Vocal Communication in Captive Male Zebra Dove (*Geopelia striata* Linn. 1766)

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ชื่อวิทยานิพนธ์ การสื่อสารด้วยเสียงของนกเขาชวา (*Geopelia striata,* Linn. 1766) เพศผู้ในกรงเลี้ยง

ผู้เขียน นางสาวพชรกมล อำนวย

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บทคัดย่อ

การใช้สัญญาณที่สลับซับซ้อนและแสดงพฤติกรรมต่างๆของเพศผู้ในการดึงดูดความสนใจจากเพศเมียพบได้ทั่วไปในนกหลายชนิด นกเขาชวาเพศผู้มักใช้เสียงร้องในการดึงดูดความสนใจจากเพศเมียซึ่งเพื่อการดึงดูดความสนใจจากคู่ผสมพันธุ์ เพศผู้อาจจะแสดงพฤติกรรมที่แตกต่างกันเมื่อเปรียบเทียบระหว่างอยู่ในช่วงก่อนจับคู่กับอยู่ในช่วงจับคู่ การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาเปรียบเทียบโครงสร้างของเสียงร้องของนกเขาชวาเพศผู้ในระหว่างช่วงก่อนจับคู่กับช่วงจับคู่ โดยบันทึกเสียงร้องของนกเขาชวาเพศผู้ ในกรงทดลองกลางแจ้งขนาด 90 X 90 X 120 ซม. ทั้งในช่วงก่อนจับคู่และในช่วงจับคู่ด้วยเทปบันทึกเสียงและบันทึกพฤติกรรมอื่นๆของนกทั้งเพศผู้และเพศเมีย โดยใช้วิธีการ time sampling ทุกๆ 30 วินาที ต่อเนื่องเป็นเวลา 30 นาที

การศึกษาครั้งนี้พบเสียงร้อง 5 รูปแบบ คือ เสียงขันโยน (advertising call) เสียงขันโกรก (settling call) เสียงคู (courtship call) เสียงออด (aggressive call) และเสียงขณะผสมพันธุ์ (copulation call) ซึ่งเสียงขณะผสมพันธุ์พบเฉพาะในช่วงจับคู่เท่านั้น โดยเสียงร้องแบ่งออกเป็น 4 ส่วน คือ พยางค์ต้น (SI) พยางค์กลาง (SM) พยางค์ท้าย (ST) และช่วงระหว่างพยางค์ (P) ได้ทำการเปรียบเทียบโครงสร้างพยางค์ของเสียงร้องระหว่างในช่วงก่อนจับคู่และในช่วงจับคู่ด้วยโปรแกรม Avisoft-SASLAB Pro

พบว่าจำนวนครั้งของการส่งเสียงร้องของเสียงร้อง ความยาวของพยางค์ ความยาวของช่วงระหว่างพยางค์ ความยาวรวมของเสียงร้อง จำนวนพยางค์ของเสียงร้อง และจำนวน harmonic ในแต่ละพยางค์ระหว่างช่วงก่อนจับคู่กับช่วงจับคู่ไม่มีความแตกต่างกัน แต่เมื่อเปรียบเทียบจำนวนครั้งของการส่งเสียงร้องระหว่างเสียงร้องแต่ละแบบเสียงพบว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ทั้งในช่วงก่อนจับคู่และในช่วงจับคู่ ($P< 0.01$, $\chi^2 = 270.73$ และ $P<0.05$, $\chi^2 = 326.38$ ตามลำดับ) นอกจากนี้เมื่อเปรียบเทียบความถี่หลักของเสียงของพยางค์ท้ายและความถี่ของ harmonic ที่ 2 ของพยางค์กลางของเสียงขันโยน ระหว่างช่วงในก่อนจับคู่กับในช่วงจับคู่พบว่ามีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติเช่นกัน ($P<0.05$, $Z = -2.060$ และ $P< 0.05$, $Z = -2.207$ ตามลำดับ)

นอกจากนี้พบว่าแนวโน้มของค่าสัมประสิทธิ์ของความแปรปรวนของความยาวของพยางค์และความถี่เสียงของพยางค์ส่วนใหญ่ของเสียงขันโยนในช่วงก่อนจับคู่สูงกว่าในช่วงจับคู่

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ABSTRACT

Males use a variety of elaborate signals and display behaviours for attracting females is very common in birds. The male Zebra Dove (*Geopelia striata*) always attracts females for mating using vocal communication. To attract a breeding partner, males may behave differently when they are single compared to when they are paired. This study explored how individual males alter their signaling behaviour with changes in pairing status. The vocalizations of captive male Zebra Doves (*G. striata*) were recorded on tape-recorder in an experimental cage (90 ×90 ×120 cm) between solitary and paired period during April-November 2008. The other behaviours of male and female were observed and recorded on data check-sheet by time sampling method every 30 second for a period of 30 minutes.

The results showed that there were five call types composed of advertising call, settling call, courtship call, aggressive call and copulation call. All of those call types were recorded from solitary period except for the copulation call was especially found in paired period. Avisoft-SASLAB Pro software was used for sonogram comparison of call syllables between solitary and paired period. The calls were divided into four parts; the syllable in the introductory phrase (SI), the syllable in the middle phrase (SM), the syllable in the terminal phrase (ST) and pause (P). There were not different in call rate, all parameters of time duration, number of syllable and number of harmonic in call within call types between solitary and paired period. However, the significant difference in call rate between call types both solitary and paired period was detected ($P<0.05$, $\chi^2 = 270.73$ and $P<0.05$, $\chi^2 = 326.38$, respectively). In addition, the fundamental frequency of syllables in the terminal phrase and the frequency of second harmonic of syllables in the middle phrase of the

advertising call between the two status of males, were significantly different ($P<0.05$, $Z = -2.060$ and $P< 0.05$, $Z = -2.207$, respectively).

Furthermore, the results also showed that the trend of the average individual coefficient of variance in most parameter of time duration and frequency within the advertising call during solitary period were higher than paired period.

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CHAPTER 1

INTRODUCTION

1. Background and Rationale

Many of the most important external stimuli detected by animals are those that come from other animals including predators, mates, flock companions, parents, and offspring. Therefore, signal transmissions which animals respond to in particular ways play a very important role in their daily lives (Barnard, 1983). These signals have evolved through natural selection (Drickamer *et al.*, 2002). Because of the effectiveness of acoustic signals (Krebs and Davies, 1993), many animals, especially birds, use acoustic signals in a wide range of contexts, for example, in mate attraction, territorial defense, alarm, maintenance of social bonds, foraging and individual recognition (Charrier and Sturdy, 2005). Birds use a variety of vocal signals while communicating with their conspecifics. These signals play an important role in their social life. A number of avian species often deliver either calls or songs or both in a variety of contexts. Information in a call usually relates to the immediate circumstances of the caller (Kumar and Bhatt, 2001). Most studies have been carried out in passerine or songbirds (Slater, 2003). Vocal signals in birds can be classified into songs and calls (Catchpole, 1979). In general, songs are longer than calls. The former represent vocalizations produced by males in the breeding season, on the other hand, the latter are short, simple and less spontaneous. The calls are contextual and often produced with reference to a particular function such as raising mild alarm, maintaining contact between mates, or coordinating flock activities (Kumar and Bhatt, 2001). Songs and calls are a fascinating aspect of bird biology. Many neurobiologists, ethologists and ecologists have used bird song as a model to understand various aspects of phonation, sexual selection and behavioural ecology of birds. Unfortunately, in Thailand, these types of studies are not common. Many species are still waiting for a proper study of their acoustical characterization. Therefore, there is a need to fill this gap through active research and characterization of vocal repertoires of Thai species. Such efforts will help understand bird behaviour and ecology, and

possibly their taxonomy as well. In non-passerines or non-songbirds, several investigations have dealt with the *Streptopelia* dove which is a related species to the Zebra Dove (*Geopelia striata* Linn. 1766) (ten Cate, 1992), found a call types and its variation of this genus. The Zebra Dove (*G. striata*), classified in the Family Columbidae, is commonly found in Asia and Australia. It is widely raised in Thailand especially in the southern part due to its beautiful voice and the dove that crows well give higher price (Supasi *et al.*, 2005). Zebra dove cooing contests are popular in southern Thailand and the prize money can be quite significant. Many aspects regarding the singing behaviour of this species are still unknown. It is not yet known what role vocal signals in zebra doves play. However, the scientific report on the presence of vocalization in this species is quite a bit. This study attempted to understand detail of vocal signal structures of this species.

2. Research questions

1. How many vocal signals do captive male zebra doves (*G. striata*) have?

2. Does the structure of vocal signals in captive male zebra doves (*G. straita*) differ when they are kept alone compare to when they are kept in pairs?

3. Research objective

To examine the vocal characteristics of different call types between captive male zebra doves (*G. striata*) kept alone and in pairs.

4. Hypothesis

The structure of vocal signals in captive male zebra doves (*G. striata*) does not differ regardless of whether they are kept alone or in pairs.

5. Literature review

5.1 What is communication?

Communication is the process in which actors use especially designed signals or displays to modify the behaviour of reactors (Krebs and Davies, 1993), as “the transmission of a signal from one animal to another such that the sender benefits,

on average, from the response of the recipient" (Slater, 1983), as an "action on the part of one organism (or cell) that alters the probability pattern of behaviour in another organism (or cell) in a fashion adaptive to either one or both of the participants" (Wilson, 1975).

A communication system consists of the following important components, as recognized by Sebeok (1965):

(1) The *sender*: an individual that transmits a signal.

(2) The *receiver*: an individual whose probability of behaving in a particular way is altered by the signal.

(3) The *channel*: the medium through which the signal is transmitted (e.g. visual or vocal/auditory channels).

(4) The *signal*: the behaviour (e.g. posture, display, vocalization) transmitted by the sender.

(5) The *context*: the setting in which the signal is transmitted and received.

(6) *Noise*: background activity in the channel, which is irrelevant to the signal being transmitted.

(7) The *code*: the complete set of possible signals and contexts.

Signals were distinguished into two fundamental types by Sebeok: discrete (digital) and grade (analogue). Discrete signals are those that operate in an 'on/off' manner, like the flash sequences of fireflies (*Photinus* spp.). Other typical examples include the adoption of steel-blue and red courtship coloration by male three-spined sticklebacks, the use of stylized preening movements during courtship in some duck species (Sebeok, 1962; Barnard, 1983), and the way in which zebra communicate hostile behaviour by flattening their ears and communicate friendly behaviour by raising their ears (Drickamer *et al*., 2002). The dichotomous nature of discrete signals is emphasized by their tendency to be performed with so-called *typical intensity* (i.e. no matter how weak or how strong the stimulus evoking a signal, the signal is always displayed with the same degree of vigour and complexity). On the other hand, graded signals can be transmitted in various degrees of intensity and complexity (Barnard, 1983) and differ in intensity in proportion to the strength of the stimulus (Drickamer *et al*., 2002). For instance, ants release quantities of alarm

substance with are roughly proportional to the degree to which they have been stimulated. Vertebrates, birds and mammals can transmit an enormous range of messages simply by varying particular postures or vocalizations. Graded signaling in relation to the degree of stimulation is shown nicely by aggressive displays in rhesus monkeys (*Marcaca mulatta*). Low-intensity arousal is manifested as a fixed stare. As the degree of arousal increases, new components are added to the display either singly or in combination. These include opening the mouth, bobbing the head up and down, vocalizing, slapping the hand on the ground, and lunging forward. If all these components appear simultaneously in the display, the monkey is likely to actually attack (Barnard, 1983).

Signals are specific to many species, especially insects and lower vertebrates; these signals are highly stereotyped and only elicit one or a small number of responses, and each response can be elicited by only a very few signals. An amazing example is found in moth sexual attractance pheromones that are geometric isomers in the *Bryotopha* moth. Field observations have shown that *Bryotopha* males respond solely to the isomer of their own species, in addition, the male's response is actually inhibited if a heterospecific isomer is present. Among vertebrates, some bird and mammal species can recognize individuals on the basis of small variations in visual or vocal signals, for example Indigo buntings and some other small passerines can distinguish the calls of neighbouring territory owners from those of nearby strangers. Discriminating the signal characteristics of particular individuals is also important in maintaining family units in some species. For example, guillemot (*Uria aalg*e) chicks learn to respond selectively to the calls of their parents within the first few days after hatching (Barnard, 1983).

5.2 Communication in Birds

Birds communicate with each other mainly by means of visual and vocal signals. Elaborate or cryptic plumage, brightly coloured bare skin, wattles, tail, beak and feet are used in communication, with or without accompanying acoustic signals. However, acoustic signals seem to be produced only when required, and sound can be used to transmit a large amount of information efficiently (Kumar, 2003). Bird vocalizations are traditionally divided into calls and songs. Although there

are considerable difficulties in exactly defining the two terms, the distinction still remains a useful one. As a general rule, *songs* are longer, more complex in structure having a variation in frequency and amplitude, and produced by males in the breeding season, whereas *calls* are short, simple and produced by both sexes throughout the year (Catchpole, 1979).

