior, psychology, and physiology (Zimecki 2006). In addition, the roosting behavior of the common cranes, which are in the same class Aves as *G. gallus,* is also strongly affected by the lunar cycle, further suggesting that the full moon result in delayed daily activity and roosting time (Alonso et al. 1985).

Although there was a lack of significant correlation between the crow counts and brightness of the sky, this did not mean the brightness of the sky is unimportant. The p-value was still small, and I found that there was a significance for the lunar cycle and cloud cover in my findings, as brightness of the sky is a cloud-modulated version of the lunar cycle (Zou et al. 2010). Shimmura (2013) found that the brightness had a strong effect on the crowing behavior of domesticated chickens. The author used various intensities of artificial light shined at different times and concluded that there is a positive correlation between the crow counts and brightness of the sky. Bright lighting induced earlier and more frequent crowing, which my results do not strongly support. Such differences could be due to different methodologies or to different natural settings.

Significance varied across different weather variables. There seemed to be no significant correlation between the crow counts and wind velocity under 25 km/h. However, wind velocity over 25 km/h resulted in no crowing even during the usual peak crow times. On the other hand, the relationship between the crow counts and cloud cover were strongly correlated, meaning the crow counts depend on the cloud cover. The roosters crowed more when the cloud cover percentage was lower and crowed less when the cloud cover percentage was higher. A study conducted by Luukonen et al. (1997) supports my results, showing that while cloud cover has an effect on the crowing behavior of *G. gallus*, wind velocity has little influences over this behavior.

The lunar cycle had a stronger effect on the crowing behavior over the cloud cover. The roosters still crowed more during the full moon with higher than average cloud cover than during the new moon with lower than average cloud cover. Many past studies have suggested that the circalunar rhythm may play an important role on various behaviors of birds and mammals (Aschoff 1957, Franke 1986, Ostatnikova 2010, Broekhuis et al. 2014). This could explain why the roosters on Mo'orea preferred lunar cycle over cloud cover.

The crowing behavior of *G. gallus* was strongly influenced by rain. There was a significant difference between rain and no rain. No crowing was detected under rain and even light sprinkles. Many authors did not make observations or gather data during windy or rainy mornings because they knew that the roosters do not crow under these conditions, thus provide meaningless analyses (Kimball 1949, Carney and Petrides 1957, Gates 1996, Luukkonen et al. 1997).

Overall, *G. gallus* crowed the most during clam, bright, and clear nights. This pattern was observed in *G. gallus* in Wisconsin (Gates 1996), ring-necked pheasant (McClure 1944), which is in the family Phasianidae, same as *G. gallus*, and spotted and tawny owls (Hansen 1952, Forsman 1983, Ganey 1990), which are in the class Aves. On Mo'orea, the rooster that made the first crow was always the same.

Because my sample size was small and only covered the territory of the Gump Station rather than Mo'orea as a whole, there may be more factors that may have influenced the territorial and predawn crowing behaviors of *G. gallus* on Mo'orea. Moreover, I was not equipped with a professional sound analysis device that records and analyzes crows more accurately than my own judgement. Rain and high wind velocity could also have lowered the volume of the crows that I was unable to account for.

Further studies with a larger sample size that covers more areas may help to clarify my assessments on their territorial and predawn crowing behaviors. Direct experiments that include the handling of *G. gallus* should also be considered to test the effects of different light settings on their crowing behavior and investigate whether the circadian rhythm plays an important role. Relocation of *G. gallus* from the other side of the island to the station can be an interesting experiment to observe territorial behavior influenced by foreign activity. Furthermore, observations of individual variation and territory is easier done in the daytime to inform interpretation of predawn crowing pattern. Following them around during the day to identify different individuals and their crows could be helpful in figuring out who is doing the crowing at dawn and what other environmental patterns may be influencing their crowing pattern.

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APPENDIX A

TABLE 1. Effects of different weather variables on the response rates of *G. gallus* on Mo'orea, French Polyneisa. Significance at the 0.05 alpha level is used.

