TÜRKİYE TABİATINI KORUMA DERNEĞİ
TABİAT VE İNSAN DERGİSİ
JOURNAL OF NATURE AND MAN
2022 1(190)

Physical characteristics and functional meaning of some vocal signals in white-spectacled bulbul (*Pycnonotus xanthopygos*)

Aziz Aslan
Akdeniz University, Faculty of Education, Basic Training Department, Antalya, Turkey
aaslan@akdeniz.edu.tr

Bekir Kabasakal
Antalya Bilim University, Vocational School of Health Services, Antalya, Turkey
bekir.kabasakal@antalya.edu.tr

Deniz Şirin
Tekirdağ Namık Kemal University, Faculty of Arts and Science, Biology Department, Tekirdağ, Turkey
dsirin@nku.edu.tr

Referans: Aslan A, Kabasakal B, and Şirin D (2022) Physical Characteristics and Functional Meaning of Some Vocal Signals in White-Spectacled bulbul (*Pycnonotus xanthopygos*)**.** Tabiat ve İnsan, 1(190), 31-41.

Physical Characteristics and Functional Meaning of Some Vocal Signals in White-Spectacled bulbul (*Pycnonotus xanthopygos*)

Abstract
The study aimed to determine physical characteristics and meaning of different vocal signals of the White-spectacled Bulbul, *Pycnonotus xanthopygos*, during breeding seasons. Six types of signals were identified in relation to their behavioural context as territory, localisation, alarm, foraging, greeting, and resting. The carrier frequency of the signals varied between 1.27 (min) to 5.35 (max) kHz, and differed between signals as well as shape, number of syllables and elements. Results of the study have shown us information about the vocal communication system of the species, and furthermore, it was determined that the White-spectacled Bulbul could be a good model species to study both acoustic and behavioural topics since they are habituated to human disturbance.

Anahtar Kelimeler: *Pycnonotus xanthopygos*, the white-spectacled bulbul, bioacoustics, vocalization

Arap Bülbülü'nde (Pycnonotus xanthopygos) Bazı Seslerin Fiziksel Özellikleri ve İşlevsel Anlamı

Özet
Çalışmada, Arap bülbülü, *Pycnonotus xanthopygos*'un üreme mevsimlerinde kullandığı bazı ötüşlerin fiziksel özellikleri, bu ötüşlerin hangi durumlarda kullanıldığı ve ne anlama geldiğinin belirlenmesi amaçlanmıştır. Sıklıkla sergilenen ötüşlerin teritoryal, lokalizasyon, alarm, yiyecek arama, selamlama ve dinlenme süreçlerinde 6 farklı sinyal şeklinde kullanıldığı belirlenmiştir. Sinyallerin taşıyıcı frekansı 1,27 (min) ile 5,35 (maks) kHz arasında değişmekte ve sinyaller arasında olduğu kadar şekil, hece sayısı ve elementler arasında da farklılıklar olduğu tespit edilmiştir. Arap Bülbülü'nün sergilemiş olduğu iletişim sistemi hakkında bilgi elde etmenin yanısıra, yerleşim alanlarında yayılış göstermesi ve dolayısıyla insana alışık olması itibariyle hem akustik hem de davranışsal konuları incelemek için iyi bir model tür olabileceği sonucuna varılmıştır.

Keywords: *Pycnonotus xanthopygos*, arap bülbülü, biyoakustik, vokalizasyon

1. INTRODUCTION

In songbirds, visual and acoustic communications are important. In the most of studies on bird acoustic communication are dealing with song and its role in inter and intra sexual selection (Andersson 1989; Andersson et al. 2002). However, vocalisation is used in a variety of contexts e.g. it may be used to trigger specific behaviours, in conspecific interactions, for individual or species recognition, to advertise status (e.g. reproductive, dominance or territorial), begging for food, to warn against predators, coordinate or synchronize reproductive efforts (e.g. courtship, copulation solicitation, physiological synchrony) (Wilson 1980). Comparatively few studies deal with acoustic communication other than male song (Kroodsma, Miller 1996; Kumar 2003; Sharp, Hatchwell 2006) and therefore, we concentrate on acoustic communication other than song in the White-spectacled Bulbul, *Pycnonotus xanthopygos*.