The investigation of acoustic variation in the structure of vocal signals has gone through an enormous revolution in the last few decades with the development of modern sonagraphic analysis techniques. With accessible software one can now easily digitize large numbers of song recordings and visualize them on the screen, after which detailed measurements can be taken with high repeatability (Bekoff, 2004). This technique is a well-established method of characterizing acoustic signals on the basis of their frequency, duration and amplitude (Kumar, 2003). In spectrograms or sonograms, the *y*-axis represents frequency, measured in kilohertz (kHz) (Catchpole, 1979). As frequency approximates to pitch, the higher the noise is, the higher it appears on the trace. The *x*-axis represents time along the abscissa that is usually measured in seconds. Characteristic of sound with characteristic of element is specific. Perhaps the most common sound people associate with birds is a whistle. If the bird makes a short whistle of constant pitch, it will appear as a pure, *unmodulated frequency* on the sonogram, a fairly straight horizontal band (**a**). A whistle that starts at a higher frequency and drops to a lower one is said to be *frequency modulated* and appears as a slope (**b**). If more rapid modulations are introduced, as in a slow (**c**) or fast (**d**) vibrato, they will be shown on the sonogram. A completely different sound is the harsh noise produced when a wide frequency spectrum is used. A short burst of wide frequency noise results in a single click (**e**) and if several occur close together a harsh buzzing or rattling is produced (**f**). Frequency modulations can occur in a wide variety of complex forms and many will be encountered later, but (**g**) for example sounds rather like a chirp. Another complication is when a sound that has a low *fundamental frequency* also has higher frequencies that occur as multiples of the fundamental. These are called *harmonics* and in the example here (**h**) result in a rather gruff barking noise (Fig.1) (Catchpole, 1979).

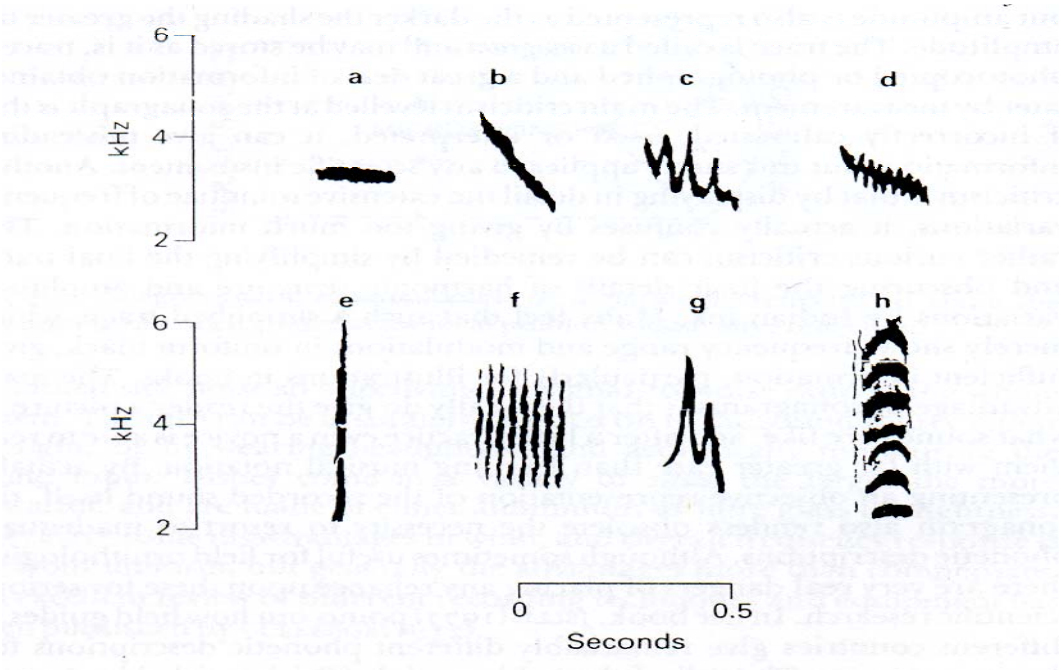


Figure 1 Sonograms of some different sounds (elements) produced by a male sedge warbler. (From Catchpole, 1979)

5.3 The study of acoustic communication in birds

Bird vocalizations are the most prominent among all animal acoustic signals (Krebs and Dawkins, 1984), because they are an amazing topic for attracting a wide variety of questions in animal behaviour (Slater, 2003). New technical advances have been responsible for opening up new possibilities in the study of vocal signals (Slater, 2003). Many studies in bird vocalization focus mainly on the structure and function of vocal signals (Slater, 2003). Most investigations have been carried out in passerine birds or songbirds (Thorpe, 1958; Catchpole, 1979; Krebs, 1977). Several studies have dealt with the structure of vocal signals by repertoire size or by the number of vocal signals (Marler, 1997; Slater, 2003). On repertoire, for example, a study on the willow warbler, *Phylloscopus trochilus,* revealed that it is a species with a limited number of elements which are recombined to give a large number of song types (Gil and Slater, 2000; Slater, 2003). Many species have been studied and it is becoming increasingly feasible to use the comparative method to see how these features of singing link with other features of their way of life (Slater, 2003). However, many examinations in non-passerines or non-songbirds have revealed a

variation in the number of elements in the perch-coo of the collared dove (*Streptopelia decaocto*) (Ballintjn and ten Cate, 1999), variation between coo types (Ballintjn and ten Cate, 1999), strength of vocal differentiation in *Streptopelia* doves in temporal components (ten Cate and Slabbekoorn, 1999), and reduction of repetitions in vocal repertoire size in *Streptopelia* dove (de Kort and ten Cate, 2004). Numerous studies have found that bird song serves a variety of functions such as mate attraction, mate guarding, territory defense, synchronization of reproductive behaviour between mates, and tutoring of young as part of their song learning process (Catchpole, 1979; Rodrigues, 1996). Many studies have been carried out to try to understand the function of song in territorial passerine birds and, as a result, two main hypotheses have emerged: (1) Song is used for territorial defense (Krebs, 1977; McGragor, 1991; Rodriques, 1996), and (2) Song is used as a sexually selected trait for attracting females as mates (Catchpole, 1979; Temsin, 1986; Bjorklund, 1990; McGregor, 1991 Albrecht and Oring, 1995; Rodrigues, 1996; Secondi *et al*., 2002; Nolan and Hill, 2004).

5.4 Animal subjects

5.4.1 Description

The Zebra Dove (*Geopelia striata*, Linnaeus 1766), also known as the Peaceful Dove or Barred Ground Dove, is classified under the Order Columbiformes, Family Columbidae and Genus *Geopelia* (Lekagul and Round, 1991)(Fig.2). It is similar to the Diamond and Bar-shouldered Dove of Australia and New Guinea (Pizzey and Doyle, 1980). The Zebra Dove is about 20-23 centimeters in height and 24-26 centimeters in length with a wingspan that is the smallest of the territorial doves of Thailand, and with a slender, long and narrow tail. The upperparts are brownish-gray with black and white barring rather than streaks on the hind neck; and with the sides of the neck and flanks barred black and white. The forehead and face are a distinct palebluish-grey. The face is blue-gray with bare blue skin around the eyes and the orbital skin is pale gray-blue. The center of the breast is unbarred vinous-pink. The underparts are pinkish with black bars on the sides of the neck, breast and belly, extending further across the breast that almost lacks vinous-pink, and warm buffish

fringes to the tail and flight feathers. There are white tips to the tail feathers. Juveniles are duller and paler than adults (Robson, 2002).

5.4.2 Feeding

It inhabits scrub, farmland and open country in lowland area and is commonly seen feeding on the ground or dry fields in rural areas and along roadsides, parks, gardens and cultivated areas, but it does not come into towns. It will fly up and perch in a tree when is disturbed. It feeds mainly on grains and seeds of grasses. Its breeding season is from September to June (Robson, 2002).

5.4.3 Reproduction

The male performs a courtship display consisting of bowing while raising and spreading the tail. The nest is a flimsy platform built in bushes or trees and sometimes on the ground from leaves and grass blades. It lays one or two white eggs that are incubated by both parents for 13-18 days (Robson, 2002).

5.4.4 Habitat and distribution

The native range of this species is from southern Thailand, the Malay Peninsula to the Indonesian islands; Sumatra, Java, Bali and Lombok, the Philippines Sunda Islands and in the Australian regions from southern Tenasserim and southern New Guinea (Robson, 2000)(Fig. 3). The zebra dove is popular in captivity especially in southern Thailand, Malaysia, Singapore and Indonesia because it is valued for its singing (Strange, 2000). Therefore, many populations have appeared outside its native range due to escaping or being deliberately released. It can be found in central Thailand, Laos, Borneo, Sulawesi, Hawaii (introduced in 1922), Tahiti (1950), New Caledonia, the Seychelles, the Chagos Archipelago (1960), Mauritius (before 1768), Reunion and Saint Helena (Wikipedia, 2009).

Classification of Zebra Dove (Lekagul and Round, 1991)

Kingdom Animalia
Phylum Chordata
Class Aves
Order Columbiformes
Family Columbidae
Genus *Geopelia*
Species *Geopelia striata*

Figure 2 Zebra Dove (*G. striata*).

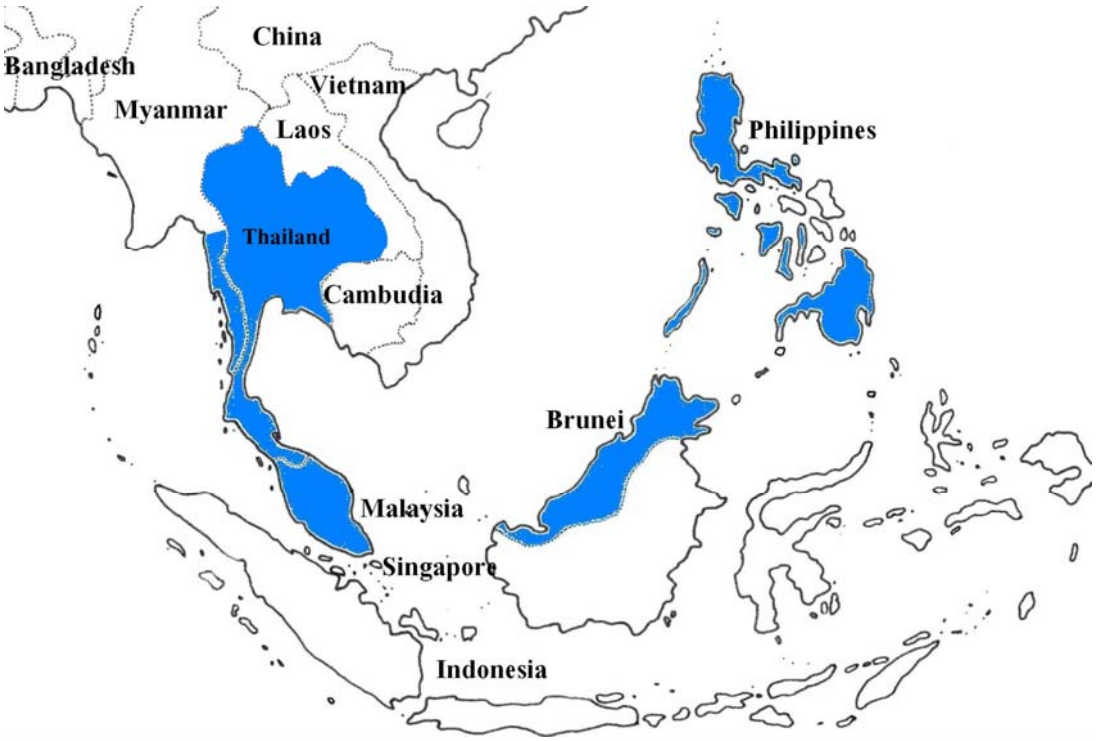


Figure 3 The native land and distribution of Zebra Dove (*G.striata*). (by Dejtharadol)

CHAPTER 2

MATERIALS AND METHODS

1. Study area

This study was carried out in Mae Lan District, Pattani Province, southern Thailand. Pattani climate is influenced by the tropical monsoon system; the southwest monsoon (May to September) and the northeast monsoon (November to January) and the dry period from January to April (Pattani dam, 2007). The average precipitation levels recorded for the period 1997-2007 ranged from 1,281.10 to 2,568.3 mm. The temperature in 2007 ranged from 19.5-37.0 ºc (Pattani Information Centre, 2009) and the average relative humidity per year is 79.0% (Pattani dam, 2007).

2. Subject maintanance

This study was conducted with twelve single male and six single female zebra doves (*Geopelia striata*) aged about nine months to one year old (born in 2007). This subject group was used sharing with another study in relating to a female choice of zebra dove (*G. striata*). Thus, the experimental design of this study was set for consistency with the experimental design of that study. Before each experiment, all zebra doves (*G. striata*) were housed individually in wooden cages with a single perch and a bar around and kept in a zone that separate from the experimental cage with natural day light at a temperature between 23-37 °c (Fig.4). Vocalization recordings were carried out in an experimental cage that consisted of three separate compartments (0.9 × 0.9 × 1.2 m). It was made from wood and mist wire with three perches; a nest perch, a high perch and a low perch (Fig.5). In each group of solitary experiments, there was one female in the middle compartment and two males in the adjacent compartments. Individuals were visually isolated from each other by attaching a blinder at a wall of each compartment of the experinmental cage but auditory contact was possible. Foods and water were provided ad libitum once per week at all times whether an experiment was taking place or not. Birds were provided with multi-vitamin supplemented mix seed that consisted of rice, millet, green mung bean and rye (Fig.6).

Figure 4 Individual cages.

Figure 5 Experimental cage.

Figure 6 Foods of Zebra Dove (A) rice, (B) millet, (C) green mung bean and (D) rye.

Figure 7 Tape recorder and cassette tapes.