Weather variables	Factor	Response Rate	df	χ^2 value	p-value
Rain	Rain	5%	1	5.58	<0.05
	No Rain	81%			
Cloud cover	>50%	63%	1	0.19	>0.05
	≤50%	80%			
Wind velocity	>29km/h	17%	1	6.08	<0.05
	≤29km/h	87%			

TABLE 2. Analysis of the crow rates of Rooster 1, Rooster 2, Rooster 3, and Rooster 4.

Minutes from Sunrise	df	χ^2 value	p-value
-60	3	1.44	>0.05
-40	3	5.96	>0.05
-20	3	3.14	>0.05
0	3	1.07	>0.05
20	3	2.11	>0.05
40	3	2.26	>0.05
60	3	1.59	>0.05

TABLE 3. χ^2 values of the time slices to compare the differences in the crow counts among the moon phases. Significance at the 0.5 alpha level is used. (*) denotes a significant relationship determined in a linear regression.

Time	χ^2 value	p-value
-30	*14.80	0.002
0	*36.28	<0.001
30	*22.43	<0.001
60	*16.57	<0.001
90	2.40	0.494
120	*24.23	<0.001
150	7.09	0.069
180	*22.87	<0.001
210	6.72	0.081
240	*71.87	<0.001
270	*77.87	<0.001
300	*55.30	<0.001
330	*19.67	<0.001
360	4.33	0.223

TABLE 4. r^2 values of the time slices between the crow counts and wind velocity. (*) denotes a significant relationship determined in a linear regression.

Time	r^2 value	p-value
-30	0.0185	0.61557
0	0.089	0.26165
30	0.0857	0.27116
60	*0.273	0.0379
90	0.229	0.060929
120	0.00611	0.77349
150	0.0304	0.51805
180	0.215	0.070117
210	0.0815	0.28379
240	*0.269	0.039696
270	0.0771	0.29756
300	0.16371	0.12006
330	0.0989	0.23541
360	*0.345	0.016828

TABLE 5. r^2 values of the time slices between the crow counts and cloud cover. (*) denotes a significant relationship determined in a linear regression.

Time	r^2 value	p-value
-30	0.1537	0.13314
0	0.087942	0.26472
30	0.22028	0.066636
60	0.10877	0.21223
90	*0.27366	0.037584
120	0.054109	0.38596
150	*0.72029	<0.0001
180	*0.48126	0.002876
210	*0.52062	0.001604
240	*0.70601	<0.0001
270	*0.45081	0.0044
300	*0.47715	0.00305
330	*0.39473	0.00916
360	*0.318	0.0229

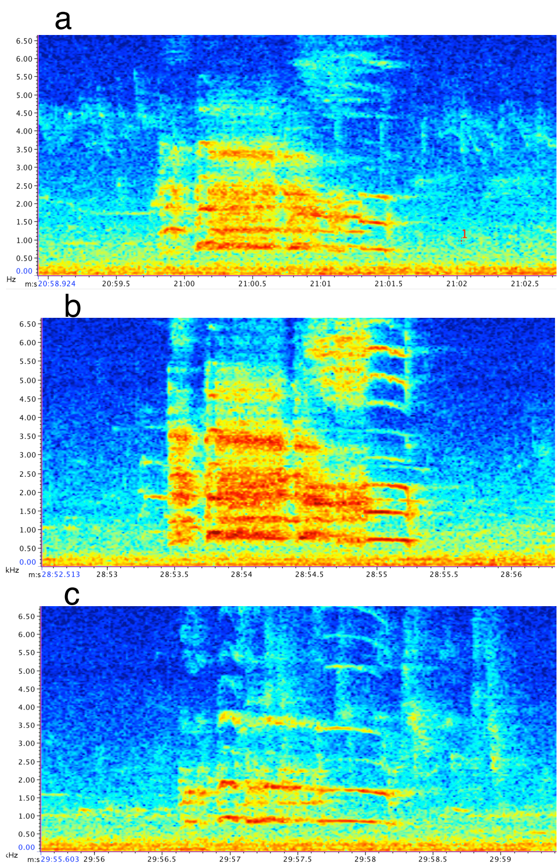

FIG. 1. Spectrogram of one crow of (a) Rooster 1, (b) Rooster 2, and (c) Rooster 3.

APPENDIX B

FIG. 1. A group of *G. gallus* that live near the bungalows.

FIG. 2. A closer look of two male *G. gallus*.