The White-spectacled Bulbul, *Pycnonotus xanthopygos* (Hemprich, Ehrenberg 1833), is a small (L 19-21cm, W 38-40g), socially monogamous passerine and does not show substantial sexual dimorphism (Roselaar 1995; Aslan 2005). In Turkey, the occurrence of the species is

exclusively restricted to the Mediterranean region and its habitat is mainly parks, palm groves, fruit gardens, scrubs, open and mixed forest lands at low altitudes up to 1500 m asl (Roselaar 1995; Mullarney et al. 1999; Aslan, Erdoğan 2004, 2007; Aslan 2005, Aslan et al. 2017). The White-spectacled Bulbul leaves in urban areas and is therefore habituated to human beings, allowing easy observations and acoustic recordings without disrupting them. There is almost nothing known about acoustic communication in the White-spectacled Bulbuls (Aslan 2005, Aslan et al. 2017). However, there are some studies investigating behaviour in particular singing behaviour, and taxonomic status of some related *Pycnonotidae* species (Kumar, Bhatt 2000; Sotthibandhu 2003; Kumar 2004; Yamasaki 2006).
Our aim was to identify different vocalisation types using physical characteristics and to determine their functional importance. To do that we recorded vocalisations and the behavioural context or ecological situation in which the signal was produced in the breeding territories of this species.

2. METHOD

The study was conducted in the Campus of Akdeniz University (36°54'N and 30°39' E in Antalya), which is about 3.7 hectare of scrub land, interspersed with gardens, lawn, and park areas (Aslan 2005, Aslan et al. 2017). In average each pair of White-spectacled Bulbuls was observed in their territory for two hours a day (between 06:00-09:00 and 16:00-19:00). The Nikon (8x40) binoculars, a Canon EOS 7D Mark II photo camera, Sony TRV 700X digital camera and a Sony tape recorder and stereo microphone were used in the field survey. To follow and record different types of signals, 22 pairs and their offspring (10 day-old) were colour ringed for individual identification. Pairs were trapped in their territories using mist nets after ringing immediately released (Erdoğan et al. 2003; Aslan et al. 2004, Aslan et al. 2017).
All recordings were taken from 10-15m distance from vocalising birds using a Sony tape recorder (WM-GX51) and stereo microphone, which is able to record signals between 1-14 kHz. Signals were transferred to a personal computer and digitized at 44100 Hz with 16-bit precision, band-pass filtered between 0 and 1, or 6 and 10 kHz to eliminate urban background noise and stored as individual computer files. Spectrograms used for measurements were produced with a 512-pt. FFT (frequency resolution 55 Hz, time resolution 2.90 ms, Hamming window, and 87.5% overlap) using Syrinx-PC for Windows Version 2.3s, software for spectral analysis, editing and playback of acoustic signals (www.syrinxpc.com). All measurements were taken using Syrinx' built-in measurement cursors.
To define variation in acoustic signals we followed Catchpole and Slater (1995) and Leader et al. (2000). Vocalizations have usually divided into calls and songs in birds (Catchpole, Slater 1995). In general, both sexes use calls as non-sexual social, and in contrast, males use songs as sexual communication signal (Kumar 2003; Marler 2004). Calls are vocalizations that are usually uttered in single elements, whereas song might contain more than one phrase including discrete units (Catchpole, Slater 1995; Bhatt et al. 2000; Kumar 2003). In spite this, it is not easy to discriminate song and calls and thereof, we used vocal signals rather than songs or calls. Each vocal signal was divided into different phrases as element and syllable. An element is an unbroken mark on a spectrogram and a syllable is a repeated portion of one or more elements. Duration, frequency range, number of syllable and elements, and gaps between elements and syllables of vocal signals were taken from spectrograms. Seconds (sec) or milliseconds (msec) were used for description of signals.