3. Experimental design

3.1 Vocalization recording

Vocalization recording and behavioural observation was performed on solitary and in pairs of zebra dove (*G. striata*) while birds were in the experimental cage (cage specifications and housing were the same as above). Six groups of experiments (N = 6) were performed on solitary birds. In each group of experiments for solitary birds, three zebra doves (*G. striata*) were used; two male and one female. Each male was housed in the compartment next to a female that was in the middle compartment of the experimental cage (Fig.5). In each group of solitary experiments, daily vocalization and behaviour recording sessions took place from 09.00 to 12.00 in the morning (active singing period) following a habituation period for one to three days and repeated for two days. A 30-minute recording session was taped every hour, depending on the length of the tape and so as to avoid disturbing the zebra doves. During recording session, vocalizations of all individuals in each group in all compartments were recorded simultaneously on a tape recorder (SONY TCM-200DV) (Fig.7) which was placed at a center and under the roof of the experimental cage. While recording vocalizations, male and female zebra dove behaviour was also recorded on a data check sheet using a time sampling technique every 30 seconds continued for 30 minutes (Altmann, 1974). Another experiment, Six groups of experiments (N = 6) were also performed with the birds in pairs. In each group of experiments involving pairs of birds two zebra doves, male and female, were used that had been used in the solitary experiments. The procedure for each experiment on pairs of birds was exactly the same as for the solitary experiments. The flow chart of experimental design sees Fig 8.

3.2 Vocalization classification

The criteria for call type classification of zebra dove vocalization was modified from ten Cate (1992) which distinguished types of vocalization according to context of vocalization, behavioural displays, performance or behaviour pattern and acoustic parameters (Goodwin 1970;ten Cate 1992, Ballintijn and ten Cate, 1999). As a result, zebra dove vocalization can be classified into six types (Amnuay, 2004). The first type is the advertising call which was found frequently especially in adult males;

the second type is the settling call that is similar to the advertising call in call structure however this call type was found in both juvenile and adult of both sexes; the third type is a courtship call that is expressed during courtship displays and fighting of male; the fourth is a aggressive call given during territorial display; The later is copulation call given during copulation. The advertising call, the settling call and the copulation call share the same basic pattern that consists of three syllable phrase: the syllable in the introductory phrase (SI), the syllable in middle phrase (SM) and the syallable in terminal phrase (ST) (Liengpornpan and Meesawat, 2004)(Fig.9). In addition, the aggressive call contains two syllable phrases: the syllable in the introductory phrase (SI) and the syllable in the terminal phrase (ST). Moreover, the courtship call is a repeatation of a single syllable in an alteration between syllable and pause.

3.3 Acoustical feature measurement

Each call consists of a series of sound syllables that vary in frequency and in temporal and structural features. In a call, a species-specific call is defined as containing the smallest stereotypic repetition of similar syllable sequences. Additionally, the silent interval between syllables is defined as pause which pauses within phrase are typically shorter than pause between phrases (Fig.9). Each call type was digitized at sampling frequency 22.1 kHz; 16 bit precision and a FFT length of 512 Hz by using Avisoft SASLab pro sound analysis software (version 4.40, Specht, R., http://www.avisoft.de) on a personal computer for producing sonagram and stored in a computer file.

In the sonogram for each call, the following vocal parameters were analyzed: duration profile or temporal characteristics of syllable (duration of syllable in the introductory phrase, duration of syllables in the middle phrase and duration of syllables in the terminal phrase in second), duration of pause (the duration of silence between syllables of call in second that divided into pause within phrase and pause between phrase in second), duration of call or total call (the sum of duration in each syllable in call and pause duration in second), frequency profile or frequency characteristics (frequency of syllable in introductory phrase, duration of syllables in the middle phrase and duration of syllables in the terminal phrase minimum and

maximum frequency in kilohertz), level of amplitude (decibel), number of harmonic in each syllable in call, number of syllables in a call and call rate in each call type**.**

3.4 Data analysis

Comparing the mean difference of all vocal parameters of advertising call; call duration (duration of syllable in the introductory phrase, duration of syllables in the middle phrase, duration of syllables in the terminal phrase, duration of pause; duration of pause within phrase, duration of pause between phrase, duration of call), call frequency (frequency of syllables in the introductory phrase, frequency of syllables in the middle phrase, frequency of syllables in the terminal phrase, minimum frequency, maximum frequency), level of amplitude, number of syllables and number of harmonic of the advertising call between birds kept alone and those in pairs which were the nonparametric data by Wilcoxon matched pair signed ranks test. In addition, the call rate within each call type was measured by the McNemar test, and between call types by the Pearson Chi-square (Runyon and Haber, 1973). Statistical analyses were performed by using SPSS program version 15.0 for Windows. In addition, measuring the individual difference in vocal parameters, the degree of individual difference was expressed by a coefficient of variance (SD/mean × 100). Firstly, the average coefficient of variance within each of the call types was determined for each vocal parameter. The coefficient of variance was calculated for each individual separately. Next, these individual coefficients were averaged over all individuals to determine the coefficient of variance (CV_w) of the population. For call rate, this calculation was performed separately for each of the call types. Next, these individual averages were used to determine the average coefficient of variance (CV_b) for the population.

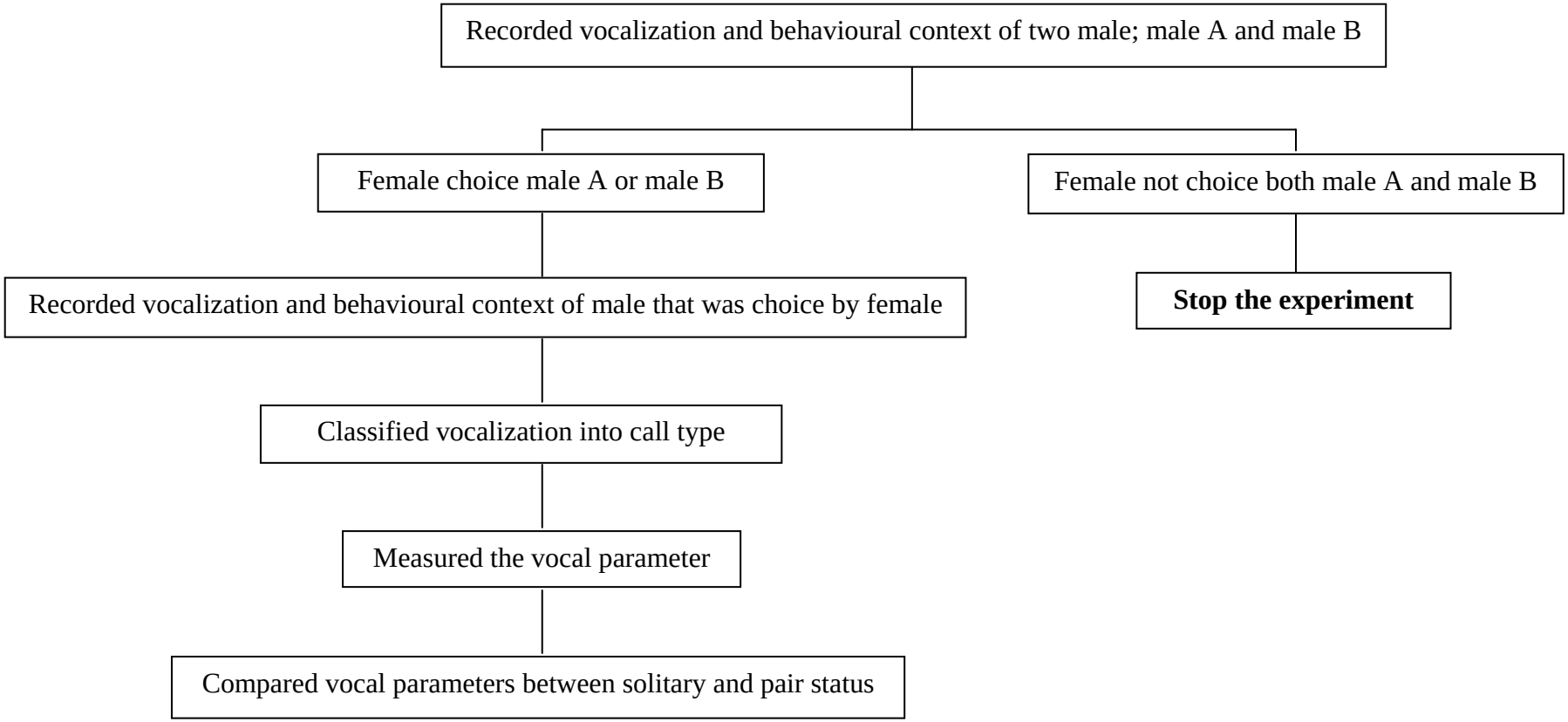


Figure 8 Diagram of the experimental design.

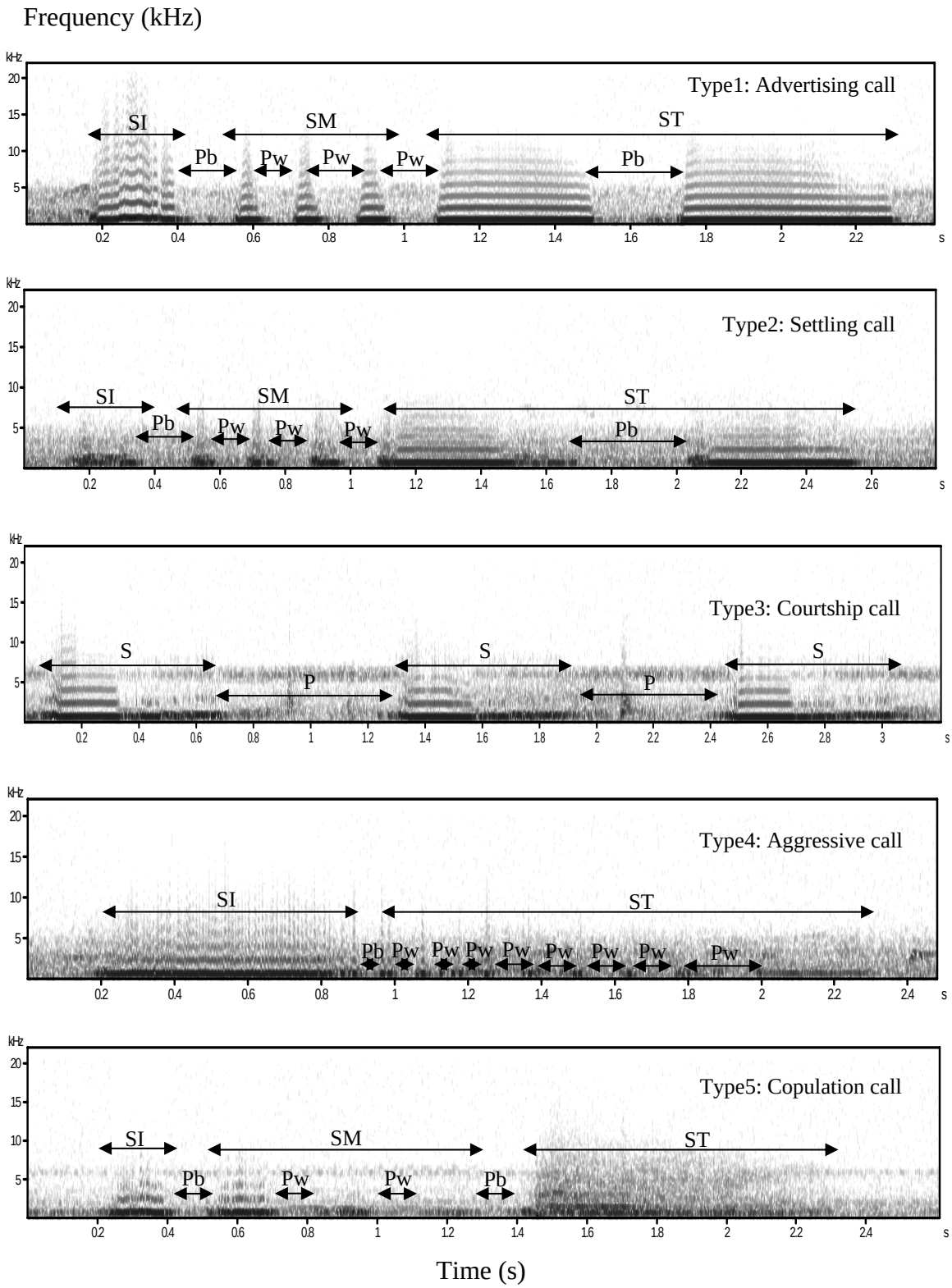


Figure 9 Sonagram representing syllables of the advertising call, the settling call, the courtship call, the aggressive call and the copulation call of zebra doves (*G. striata*), SI = syllable in the introductory phrase, SM = syllable in the middle phrase, ST = syllable in the terminal phrase, P_b = pause between phrase, P_w = pause within phrase.

CHAPTER 3

RESULTS

Total five call types of captive male Zebra Dove (*Geopelia striata*)'s vocalization were recorded during solitary period and paired period. Four call types were found during solitary period including the advertising call, the settling call, the courtship call, the aggressive call and five call types were found during paired period including the advertising call, the settling call, the courtship call, the aggressive call and the copulation call. In addition, calls were shared the main basic acoustic parameters which consist of duration, frequency, amplitude, number of syllable and number of harmonic.

1. General description of the call types

1.1 Advertising call

The advertising call, call noted as "coo-cuk-cuk-cuk-cook", produced predominantly and frequently only by adult male while often from a high perch in morning and evening. Call structure typically consisted of three syllable phrases; the syllable in the introductory phrase, the syllable in the middle phrase and the syllable in the terminal phrase. The beginning, the introductory phrase, there was a single syllable in the introductory phrase. The Following were the middle phrase and the terminal phrase which the numbers of syllables in middle phrase and syllable in the terminal phrase were varied. The number of syllable in the middle phrase was not less than two syllables and the number of syllable in the terminal phrase was at least one syllable. In addition, the duration of syllables in the middle phrase was shorter than the duration of syllable in the introductory phrase and syllable in the terminal phrase. Similarly, the pause or interval of silence between syllables in the middle phrase was also shorter than the pause between phrases. Moreover, the frequency of syllable in the introductory phrase was higher than the frequency of syllable in the middle phrase

and the frequency of syllable in the terminal phrase. This call type was frequently found both during solitary period and during paired period (Fig. 10, 12).

Figure 10 Typical posture of zebra dove (*Geopelia striata*) while producing the advertising call.

1.2 Settling call

The settling call, call noted as “cor-cor-cor-cor-cor”, uttered by both juvenile and adult of both sexes in relaxing mode, was composed of three syllable phrases which seem similar to advertising call in structure; the syllable in the introductory phrase, the syllable in the middle phrase and the syllable in the terminal phrase. The beginning, the introductory phrase, there was single syllable in the introductory phrase as in the advertising call. Following by the middle phrase and in the terminal phrase, the numbers of syllables in those phrases were varied. In addition, the duration of syllables in the middle phrase was shorter than the duration of syllable in the introductory phrase and syllable in the terminal phrase. Similarly, the pause or interval of silence between syllables in the middle phrase was also shorter than the pause between phrases. Moreover, the frequency of syllable in the introductory phrase was higher than the frequency of syllable in the middle phrase and the frequency of syllable in the terminal phrase. This call type was also found both during solitary and during paired period (Fig. 13).

1.3 Courtship call

The courtship call, call noted as “coo-coo-coo-coo-coo…”, was a series of emphatic repetitions of a long note which differed from other calls displayed mainly by male while in close proximity to their own mates and also to strange birds either sex for attracting female, in contrast, for repelling other male or other species. In addition, while the male zebra doves present this call type, they act a bowing display which bows down their head and lifts their tail up. This call type was composed of only single syllable in repetition, an alternation between syllable and pause. The duration of call bout in this call type was longer than other call type. This call type was found both during solitary period and during paired period (Fig.11, 14).

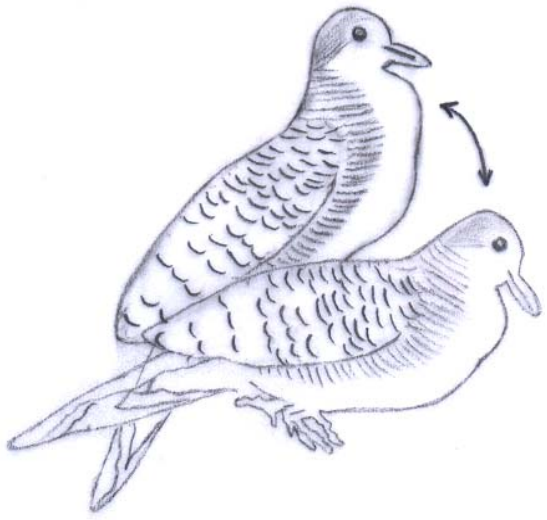


Figure 11 Typical posture of zebra dove (*Geopelia striata*) while producing the courtship call.

1.4 Aggressive call

The aggressive call, call noted as “Aood-aod-aod-aod-aod…”, exhibited by male only while other male or other species intruded on its territory, was composed of two phrase; the introductory phrase and the terminal phrase. The introductory phrase, in the introductory phrase, there was single syllable which duration of this syllable was longer in duration and higher frequency in frequency than the syllable in the terminal phrase. Secondly, in the terminal phrase, there were

many syllables in short duration and low frequency. This call type was found both during solitary period and during paired period (Fig. 15).

1.5 Copulation call

The copulation call, call noted as “kwak, kwak, kwak, kwak, kwaw”, displayed by male during copulation, consisted of three syllable phrases; the introductory phrase, the middle phrase and the terminal phrase. The introductory phrase, in the introductory phrase of this call begin with two syllables which almost same in duration and frequency differed from other calls. The next, in the middle phrase also composed of two syllables as the introductory phrase but were shorter in duration and were lower in frequency. The last, in the terminal phrase, there was only one syllable in a longer duration and a higher in frequency than a syllable in other phrase (Fig. 16). In addition, this call associated with the courtship call by the male displayed a courtship call previous the copulation.

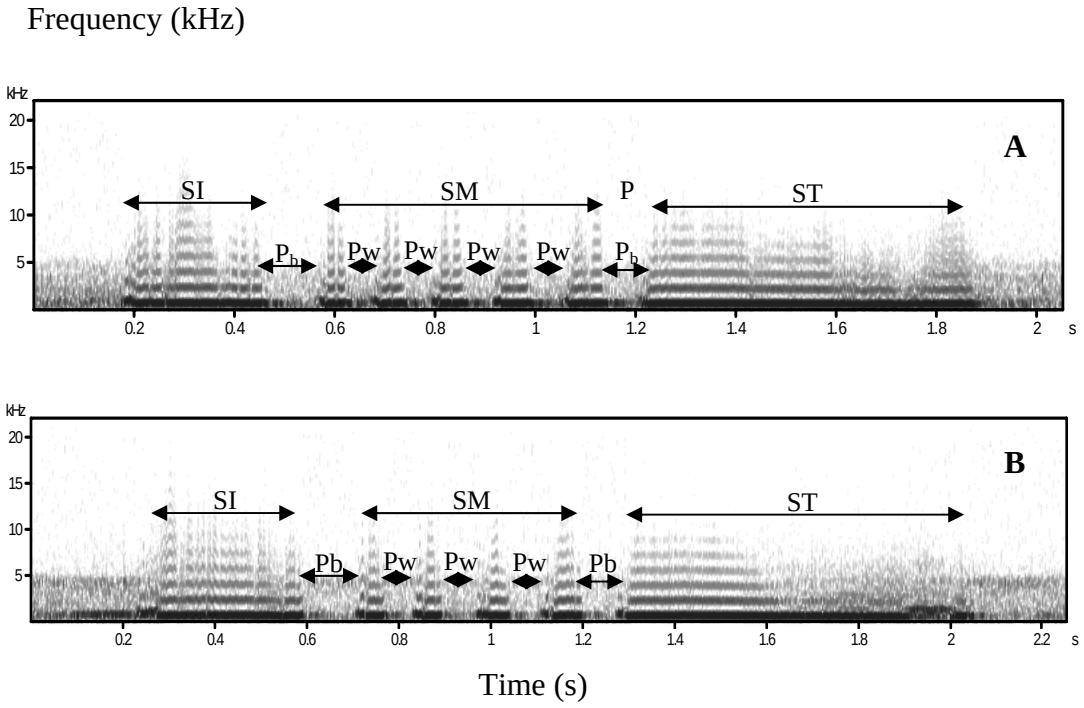
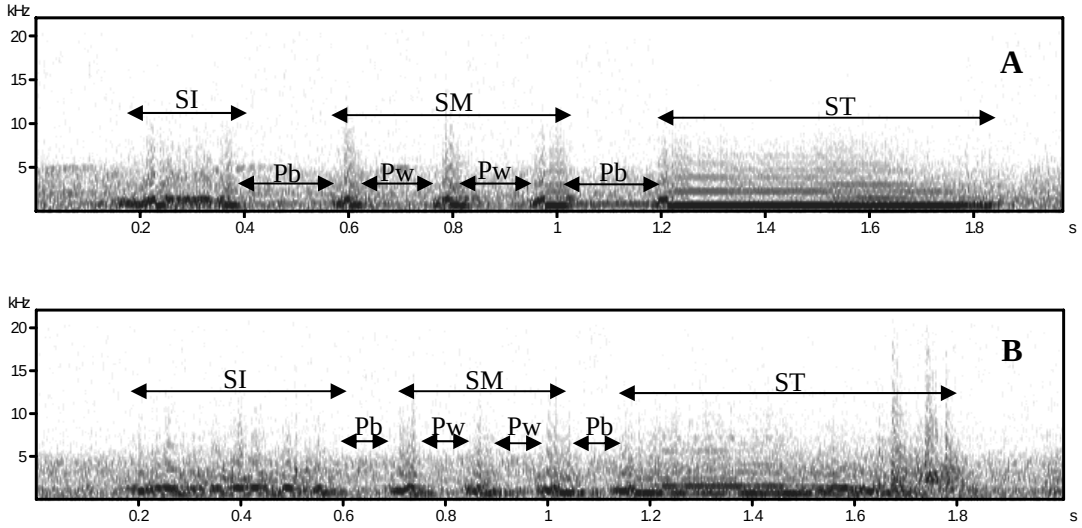


Figure 12 Sonagram of the advertising call; (A) during solitary period, (B) during paired period, SI = syllable in introductory phrase, SM = syllable in middle phrase, ST = syllable in terminal phrase, P_b = pause between phrase, P_w = pause within phrase.

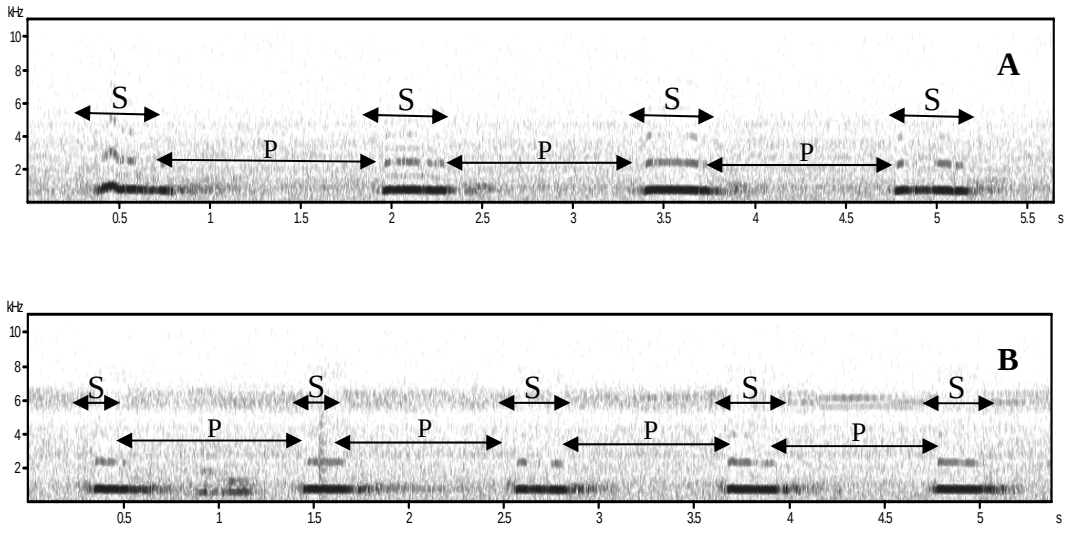
Frequency (kHz)



Time (s)

Figure 13 Sonagram of the settling call; (A) during solitary period, (B) during paired period, SI = syllable in introductory phrase, SM = syllable in middle phrase, ST = syllable in terminal phrase, P_b = pause between phrase, P_w = pause within phrase.

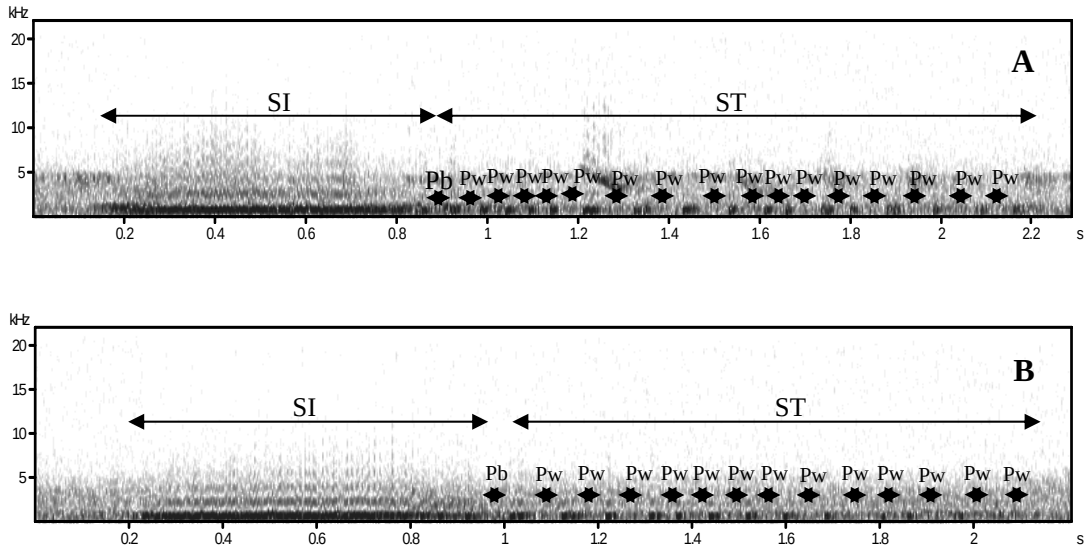
Frequency (kHz)



Time (s)

Figure 14 Sonagram of the courtship call; (A) during solitary period, (B) during paired period, S = syllable, P = pause.

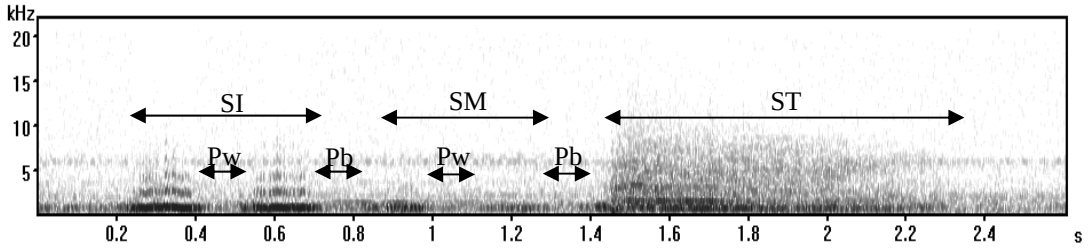
Frequency (kHz)



Time (s)

Figure 15 Sonagram of the aggressive call; (A) during solitary period, (B) during paired period, SI = syllable in introductory phrase, ST = syllable in terminal phrase, P_b = pause between phrase, P_w = pause within phrase.