3. RESULTS

Based on our vocal samples of the White-spectacled Bulbul, we could identify six signal types. Samples were pooled because they are coming from different pairs (individuals). In relation to their behavioural context, we could describe their function in relation to territoriality, alarm, localisation, foraging, greeting, and resting. The territorial and alarm signals were uttered to inform and defend the territory against conspecifics; localisation (contact) and feeding signals were used to localize family members and to find them; greeting signals were used by males when meeting the mate; and during resting both sexes produce resting signal. In overall, 300 hours of tape recordings were digitized, and 246 signals could be used for the analysis. Of those, 58, 82, 41, 17, 32 and 16 of them belonged, in relation to behavioural context, to territoriality, alarm, localization, greeting, foraging and resting, respectively. The identified vocal signals differed in carrier frequency (e.g., between 1.27 to 5.35 kHz), shape and number of elements, and syllables.

3.1. Territorial signal

The carrier frequency of the territorial signal varied between 2.01-3.7 kHz. For each phrase the number of syllables varied between 3 to 4 (Figure 1). The duration of syllables from two-, three- and four-elemental phrases were measured within 533-560 (547±9, n=16), 904-1210 (1038±87, n=22) and 506-552 (526±15, n=20) msec, respectively.

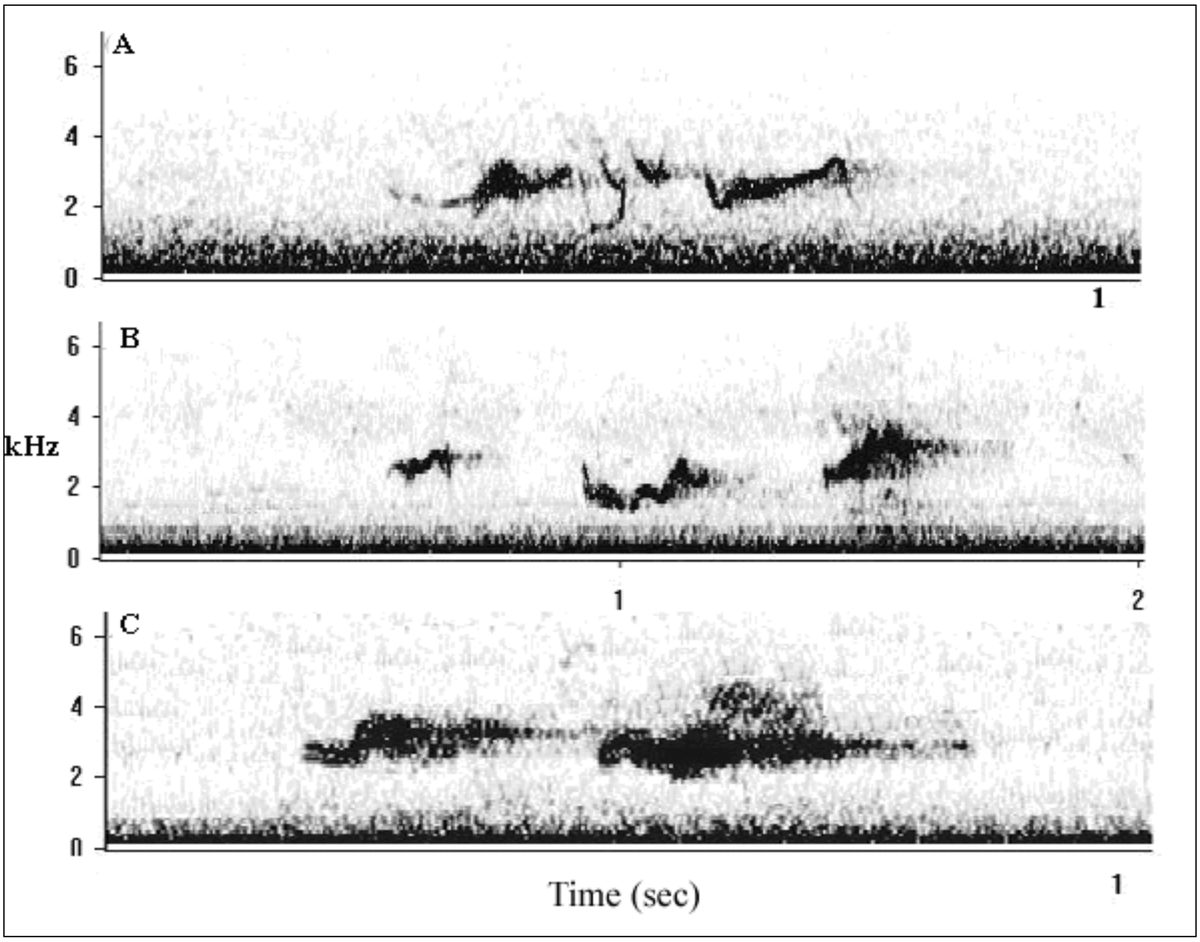

Figure 1. Syllables of territorial signal with two (A), three (B) and four (C) elements.