Frequency (kHz)



Time (s)

Figure 16 Sonagram of the copulation call during paired period.

2. Call rate

The call rate or number of time that each call types occurred during sampling period was shown in Table 1, the average of call rate in advertising call during solitary period was 0.96 ± 0.47 % and during paired period was 1.22 ± 0.10 %. The average of call rate in advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.542, P = 0.344). Next, in settling call, the average of call rate during solitary period was 0.10 ± 0.24 % and during paired period was 0.09 ± 0.23 %. The average of call rate in settling call between solitary period and paired period were also not significantly different (Wilcoxon signed ranks test, z = -1.000, P = 0.500). In addition, in courtship call, there was only one zebra dove displayed a sign of courtship during solitary period which was 0.02 ± 0.06 % and during paired period was 0.28 ± 0.24 %. The average of call rate in courtship call between solitary period and paired period were significantly different (Wilcoxon signed ranks test, z = -2.032, P = 0.031). Later, in aggressive call, the average of call rate during solitary period was 0.06 ± 0.11 % and during paired period was 0.25 ± 0.28 %. The average of call rate in settling call between solitary period and paired period were also not significantly different (Wilcoxon signed ranks test, z = -1.461, P = 0.125). Finally, the copulation call that occurred particularly during paired period was 0.02 ± 0.04 %.

By comparing between call types found that the average call rate of all call types during solitary period were significantly different (χ^2 test = 270.73, P < 0.01, df = 3, n = 2160), also of paired period were significantly different (χ^2 test = 326.38, P < 0.01, df = 4, n = 2160) (Table1).

Concerning the degree of individual difference that was indicated by the coefficient of variance (CV). The Difference in call rate during solitary period and paired period showed by the average coefficient of variance within call types (CV_w) (Table1). Firstly, in advertising call, the coefficient of variance in call rate during solitary and paired period were 48.96 and 8.20 which showed that the individual difference of call rate of advertising call both during solitary period and paired period were slight. Secondly, in settling call, the coefficient of variance in call rate solitary and paired period were 240.00 and 255.55 which showed that the individual

difference of call rate in settling call both during solitary and paired period were considerable. Thirdly, in courtship call, the coefficient of variance in call rate during solitary and paired period were 300.00 and 85.71 which exhibited that the individual difference of call rate in courtship call during solitary period was substantial but during paired paired period was slight. Finally, in the aggressive call, the coefficient of variance in call rate solitary and paired period were 183.33 and 112.00 which showed that the individual difference of call rate in the aggressive call both during solitary period and paired period were considerable.

Moreover, regarding to the coefficient of variance between call types (CV_b) (Table1), the coefficient of variance between call types during solitary was 193.07 and during paired period was 132.29.

Table 1. The call rate (%) of each call type of captive male zebra dove (*G. striata*) by time sampling every 30 second for 180 minutes during solitary and paired period.
Note: CV_w = the average individual coefficient of variance within a call types
CV_b = the average individual coefficient of variance between call types

Type of call	Solitary			Pair			P
	Mean ± SD	CV_w	Range	Mean ± SD	CV_w	Range	
Advertising	0.96±0.47	48.96	8-39	1.22±0.10	8.20	6-54	0.344
Settling	0.10±0.24	240.00	0-13	0.09±0.23	255.55	0-12	0.500
Courtship	0.02±0.06	300.00	0-3	0.28±0.24	85.71	0-12	0.031
Aggressive	0.06±0.11	183.33	0-6	0.25±0.28	112.00	0.14	0.125
Copulation	-		-	0.02±0.04	200	0-2	-
CV_b		193.07			132.29		
P		0.000			0.000		

3. The acoustic characteristics of the advertising call

3.1 Call duration

3.1.1) Duration of syllable in the introductory phrase

Regarding the duration of syllables in the introductory phrase of advertising call was shown in Table 2. The average duration of syllable in introductory phrase of advertising call during solitary period was 0.28 ± 0.07 second and during paired period was 0.32 ± 0.08 second. The average duration of syllable in introductory phrase of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -1.572, P = 0.078).

With regard to the coefficient of variance within call types (CV_w) of duration of syllable in the introductory phrase of advertising call was shown in Table2. The coefficient of variance of duration of syllable in the introductory phrase of advertising call during solitary period and paired period were the same value 25.00.

Table 2. Time duration (s) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllable in the middle phrase (SM), syllable in the terminal phrase (ST), pause between introductory and middle phrase (SI-SM), pause between middle and terminal phrase (SM-ST), pause within phrase (WP), total call (TC).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	Solitary		Pair		P
	Mean ± SD	CVw	Mean ± SD	CVw	
SI	0.28 ± 0.07	25.00	0.32 ± 0.08	25.00	0.078
SM	0.06 ± 0.03	50.00	0.05 ± 0.01	20.00	0.344
ST	0.32 ± 0.17	53.12	0.24 ± 0.07	29.17	0.281
SI-SM	0.38 ± 0.08	21.05	0.40 ± 0.09	22.05	0.094
SM-ST	0.28 ± 0.14	50.00	0.36 ± 0.15	41.67	0.219
WP	0.16 ± 0.03	18.75	0.16 ± 0.04	25.00	0.422
TC	1.49 ± 0.33	22.15	1.54 ± 0.12	7.79	0.281

3.1.2) Duration of syllables in the middle phrase

As regards to the syllables in middle phrase, the duration of syllables in middle phrase of advertising call was shown in Table 2. The average duration of syllables in middle phrase of advertising call during solitary period was 0.06 ± 0.03 second and during paired period was 0.05 ± 0.01 second. The average duration of syllables in middle phrase of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, two-tailed: z = -0.542, P = 0.344).

Concerning the coefficient of variance within call types (CV_w) of duration of syllables in the middle phrase was showed in Table2. The coefficient of variance of duration of syllables in the middle phrase of advertising call during solitary period and paired period were 50.00 and 20.00.

3.1.3) Duration of syllables in the terminal phrase

Concerning the syllables of terminal phrase, the syllables of terminal phrase of advertising call was shown in Table 2. The average duration of syllables in the terminal phrase of advertising call during solitary period was 0.32 ± 0.17 second and during paired period was 0.24 ± 0.07 second. The average duration of syllables in the terminal phrase of advertising call compare between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.734, P = 0.281).

Regarding the coefficient of variance within call types (CV_w) of duration of syllables in the terminal phrase was shown in Table 2. The coefficient of variance of duration of syllables in the terminal phrase of advertising call during solitary period and paired period were 53.12 and 29.17.

3.1.4) Duration of pause between introductory and middle phrase

Concerning duration of pause or interval of silence in advertising call, the average duration of pause between introductory phrase and middle phrase of advertising call during solitary period was 0.38 ± 0.08 second and during paired

period was 0.40 ± 0.09 second. The average duration of pause between introductory phrase and middle phrase of advertising call during solitary period compare with during paired period found that the average duration of pause between introductory phrase and middle phrase of advertising call during solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -1.472, P = 0.094).

With regard to the coefficient of variance within call types (CV_w) of duration of pause between introductory phrase and middle phrase of advertising call was shown in Table 2. The coefficient of variance of duration of pause between introductory phrase and middle phrase of advertising call during solitary period and paired period were 21.05 and 22.05.

3.1.4) Duration of pause between middle and terminal phrase

As regards to duration of pause between middle phrase and terminal phrase of advertising call was shown in Table 2. The duration of pause between middle phrase and terminal phrase of advertising call during solitary period was 0.28 ± 0.14 second and during paired period was 0.36 ± 0.15 second. The average duration of pause between middle phrase and terminal phrase of advertising call during solitary period compare with during paired period found that the average duration of pause between middle phrase and terminal phrase of advertising call during solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.944, P = 0.219).

Regarding the coefficient of variance within call types (CV_w) of duration of pause between middle phrase and terminal phrase of advertising call was shown in Table 2. The coefficient of variance of duration of pause of advertising call during solitary period and paired period were 50.00 and 41.67.

3.1.5) Duration of pause within phrase

Concerning duration of pause within phrase of advertising call during solitary period was 0.16 ± 0.03 second and during paired period was 0.16 ± 0.04 second. The average duration of pause within phrase of advertising call during solitary period compare with during paired period found that the average duration of

pause of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.314, P = 0.422).

Regarding the coefficient of variance within call types (CV_w) of duration of pause within phrase of advertising call was shown in Table 2. The coefficient of variance of duration of pause within phrase of advertising call during solitary period and paired period were 18.75 and 25.00.

3.1.5) Duration of total call

Concerning duration of total call of advertising call during solitary period was 1.49 ± 0.33 second and during paired period was 1.54 ± 0.12 second. The average duration of total call of advertising call during solitary period compare with during paired period found that the average duration of total call of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.734, P = 0.281)(Table 2).

Regarding the coefficient of variance within call types (CV_w) of duration of total call of advertising call was shown in Table 2. The coefficient of variance of duration of total call of advertising call during solitary period and paired period were 22.15 and 7.79.

3.2 Call frequency

3.2.1 Fundamental frequency

Concerning fundamental frequency of advertising call was shown in Table 3. Firstly, the fundamental frequency of syllable in the introductory phrase during solitary period was 0.83 ± 0.09 kHz and during paired period was 0.60 ± 0.22 kHz. The average fundamental frequency of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -1.826, P = 0.063). Secondly, the fundamental frequency of syllables in the middle phrase during solitary period was 0.72 ± 0.10 kHz and during paired period was 0.72 ± 0.10 kHz. Comparing the

average fundamental frequency of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.314, P = 0.422). The later, the fundamental frequency of syllables in the terminal phrase during solitary period was 0.80 ± 0.07 kHz and during paired period was 0.74 ± 0.14 kHz. Comparing the average fundamental frequency of syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were significant difference (Wilcoxon signed ranks test, z = -2.060, P = 0.031).

With regard to the coefficient of variance within call types (CV_w) of fundamental frequency of advertising call was shown in Table 3. Firstly, the coefficient of variance of fundamental frequency of advertising call during solitary period and paired period of syllable in the introductory phrase were 10.84 and 36.67. Secondly, the coefficient of variance of fundamental frequency of advertising call during solitary period and paired period of syllables in the middle phrase were 13.89 and 13.89. The later, the coefficients of variance of fundamental frequency in advertising call during solitary period and paired period of syllables in the terminal phrase were 8.75 and 18.92.

Table 3. Fundamental frequency (kHz) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllables in the middle phrase (SM), syllables in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	**Solitary period**		**Paired period**		**P**
	Mean ± SD	**CVw**	**Mean ± SD**	**CVw**	
SI	0.83 ± 0.09	10.84	0.60 ± 0.22	36.67	0.063
SM	0.72 ± 0.10	13.89	0.72 ± 0.10	13.89	0.422
ST	0.80 ± 0.07	8.75	0.74 ± 0.14	18.92	0.031

3.2.2 Minimum frequency

Concerning minimum frequency of advertising call was shown in Table 4. Firstly, the minimum frequency of syllable in the introductory phrase during solitary period was 0.23 ± 0.22 kHz and during paired period was 0.20 ± 0.12 kHz. The average minimum frequency of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -0.272, P = 0.500). Secondly, the minimum frequency of syllables in the middle phrase during solitary period was 0.36 ± 0.15 kHz and during paired period was 0.34 ± 0.33 kHz. Comparing the average minimum frequency of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.368, P = 0.375). The later, the minimum frequency of syllables in the terminal phrase during solitary period was 0.27 ± 0.18 kHz and during paired period was 0.19 ± 0.12 kHz. Comparing the average fundamental frequency of syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.813, P = 0.250).

Regarding the coefficient of variance within call types (CV_w) of minimum frequency of advertising call was shown in Table 4. First, the coefficient of variance in minimum frequency of syllable in the introductory phrase of advertising call during solitary period and paired period were 95.65 and 60.00. Second, the coefficient of variance in minimum frequency of syllables in the middle phrase of advertising call during solitary period and paired period were 41.67 and 97.06. Finally, the coefficient of variance in minimum frequency of syllables in the terminal phrase of advertising call during solitary period and paired period were 66.67 and 63.16.

Table 4. Minimum frequency (kHz) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllables in the middle phrase (SM), syllables in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	Solitary period		Paired period		P
	Mean ± SD	CVw	Mean ± SD	CVw	
SI	0.23 ± 0.22	95.65	0.20 ± 0.12	60.00	0.500
SM	0.36 ± 0.15	41.67	0.34 ± 0.33	97.06	0.375
ST	0.27 ± 0.18	66.67	0.19 ± 0.12	63.16	0.250

3.2.3 Maximum frequency

Concerning maximum frequency of advertising call was shown in Table 5. Firstly, the maximum frequency of syllable in the introductory phrase during solitary period was 4.76 ± 1.47 kHz and during paired period was 4.72 ± 1.10 kHz. The average maximum frequency of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -0.314, P = 0.422). Secondly, the maximum frequency of syllables in the middle phrase during solitary period was 3.53 ± 1.26 kHz and during paired period was 3.32 ± 0.82 kHz. Comparing the average maximum frequency of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.314, P = 0.422). The later, the maximum frequency of syllables in the terminal phrase during solitary period was 3.38 ± 1.61 kHz and during paired period was 3.49 ± 0.89 kHz. Comparing the average maximum frequency of syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.674, P = 0.313).

Regarding the coefficient of variance within call types (CV_w) of maximum frequency of advertising call was shown in Table 4. First, the coefficient of variance in maximum frequency of syllable in the introductory phrase of advertising call during solitary period and paired period were 30.88 and 23.30. Second, the coefficient of variance in maximum frequency of syllables in the middle phrase of

advertising call during solitary period and paired period were 35.69 and 24.70. Finally, the coefficient of syllables in the terminal phrase of variance in maximum frequency of advertising call during solitary period and paired period were 47.63 and 25.50.