3.2. Alarm Signal

The alarm signal consisted of phrases that last about 7.5-9.5 (8.39±0.6) sec. Their carrier frequency varied between 1.4-4.7 kHz. For the first type of alarm signals we found twelve syllables within a time interval of 8 sec (see Fig. 2a) and each syllable consisted of one to three elements; The second type of alarm signal (Figure 2B) contained 4 syllables consisting of 4 to 5 elements; and the last type (Figure 2C) has more syllables and consisted of two up to seven elements and end with a trill. The length of syllables increased based on the number of elements, which were determined within 58-744 (576±206, n=82) msec. The length of the trill takes among 250-300 (279.6±54.7, n=25) msec.

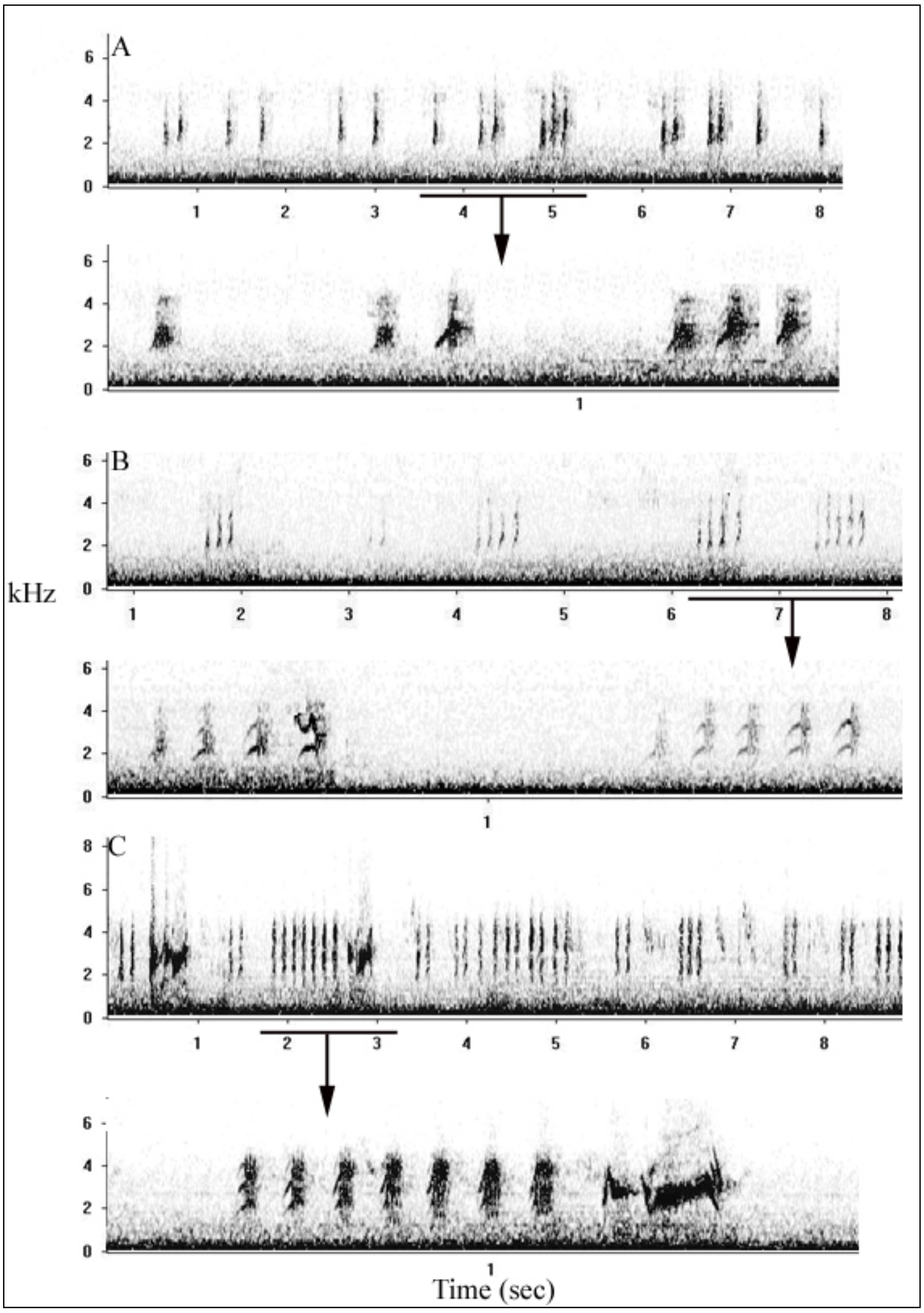