Table 5. Maximum frequency (kHz) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllables in the middle phrase (SM), syllables in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	Solitary period		Paired period		P
	Mean ± SD	CVw	Mean ± SD	CVw	
SI	4.76 ± 1.47	30.88	4.72 ± 1.10	23.30	0.422
SM	3.53 ± 1.26	35.69	3.32 ± 0.82	24.70	0.422
ST	3.38 ± 1.61	47.63	3.49 ± 0.89	25.50	0.313

3.2.4 Frequency of first harmonic

Concerning frequency of first harmonic of advertising call was shown in Table 6. Firstly, the frequency of first harmonic of syllable in the introductory phrase during solitary period was 0.69 ± 0.29 kHz and during paired period was 0.78 ± 0.14 kHz. The average frequency of first harmonic of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -1.342, P = 0.250). Secondly, the frequency of first harmonic of syllables in the middle phrase during solitary period was 0.73 ± 0.14 kHz and during paired period was 0.64 ± 0.21 kHz. Comparing the average frequency of first harmonic of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -1.472, P = 0.094). The later, the frequency of first harmonic of syllables in the terminal phrase during solitary period was 0.80 ± 0.07 kHz and during paired period was 0.72 ± 0.12 kHz. Comparing the average fundamental frequency of syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -1.461, P = 0.125).

With regard to the coefficient of variance within call types (CV_w) of frequency of first harmonic of advertising call was shown in Table 6. First, the coefficient of variance in frequency of first harmonic of syllable in the introductory phrase of advertising call during solitary period and paired period were 42.03 and 17.95. Second, the coefficient of variance in frequency of first harmonic of syllables in the middle phrase of advertising call during solitary period and paired period were 19.18 and 32.81. Finally, the coefficient of variance in frequency of first harmonic of syllables in the terminal phrase of advertising call during solitary period and paired period were 8.75 and 16.67.

Table 6. Frequency of first harmonic (kHz) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllables in the middle phrase (SM), syllables in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	**Solitary period**		**Paired period**		**P**
	Mean ± SD	**CV_w**	**Mean ± SD**	**CV_w**	
SI	0.69 ± 0.29	42.03	0.78 ± 0.14	17.95	0.250
SM	0.73 ± 0.14	19.18	0.64 ± 0.21	32.81	0.094
ST	0.80 ± 0.07	8.75	0.72 ± 0.12	16.67	0.125

3.2.5 Frequency of second harmonic

Concerning frequency of second harmonic of advertising call was shown in Table 7. Firstly, the frequency of second harmonic of syllable in the introductory phrase during solitary period was 2.40 ± 0.16 kHz and during paired period was 3.08 ± 1.75 kHz. The average frequency of second harmonic of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -1.633, P = 0.125). Secondly, the frequency of second harmonic of syllables in the middle phrase during solitary period was 2.43 ± 0.21 kHz and during paired period was 2.22 ± 0.13 kHz. Comparing the average frequency of second harmonic of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were significant difference (Wilcoxon signed ranks test, z = -2.207, P = 0.016). The later, the frequency of second harmonic of syllables in the terminal

phrase during solitary period was 2.40 ± 0.26 kHz and during paired period was 2.30 ± 0.16 kHz. Comparing the average frequency of second harmonic syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.271, P = 0.438).

Regarding the coefficient of variance within call types (CV_w) of frequency of second harmonic of advertising call was shown in Table 7. First, the coefficient of variance in frequency of second harmonic of syllable in the introductory phrase of advertising call during solitary period and paired period were 6.67 and 56.81. Second, the coefficient of variance in frequency of second harmonic of syllables in the middle phrase of advertising call during solitary period and paired period were 8.64 and 5.86. Finally, the coefficient of variance in frequency of second harmonic of syllables in the terminal phrase of advertising call during solitary period and paired period were 10.83 and 6.96.

Table 7. Frequency of second harmonic (kHz) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllable in the middle phrase (SM) syllable in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	Solitary period		Paired period		P
	Mean ± SD	CVw	Mean ± SD	CVw	
SI	2.40 ± 0.16	6.67	3.08 ± 1.75	56.81	0.125
SM	2.43 ± 0.21	8.64	2.22 ± 0.13	5.86	0.016
ST	2.40 ± 0.26	10.83	2.30 ± 0.16	6.96	0.438

3.2.6 Level of amplitude

Concerning level of amplitude of advertising call was shown in Table 8. Firstly, the level of amplitude of syllable in the introductory phrase during solitary period was -6.26 ± 0.18 dB and during paired period was -6.13 ± 0.23 dB. The average level of amplitude of syllable in the introductory phrase of advertising call during solitary period compare with during paired period were not significant difference (Wilcoxon signed ranks test, z = -1.153, P = 0.156). Secondly, the level of amplitude of syllables in the middle phrase during solitary period was -6.47 ± 0.22 dB

and during paired period was -6.49 ± 0.16 dB. Comparing the average level of amplitude of syllables in the middle phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.315, P = 0.391). The later, the level of amplitude of syllables in the terminal phrase during solitary period was -6.58 ± 0.47 dB and during paired period was -7.06 ± 1.32 dB. Comparing the average level of amplitude of syllables in the terminal phrase of advertising call between during solitary period and during paired period found that were not significant difference (Wilcoxon signed ranks test, z = -0.105, P = 0.500).

With regard to the coefficient of variance within call types (CV_w) of level of amplitude of advertising call was shown in Table 8. First, the coefficient of variance in level of amplitude of syllable in introductory phrase of advertising call during solitary period and paired period were 2.88 and 3.75. Next, the coefficient of variance in level of amplitude of syllables in middle phrase of advertising call during solitary period and paired period were 3.40 and 2.46. Finally, the coefficient of variance in level of amplitude of syllables in terminal phrase of advertising call during solitary period and paired period were 7.14 and 18.70.

Table 8. Level of amplitude (dB) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllables in the middle phrase (SM) syllables in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call type

Parameters	Solitary period		Paired period		P
	Mean ± SD	CVw	Mean ± SD	CVw	
SI	-6.26 ± 0.18	2.88	-6.13 ± 0.23	3.75	0.156
SM	-6.47 ± 0.22	3.40	-6.49 ± 0.16	2.46	0.391
ST	-6.58 ± 0.47	7.14	-7.06 ± 1.32	18.70	0.500

3.3 Number of syllable in call

The number of syllable of advertising call of solitary and paired period was shown in Table 9. It was found that the average number of syllable in the introductory phrase of advertising call during solitary period was 1.00 ± 0.00 syllables and during paired period was 1.00 ± 0.00 syllables. The Wilcoxon sign rank test

indicated that average number of syllable in advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.000, P = 1.000). In addition, the average number of syllables in the middle phrase of advertising call during solitary period was 4.33 ± 1.86 syllables and during paired period was 3.67 ± 1.63 syllables. The Wilcoxon sign rank test indicated that average number of syllable in advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -2.000, P = 0.063). The later, the average number of syllables in the terminal phrase of advertising call during solitary period was 1.67 ± 1.21 syllables and during paired period was 2.17 ± 1.60 syllables. The Wilcoxon sign rank test indicated that average number of syllables in terminal phrase of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -1.732, P = 0.125).

With regards to the coefficient of variance within call types (CV_w) (Table 9), the coefficient of variance of number of syllable in introductory phase of advertising call during solitary period and paired period were 0 and 0. The next, the coefficient of variance of number of syllables in middle phase of advertising call during solitary period and paired period were 42.96 and 44.41. The later, the coefficient of variance of number of syllables in terminal phase of advertising call during solitary period and paired period was 72.46 and 73.73.

Table 9. Number of syllable (syllable) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllable in the middle phrase (SM) syllable in the terminal phrase (ST)
Note: CV_w = the average individual coefficient of variance within a call types

Parameters	Solitary period		Paired period		P
	Mean ± SD	CV_w	Mean ± SD	CV_w	
SI	1.00 ± 0.00	0	1.00 ± 0.00	0	1.000
SM	4.33 ± 1.86	42.96	3.67 ± 1.63	44.41	0.063
ST	1.67 ± 1.21	72.46	2.17 ± 1.60	73.73	0.125

3.4 Number of harmonic in syllable

The number of harmonic of advertising call of solitary and paired period was shown in Table 10. It was found that the average number of harmonic in syllable in the introductory phrase of advertising call during solitary period was 1.83 ± 0.41 harmonic and during paired period was 1.83 ± 0.41 harmonic. The Wilcoxon sign rank test indicated that average number of harmonic of syllable in the introductory phrase of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.000, P = 0.750). In addition, the average number of harmonic in syllable of the middle phrase of advertising call during solitary period was 1.86 ± 0.31 harmonic and during paired period was 1.74 ± 0.40 harmonic. The Wilcoxon sign rank test indicated that average number of harmonic of syllable in the middle phrase of advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -0.447, P = 0.500). The later, the average number of harmonic in the syllable of the terminal phrase of advertising call during solitary period was 1.75 ± 0.42 harmonic and during paired period was 1.57 ± 0.39 harmonic. The Wilcoxon sign rank test indicated that average number of harmonic of syllable of the terminal phrase in advertising call between solitary period and paired period were not significantly different (Wilcoxon signed ranks test, z = -1.604, P = 0.125).

With regards to the coefficient of variance within call types (CV_w) (Table 10), the coefficient of variance of number of harmonic of syllable in the introductory phase of advertising call during solitary period and paired period were 22.40 and 22.40. The next, the coefficient of variance of number of harmonic of syllables in the middle phase of advertising call during solitary period and paired period were 16.67 and 22.99. The later, the coefficient of variance of number of harmonic in syllables the terminal phase of advertising call during solitary period and paired period was 24.00 and 24.84.

Table 10. Number of harmonic (harmonic) of advertising call of zebra dove (*G. striata*) between solitary period and paired period in syllable of introductory phrase (SI), syllable in the middle phrase (SM) syllable in the terminal phrase (ST).
Note: CV_w = the average individual coefficient of variance within a call types

Parameters	**Solitary period**		**Paired period**		**P**
	Mean ± SD	**CVw**	**Mean ± SD**	**CVw**	
SI	1.83 ± 0.41	22.40	1.83 ± 0.41	22.40	0.750
SM	1.86 ± 0.31	16.67	1.74 ± 0.40	22.99	0.500
ST	1.75 ± 0.42	24.00	1.57 ± 0.39	24.84	0.125

CHAPTER 4

DISCUSSION

1. General description of the calls

In the present study totally discovered five call types of captive male Zebra Dove (*Geopelia striata*) vocalization by time sampling. During solitary period was found four call types which consisted of the advertising call, the settling call, the courtship call and the aggressive call and during paired period was observed five call types including the advertising call, the settling call, the courtship call, the aggressive call and the copulation call.

Firstly, the advertising call, the advertising call of Zebra Dove (*G. striata*) is quite similar to the advertisement call of Peaceful Dove (*Geopelia placida*) in the number of syllable in introductory phrase (Harrison, 1969). The number of syllable in introductory phrase of Zebra Dove (*G. striata*) was single syllable as same as Peaceful Dove (*G. placida*). On the other hand, the number of syllable in middle phrase and terminal phrase of Zebra Dove (*G. striata*) differed from the number of syllable in middle phrase and terminal phrase of Peaceful Dove (*G. placida*). The number of syllable in middle phrase of Zebra Dove (*G. striata*) was more than the number of syllable in middle phrase of Peaceful Dove (*G. placida*). In the same way, the number of syllable in terminal phrase of Zebra Dove (*G. striata*) which was at least one syllable was also more than the number of syllable in terminal phrase of Peaceful Dove (*G. placida*) that was single syllable. In addition, duration of syllable in the middle phrase of Zebra Dove (*G. striata*) was shorter than the others as same as in Peaceful Dove (*G. placida*) (Harrison, 1969). Moreover, concerning frequency of syllable of advertising call of Zebra Dove (*G. striata*) and Peaceful Dove (*G. placida*), frequency syllable of advertising call of Zebra Dove (*G. striata*) might be slight higher than frequency of advertising call of Peaceful Dove (*G. placida*) (Harrison, 1969).

Secondly, the settling call seems fairly similar to advertising call in structure of call. However, it differed from the advertising call in level of vocal frequency which was lower than of the advertising call. In addition, the behavioural context of the settling call also differed from of the advertising call. The settling call

was uttered by both juvenile and adult of both sexes in mode of relaxing, on the other hand, the advertising call was produced frequently only by adult male. However, this study is the first report about this call type. Thus, none of previous scientific report describe to this call neither in same species nor related species.

Thirdly, the courtship call, this call was distinct from other calls was displayed especially by male in bouts that was a repetition of single form of syllable. In addition, while expressed this call, Zebra Doves (*G. striata*) usually orientates a bowing display. Similarly, in *Streptopelia* doves, in the Barbary Doves (*Streptopelia risoria*) have the bowing display which is an alternation between two postures, one upright and one crouched (Davies, 1970). In addition, the studies on the Barbary Doves (*S. risoria*) have shown that bow coo (courtship call) is an aggressively motivated behaviour, although it plays a role in the initial phase of pair formation (Davies, 1974, Lovari and Hutchison, 1975; ten Cate *et. al*, 2002).

Later, the aggressive call, the aggressive call of Zebra Dove (*G. striata*) began with a syllable that was long in duration and high in frequency and followed by many syllable in short duration and low in frequency. This characteristic of aggressive call in Zebra Dove (*G. striata*) was distinct from aggressive call of Peaceful Dove (*G. placida*) in duration and frequency of introductory syllable. The duration introductory syllable of Zebra Dove (*G. striata*) was longer than the duration of introductory syllable of Peaceful Dove (*G. placida*) and frequency of introductory syllable Zebra Dove (*G. striata*) was also higher than of Peaceful Dove (*G. placida*)(Harrison, 1969).