Figure 2. Spectrogram of alarm signals (A: syllables with one to three elements, B: syllables with four to five elements and C: syllables with two to seven elements ending with a trill.

3.3. Localisation signal

The localisation signal has three elements (Figure 3) and lasts for 11 sec. However, the length of the phrase might be longer depending how frequently repeated. The frequency of the phrase ranges from 1.4 to 3.4 kHz, and the duration of syllables was measured within 1010-1202 (1123±55, n=126) msec.

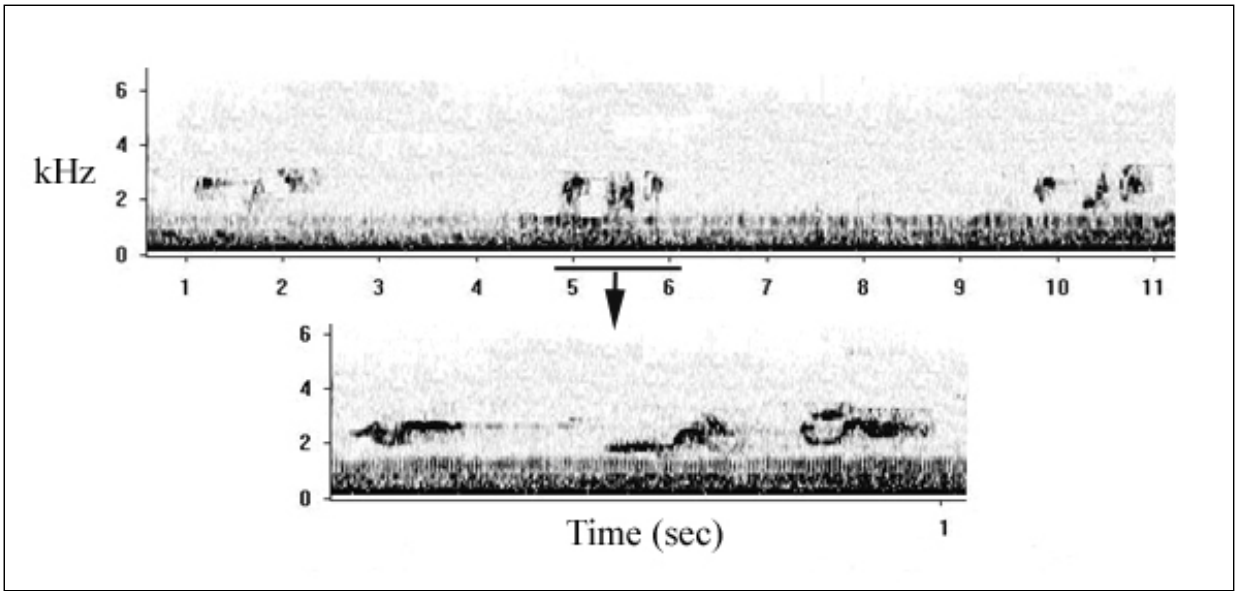

Figure 3. The spectrogram of localisation signal

3.4. Foraging signal

The carrier frequency of the feeding ranged between 1.3 to 3.6 kHz and phrases lasted about 1696-1900 (1815±55) msec. The syllables of a strophe were formed by two elements (Figure 4) and the duration of each syllable was about 350-400 (372.2±16, n=128) msec.