Finally, the copulation call, the copulation call in this species consisted of three syllable phrases; two syllables of the introductory phrase, two syllables in the middle phrase and a single syllable in the terminal phrase. The duration of syllable in the introductory phrase and in the middle phrase were shorter than the duration of syllable in the terminal phrase as same as the frequency of syllable, the frequency of syllable in the introductory phrase and the middle phrase were lower than the frequency of syllable in the terminal phrase. In addition, this call associated with the courtship call by the male uttered this call followed the courtship call. This behaviour of Zebra Dove (*G. striata*) was similar to the finding in Morning Dove (*Zenaidura macroura*); the male displayed a series of bow coo (courtship call) in front of the female that female may permit copulation and formation of the pair bond (Jackson and

Baskett, 1964). However, the vocalization of male Zebra Dove (*G. striata*) has a distinctive point in the advertising call. Because of this call was appeared more frequently than other calls. Thus, this call seems as a prime vocal signal of this species.

2. Call rate

The parameter of call rate or frequency of call during the 180 minute interval was used to describe the call activity of captive male Zebra Dove both during solitary period and paired period. The present study both during solitary period and paired period were observed the advertising call more frequently than other calls.

Firstly, the call rate of the advertising call during solitary period was 0.96 ± 0.47 % and during paired period was 1.22 ± 0.10 % (Table 1). However, the discrepancy of the call rate in this call between during solitary period and paired period were not appeared. Thus, it showed that the advertising call of captive male Zebra Dove played a considerable role in both solitary period and paired period. In addition, as a result of this species has a small repertoire size, number of call types, this call might be displayed different meaning in different pairing status of male (Rodrigues, 1996). Similarly, in Western Grebes (*Aechmophorus occidentalis*), the advertising call of this species appears to provide a crucial means by both unpaired male and paired male (Nuechterlein, 1981). However, the result of this study was different from other investigations. For example, in White-Winged Dove (*Zenaida asiatica*), pair bond status has been found to affect song rate; unpaired males seeking mate sing more often than paired males (Rappole and Waggerman, 1986). In addition, in Morning Dove (*Zenaidura macroura*), unmated male performed the perch-coo (advertising call) much more frequently than mated male (Jackson and Baskett, 1964). Moreover, in Barbary Dove (*Streptopelia risoria*), the perch-coo was the most common use in ummated dove in both sexes (Davies, 1974). Furthermore, in Kirtland ' s Warblers (*Dendroica kirtlandii*), the mean song rate of unmated birds was higher than of mated birds (Hayes *et al.*, 1986).

Secondly, the trend in the call rate of the courtship call and aggressive call were similar to the call rate of the advertising call. The call rate of the courtship call during solitary period and paired period were 0.02 % and 0.28 % and the call rate

of the aggressive call during solitary period and paired period were 0.06 % and 0.25 %. However, the distinction of call rate between solitary and paired period was also not found both in the courtship call and the aggressive call. These results indicated that the courtship call and the aggressive call played an important role in paired period of Zebra Dove (*G. striata*) more than in solitary period. These findings were consistent with the result of the study in Canvasbacks (*Aythya valisineria*) that the frequencies of courtship display (kink-neck call) of paired males were greater than in unpaired males and paired Canvasbacks (*A. valisineria*) tended to spend more time in aggression and initiated and won more aggressive encounters than unpaired Canvasbacks (Lovvorn, 1990).

Regarding the difference of call rate between call types found that both during solitary period and paired period the call rate between call types were different. This result showed that the role of each call types was different in each status of male. During solitary period, the highest of call rate to the lowest in order that was the advertising call (0.96 %), the settling call (0.10 %), the aggressive call (0.06 %) and the courtship call (0.02 %). On the other hand, during paired period, the highest of call rate to the lowest in order that was the advertising call (1.22 %), the courtship call (0.28 %), the aggressive call (0.25 %), the settling call (0.09 %) and the copulation call (0.02 %). These results revealed that both during solitary period and paired period the advertising call played an important role in social life of male Zebra Dove (*G. striata*) more than other calls. This outcome indicated that pairing status of male Zebra Dove affected the call rate. Thus, each call type was dominant in different status of male. Likewise, in Chestnut-sided Warbler (*Dendroica pensylvanica*) breeding status was strongly associated with song category. Because unpaired males were more likely to sing accented-ending song. However, this song type was smaller dropped-off during egg laying (Byers, 1996).

According to the individual difference in the call rate within call type that indicated by coefficient of variance within call type (CV_w), the coefficient of variance in the advertising call during solitary period and during paired period were 48.96 and 8.20 respectively. It means that call rate of solitary period have various pattern of call rate of advertising call more than paired period. This various patterns may be a signaling to female in order to advertise that males are in receptive status.

This finding differed from the outcome of the former investigation in American Redstart (*Setophaga ruticilla*) that unpaired males sang in repeat mode at significantly higher than paired males but less variable rates than did paired males (Staicer *et al*., 2006).

In the same way, variation in call rate between call types that showed by coefficient of variance between call types (CV_b), during solitary period the coefficient of variance between call types was 193.07 which similar to during paired period the coefficient of variance between call types was 132.29. It indicates that the paired period have less variation of call rate than solitary period, especially copulation call does not exist in solitary period group. This finding represents the trend of call rate between call types of individual males during solitary and paired period in order to explain a role of each call types in each individual male during solitary and paired period.

3. Temporal characteristics (time duration)

The difference of temporal parameters within call types was not found in all parameters of the advertising call (Table 2). Firstly, syllable in the introductory phrase, duration of syllable in the introductory phrase of advertising call during solitary period and paired period were 0.28 second and 0.32 second. The discrepancy of duration of syllable in the introductory phrase of the advertising call between solitary period and paired period was not appeared. This outcome revealed that duration of syllable in introductory phrase of the advertising call was quite stable and was not influenced by pairing status. This result confirm to the results of the study in Eagle Owls (*Bubo Bubo*) which temporal characteristics of call showed a great constancy during a round the year (Lengagne, 2001).

Secondly, syllables in the middle phrase of the advertising call, duration of syllables in the middle phrase of advertising call during solitary period and paired period were 0.06 second and 0.05 second respectively. The difference in duration of syllable in the middle phrase of the advertising call between solitary period and paired period were not detected. This result indicated that duration of syllable in the middle phrase of the advertising call of Zebra Dove (*G. striata*) was not affected by pairing status and was highly stable. This phenomenon also appeared in Collared

Dove (*Streptopelia decaocta*). Ballintijn and ten Cate (1999) found that duration of e2, as the syllable in the middle phrase of Zebra Dove (*G. striata*), in perch-coo, bow-coo and nest-coo of unpaired male Collared Dove showed a great constancy.

Moreover, syllables in the terminal phrase, duration of syllables in the terminal phrase of advertising call during solitary period and paired period were 0.32 second and 0.24 second respectively. The dissimilarity of duration of syllable in the terminal phrase of the advertising call between solitary period and paired period was not found. This occurrence indicated that pairing status also not influenced on duration of syllables in the terminal phrase of advertising call. This result of Zebra Dove (*G. striata*) confirmed to the finding in the Rufous-and-White Wrens (*Thryothorus rufalbus*) which the bandwidth (duration of syllable) of the terminal syllable of this species did not change with pairing status (Hennin *et al*., 2009).

Regarding the duration of pause which was divided into pause between phrase; pause between the introductory phrase and the middle phrase (SI-SM), pause between the middle phrase and the terminal phrase (SM-ST) and pause within phrase (WP). Firstly, pause between the introductory phrase and the middle phrase (SI-SM), duration of pause between the introductory phrase and the middle phrase of the advertising call during solitary period and paired period were 0.38 second and 0.40 second respectively. Second, pause between the middle phrase and the terminal phrase (SM-ST), duration of pause between the middle phrase and the terminal phrase of the advertising call during solitary period and paired period were 0.28 second and 0.36 second respectively. The later, pause within phrase (WP), duration of pause within phrase of the advertising call during solitary period and paired period were 0.16 second and 0.16 second respectively. The difference between solitary period and paired period of all duration of pause parameters were the same trend with of duration of syllables which were unchanged crossing the pairing status. This result revealed that temporal parameters of advertising call in Zebra Dove were not influenced by pairing status. These occurrences were caused by the duration of syllable and duration of pause correlated with limitation of sound production (respiratory and syringeal musculature) that depended on the expiratory phrase of respiration. During the expiratory phrase, sound or syllables were produced and during inspiration, the pause or silent period occurred. (Suthers and Goller, 1998; Suthers *et al*, 1999; Goller and

Deley, 2001; Oberweger and Goller, 2001). For instance, the European nightjar (*Caprimulgas european*) switched phonation from expiration to inspiration that has been proposed as a possible mechanism to enable minute-long uninterrupted song (reviewed in Goller and Deley, 2001; Hunter, 1980). In addition, a research in physiology of the syrinx of the ring dove (*S. risoria*) found that this species generates a relatively simple, highly stereotyped song that is controlled by superfast muscles of their syrinx (Elemans *et al*, 2004). Moreover, another cause might be the minimization for consistency of syllable duration (Botero *et.al*, 2009). Concerning the consistency of syllable duration, vocalizations are used both for attracting females and for territorial defence. Thus, to be fully effective in the social context of territoriality, the call of any particular male must have certain acoustic features that are unique to that male (Langagne, 2001).

The later, total call, duration of total call of the advertising call during solitary period and paired period were 1.49 second and 1.54 second respectively. The discrepancy of duration of total call between solitary period and paired period was also not detected. This result revealed that the pairing status not affected the duration of total call of the advertising call. This finding was consistent with the result of the study in Rofous-white-Wren (*Thryothorus rufalbus*) which song length of this species did not change with pairing status (Hennin *et al.*, 2009).

Furthermore, concerning individual difference of duration of syllable in the SI, SM and ST within the advertising call was shown by the coefficient of variance (CV_w) during solitary and paired period. The results indicated that SM was more variation range of spending time duration more than SI and ST during solitary period. Whereas ST of advertising call during paired period was more variation range of spending time duration than SI and SM of advertising call. It means that in advertising call, SM of solitary period differs among individual. This result in syllable of middle phrase of advertising call of solitary period may be caused by a role of individual recognition. Because there was a competition between males during solitary period, thus individual males need to advertise individual character for female attraction (Catchpole and Slater, 2003). While during paired period, ST also differed among individual and make an impact. However, time duration of ST was not significantly different between solitary and paired period. These occurrences indicated that pairing

status not influenced on duration of syllables in the terminal phrase of advertising call. This phenomenon may be affected by male quality which each individual males was able to produce the syllables in the terminal phrase in different length. However, this result of Zebra Dove (*G. striata*) was consistent with the result in the Rufous-and-White Wrens (*Thryothorus rufalbus*) which the bandwidth of the terminal syllable of this species did not change with pairing status (Hennin *et al.*, 2009).

4. Frequency characteristics

The comparison of the structure of the advertising call that were sung by male Zebra Dove (*G. striata*) between during solitary period and during paired period, it was found that no difference in all frequency parameters of syllables except for the fundamental frequency of the terminal syllable (ST) and the frequency of second harmonic of the middle syllable (SM).

Concerning the frequency parameters of SI, SM, ST of the advertising call between during solitary period and during paired period, it was found that the trend of frequency parameters of SI, SM, ST in advertising call during solitary period were higher than during paired period. Especially, fundamental frequency of ST and frequency of second harmonic of SM were significantly different between during solitary and during paired period. It means that the pairing status affected the fundamental frequency of ST and frequency of second harmonic of SM. These occurrences in the advertising call frequency during solitary period may caused by a male-male competition. Thus, during the solitary period males have to advertise themselve for attracting female by adjusting the fundamental frequency and second harmonic of their calls to avoid overlapping with other males. For instance, blue whales changed their fundamental frequency of their call to avoid overlap with the frequency band of the fin whales calls, because interactions between blue whales and fin whales affected call frequency of blue whales (McDonald *et.al*, 2009). In addition, Males calls could be honest indicators of their genetic diversity, sound frequency are biomachanically difficult to produce. Males that are genetically diverse, expected to be in better physical condition, are able to produce sound frequencies that males with less genetic variation are unable to reach. Thus, female might listen carefully to the male sound frequency when selecting a mate. Females may prefer to mate with male that

can produce the highest frequency of syllables, because their offspring will have more genetic diversity. For example, individuals of male ocellated antbirds (*Phaenostictus mcleannani*) with higher genetic diversity produced notes in higher pitch during aggressive interactions (Araya-Ajoy *et.al.*, 2009). However, Phromchan *et al*. (2010) found that frequency of the advertising call of unselected male Zebra Dove (*G. striata*) was higher than of selected male. Moreover, these findings in Zebra Dove (*G. striata*) contrasted with the outcome of the study in Rufous-and-White Wren which the frequency of the trill (syllables) did not change with pairing status (Hennin *et al.*, 2009).

Moreover, the amplitude (the intensity of sound) in each syllables; SI, SM and ST of the advertising call, the comparison between during solitary period and during paired found that the amplitude of SI, SM and ST of the advertising call were not significantly different between during solitary period and paired period. Vocal amplitude or intensity of an acoustic signal could encode information to a receiver and can be important to repel rival males, as has been shown for anurans (review in Gerhardt and Huber, 2002), however, this study not found a significant difference in vocal amplitude between two status of male. This phenomenon may constrain by the limit of the vocal apparatus (Araya-Ajoy *et.al.*, 2009). Nonetheless, the outcome of this study differed from the result of a study in male Nightingales (*Luscinia megarhynchos*) that while interacting with the playback of a simulated conspecific rival, male Nightingales (*L. megarhynchos*) increased the sound level of their song, on average, by more than 5 dB (Brumn and Todt, 2004). Nevertheless, this study is still not showing obviously in this point that is require more studies examining social influences on vocal-level variation and effects of sexual selection to understand more thoroughly the role of vocal amplitude in birdsong.