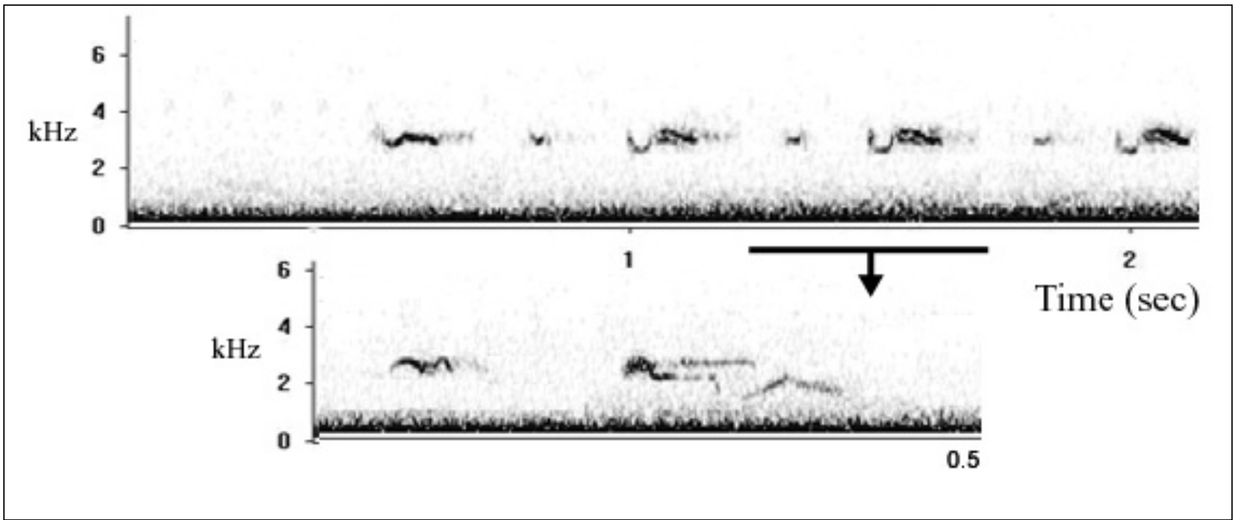

Figure 4 The spectrogram of foraging signal

3.5. Greeting signal

This signal was quite complex and formed with phrase of at least ten elements (Figure 5). The phrase lasted about 7.25-10.47 (8.86±1.98) sec. or could be even longer. The carrier frequency of the signal occurred between 1.27-5.35 kHz, the number of elements varied from nine to twelve per syllable and duration of syllables was measured within 860-1270 (978±115, n=34) msec.