Regarding the individual difference in all frequency parameters of the advertising call that indicated by the coefficient of variance (CV_w). The trend of the coefficient of variance of the advertising call during solitary period and during paired period was not obviously recognized in all frequency parameters except for fundamental frequency and maximum frequency which the coefficient of variance during solitary period was less than during paired period in fundamental frequency, in contrast, during solitary period was higher than during paired period in maximum

frequency. These results showed that the fundamental frequency was more consistent during solitary period. These phenomena may be caused by the amount of variability in frequency of syllable type performance that could be a signal of individual quality both during solitary period and paired period, with higher quality individuals showing less variability. Thus, individual males try to minimize variability among of each performance type (Botero *et al*, 2008). For example, in Tropical Mockingbirds (*Minus gilvus*) more consistent males tented to have higher dominant status and reproductive success (Betero *et al.*, 2008). In contrast, the maximum frequency was less consistent during solitary period. For instance, studies in the Zebra Finch (*Taeniopygia guttata*) indicated that variability in the structure of individual syllables is actively regulated and may serve a function, because male sing alone, the variability in syllable structure is elevated relative to sing to female (Sakata *et al*., 2008).

5. Number of syllables and number of harmonic

The call syllables play a role in mating behaviour (Hedrick and Weber, 1998). In this study found that number of syllable in each phrase of the advertising call was not significantly different between during solitary period and during paired period (Table 9). The number of syllable in the introductory phrase was stable, in contrast, the number of syllable in the middle phrase and the terminal phrase were varied. Especially, in the middle phrase, the number of syllable between during solitary period and paired period was nearly significant difference. The syllable number of the middle phrase of the advertising call during solitary period was higher than during paired period. It indicates that the number of call syllables in the middle phrase of the advertising call of Zebra Dove (*G. striata*) may affect a female preference. This particular characteristic may help to attract mates if they act as honest indicators of male quality. This result consistent with the result of Rufous-and-white Wrens that song sung by bachelor male were more syllabic diversity than the songs those male sang with pairing status (Hennin *et al*., 2009). In addition, in Pied Flycatcher (*Ficedula hypoleuca*) the number of figure (number of syllable) in the advertising call of paired males also became fewer than unpaired period (Espmark and Lampe, 1993).

Regarding the number of harmonic of syllable in advertising call of Zebra Dove (*G. striata*)(Table 10). The comparison the number of harmonic of syllable in each phrases of advertising call between during solitary and during paired period found that no significantly different. In addition, the number of harmonic of syllable in the introductory phrase was higher constant than the syllable in the middle phrase and the syllable in the terminal phrase that there was more different between during solitary and during paired period than the introductory phrase and the syllable in the middle phrase. The result in number of harmonic of the syllable in the terminal phrase was almost similar to the result in fundamental frequency of the syllable in the terminal phrase that was significantly different between during solitary and during paired period. Moreover, the number of harmonic of syllable in call could show a complexity of call. However, this result indicated that the pairing status did not affect the number of harmonic in the advertising call of Zebra Dove (*G. striata*). This finding confirmed to the result in Rofous-and-White Wren that the complexity of songs did not change with pairing status (Hennin *et.al.*, 2009).

CHAPTER 5

CONCLUSIONS

A total vocalization of captive male Zebra Dove (*Geopelia striata*) in the present study was found five call types, including the advertising call, the settling call, the courtship call, aggressive call and copulation call. Besides, the number of call types which were observed between solitary and paired period was different. During paired period was found five call types, whereas during solitary period was not found the copulation call.

The results from this study also showed that the component of call types; call rate, time duration, frequency of syllables, number of syllable and number of harmonic of syllable in call were different between two status of male group.

Firstly, the call rate among call types was significantly different both during solitary period and during paired period ($P<0.01$, $\chi^2 = 270.73$ and $P<0.01$, $\chi^2 = 326.38$ respectively). The call rate for call type during solitary period was highest in advertising call both during solitary period (0.96 %) and during paired period (1.22 %). However, there was not significantly different in call rate within call types between solitary and paired period in all call types.

Secondly, when all parameters of time duration were compared between duing solitary period and paired period of male did not find the dissimilarity in all of the parameters.

Thirdly, the fundamental frequency of syllables in the terminal phrase and the frequency of second harmonic of syllables in the middle phrase of the advertising call were significant difference between duing solitary period and paired period of male ($P<0.05$, $z = -2.060$ and $P<0.05$, $z = -2.207$ respectively).

Moreover, number of syllables and number of harmonic in each syllables of advertising call between solitary and paired status were not significant

difference in this study that the number of harmonic in all syllables during solitary period were more than during paired period.

Furthermore, the results also showed that the trend of the average individual coefficient of variance in most parameters of time duration and frequency within the advertising call during solitary period were higher than and paired period.

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APPENDIX

Table 1. Number of times that each call types occurred during solitary and paired period of male zebra dove (*Geopelia striata*).

Male No.	Period	Call Type	Date1			Date2			Total
			09.00-09.30	10.00-10.30	11.00-11.30	09.00-.9.30	10.00-10.30	11.00-11.30	
1	Solitary	1	6	-	4	1	-	10	21
		2	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-
		4	1	-	-	5	-	-	6
		5	-	-	-	-	-	-	-
1	Pair	1	6	1	1	3	-	-	11
		2	-	-	-	-	-	-	-
		3	-	-	-	-	1	-	1
		4	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-
2	Solitary	1	-	6	-	-	1	11	18
		2	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-
		4	1	-	-	-	-	-	1
		5	-	-	-	-	-	-	-
2	Pair	1	13	3	5	11	11	4	47
		2	-	-	-	-	-	-	-
		3	-	1	-	-	1	2	4
		4	2	2	2	-	1	3	10
		5	-	-	-	-	-	-	-
3	Solitary	1	1	4	-	-	2	1	8
		2	5	3	5	-	-	-	13
		3	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-
3	Pair	1	-	-	2	-	4	-	6
		2	3	-	8	-	1	-	12
		3	5	4	3	-	-	-	12
		4	-	-	-	-	-	-	-
		5	-	-	-	1	-	-	1

Table 1(Continued).

Male No.	Period	Call Type	Date1			Date2			Total
			09.00-09.30	10.00-10.30	11.00-11.30	09.00-.9.30	10.00-10.30	11.00-11.30	
4	Solitary	1	2	4	3	2	7	2	20
		2	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-
4	Pair	1	6	2	22	1	2	21	54
		2	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-
		4	-	-	-	13	1	-	14
		5	-	-	-	-	-	-	-
5	Solitary	1	6	1	2	5	1	4	19
		2	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-
		4	1	-	-	-	-	-	1
		5	-	-	-	-	-	-	-
5	Pair	1	26	-	5	3	-	-	34
		2	-	-	-	-	-	-	-
		3	3	5	3	1	-	-	12
		4	-	-	-	8	-	-	8
		5	-	-	-	-	-	-	-
6	Solitary	1	-	-	1	17	21	-	39
		2	-	-	-	-	-	-	-
		3	1	-	2	-	-	-	3
		4	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-
6	Pair	1	1	1	4	-	-	-	6
		2	-	-	-	-	-	-	-
		3	7	-	-	1	-	-	8
		4	-	-	-	-	-	-	-
		5	-	-	-	-	1	1	2

Table 2. Duration of syllable and pause of advertising call of male zebra dove (*Geopelia striata*) during solitary and paired period (SI= syllable in the introductory phrase, SM= syllable in the middle phrase, ST= syllable in the terminal phrase, SI-SM= pause between the introductory phrase and the middle phrase, SM-ST= pause between the middle phrase and the terminal phrase, WP= pause within phrase, TC= total call, measured in second (s)).

Period	Male No.	Parameters						
		SI	**SM**	**ST**	**SI-SM**	**SM-ST**	**WP**	**TC**
Solitary	1	0.208	0.053	0.272	0.348	0.185	0.154	1.220
	2	0.327	0.125	0.664	0.426	0.304	0.131	1.977
	3	0.229	0.038	0.171	0.258	0.214	0.177	1.087
	4	0.365	0.048	0.313	0.476	0.162	0.136	1.500
	5	0.220	0.075	0.243	0.359	0.313	0.206	1.416
	6	0.319	0.042	0.272	0.446	0.534	0.146	1.759
Pair	1	0.342	0.046	0.220	0.342	0.336	0.212	1.498
	2	0.345	0.045	0.235	0.470	0.510	0.127	1.732
	3	0.238	0.043	0.181	0.278	0.560	0.135	1.435
	4	0.406	0.042	0.383	0.493	0.162	0.127	1.613
	5	0.197	0.077	0.255	0.342	0.336	0.212	1.419
	6	0.383	0.063	0.201	0.481	0.249	0.162	1.539

Table 3. Frequency characteristic of advertising call of male zebra dove (*Geopelia striata*) during solitary and paired period measured in kilohertz (kHz).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Fundamental frequency	Solitary	1	0.86	0.92	0.94
		2	1.00	0.70	0.80
		3	0.80	0.74	0.78
		4	0.74	0.73	0.74
		5	0.77	0.62	0.77
		6	0.83	0.66	0.80
	Pair	1	0.80	0.76	0.94
		2	0.50	0.53	0.50
		3	0.80	0.80	0.76
		4	0.43	0.72	0.71
		5	0.77	0.73	0.74
		6	0.29	0.76	0.77

Table 3(Continued).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Minimum frequency	Solitary	1	0.51	0.51	0.51
		2	0.10	0.10	0.10
		3	0.10	0.30	0.15
		4	0.08	0.31	0.43
		5	0.08	0.46	0.08
		6	0.51	0.45	0.34
	Pair	1	0.34	0.34	0.34
		2	0.10	0.10	0.10
		3	0.10	0.13	0.18
		4	0.08	0.08	0.08
		5	0.34	0.46	0.34
		6	0.25	0.94	0.08

Table 3(Continued).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Maximum frequency	Solitary	1	4.65	3.20	3.10
		2	6.50	6.00	6.50
		3	6.50	3.51	3.42
		4	3.96	2.55	2.58
		5	4.13	2.67	2.67
		6	2.84	3.23	1.98
	Pair	1	4.22	2.64	3.74
		2	5.10	3.67	3.60
		3	6.80	4.77	4.72
		4	3.78	2.58	2.58
		5	4.22	3.07	3.96
		6	4.22	3.16	2.35

Table 3(Continued).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Frequency of first harmonic	Solitary	1	0.86	0.92	0.94
		2	0.10	0.70	0.80
		3	0.80	0.77	0.75
		4	0.77	0.74	0.77
		5	0.77	0.49	0.77
		6	0.86	0.75	0.77
	Pair	1	0.86	0.74	0.86
		2	0.50	0.53	0.50
		3	0.80	0.80	0.76
		4	0.86	0.71	0.68
		5	0.77	0.26	0.77
		6	0.86	0.77	0.77

Table 3(Continued).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Frequency of second harmonic	Solitary	1	2.58	2.80	2.84
		2	-	2.50	-
		3	-	2.44	2.35
		4	2.23	2.20	2.23
		5	2.32	2.32	2.32
		6	2.49	2.32	2.23
	Pair	1	2.41	2.26	2.32
		2	-	2.00	-
		3	6.20	2.40	2.46
		4	2.15	2.17	2.15
		5	2.32	2.20	2.23
		6	2.32	2.29	2.32

Table 3(Continued).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Amplitude	Solitary	1	-6.39	-6.53	-6.35
		2	-5.96	-6.04	-6.07
		3	-6.19	-6.50	-6.48
		4	-6.27	-6.47	-6.51
		5	-6.49	-6.62	-6.62
		6	-6.26	-6.67	-7.46
	Pair	1	-6.41	-6.78	-9.73
		2	-6.17	-6.33	-6.39
		3	-6.00	-6.34	-6.31
		4	-5.75	-6.53	-6.54
		5	-6.27	-6.47	-6.45
		6	-6.19	-6.51	-6.95

Table 4. Number of syllable and number of harmonic of each syllables in advertising call of male zebra dove (*Geopelia striata*).

Parameter	Period	Male No.	Syllable		
			SI	**SM**	**ST**
Number of syllable	Solitary	1	1.00	4.00	1.00
		2	1.00	4.00	1.00
		3	1.00	8.00	4.00
		4	1.00	3.00	1.00
		5	1.00	3.00	1.00
		6	1.00	4.00	2.00
	Pair	1	1.00	3.00	2.00
		2	1.00	3.00	1.00
		3	1.00	7.00	5.00
		4	1.00	3.00	1.00
		5	1.00	3.00	1.00
		6	1.00	3.00	3.00

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List of Publication and Proceeding

Proceeding

Oral presentation

Amnuay, P., Wattanasit, S. and Sitasuwan, N. 2010. Vocal Communication of Captive Zebra Dove (*Geopelia striata*, Linnaeus 1766). Proceeding of the 11th Graduate Research Conference. Khon Kaen University, Khon Kaen, Thailand, February 12, 2010. pp. 647-652.

Poster presentation

Amnuay, P., Wattanasit, S. and Sitasuwan, N. 2010. Vocal Communication of Captive Zebra Dove (*Geopelia striata*, Linnaeus 1766). Proceeding of Thailand Wildlife Seminar 30th. Faculty forestry, Kasetsart University, Bangkok, Thailand, December 17-18, 2009.

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