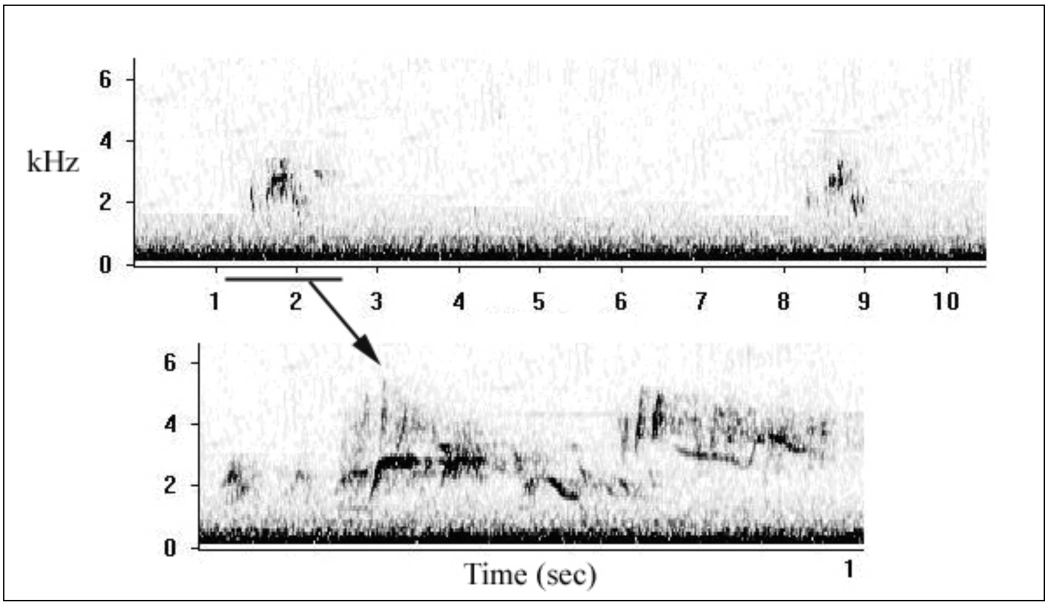

Figure 5 The spectrogram of greeting signal

3.6. Resting signal

The resting signal was usually uttered at perches or branches after foraging. A phrase consists of syllables that were formed by two elements (Figure 6). The carrier frequency of the signal was between 1.98-4.33 kHz. Syllable length varied between 321 and 333 (327±4, n=32) msec.

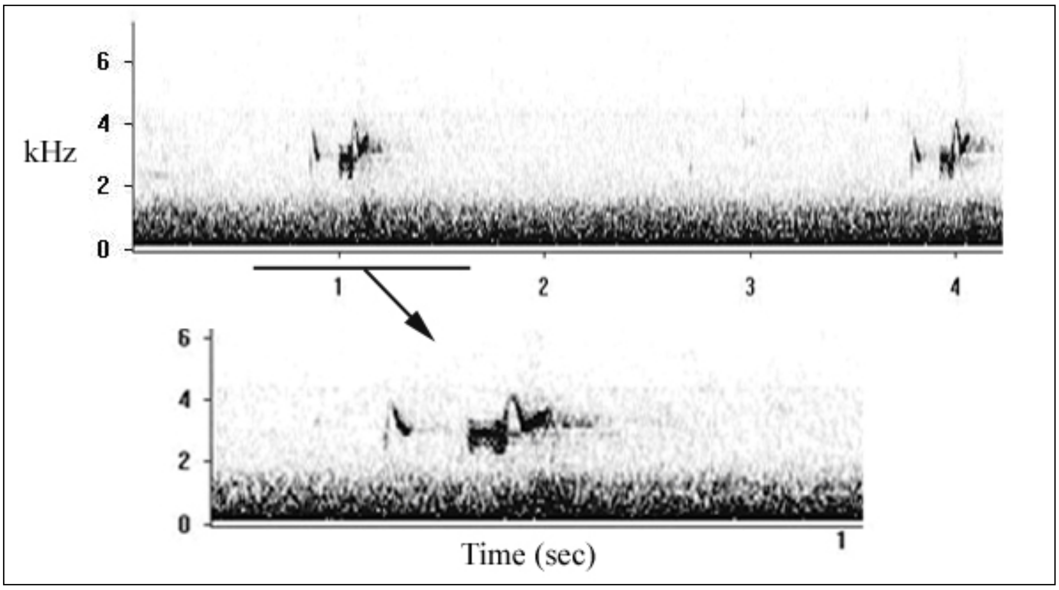

Figure 6 The spectrogram of resting signal

4. DISCUSSION

We found that the vocalization of the White-spectacled Bulbul consists of at least six signal types with different meanings which are used to coordinate breeding activities and for communication between family members during the breeding, but they are probably also used throughout the rest of the year (Aslan 2005, Aslan et al. 2017). Both of males and females of the species uttered alarm, location, feeding and resting signals, which are known that produced by both gender of some songbirds' species (Kumar 2004; Brunton, Li 2006), but territorial and greeting signals displayed only by males within breeding season. Range of frequency of analyzed signals located between 1.27 to 5.35 kHz, and elements of each signal are distinctive and have various shapes (see figures), and these are expected results that have been showed for number of songbirds (Lloyd et al. 1996; Kumar, Bhatt 2000; Seddon et al. 2002; Kumar 2004). In songbirds' territorial signals is usually uttered to advertise a territory, to repel intruders and mark territory boundaries (Catchpole 1979). That *Pycnonotus* species use vocalizations in relation to territoriality has been already mentioned by some other authors (Sotthibandhu 2003; Lloyd et al. 1996). In the White-spectacled Bulbul, three types of territorial signals were determined and the phrase consisting of four-elemental syllables (see figure 1A) was used in short intervals for territorial advertisement during territory establishment early in the season. However, the second type (see figure 1B) was used during incubation and chick feeding period with middle long intervals and the third type (see figure 1C) was mainly used at the end of the breeding cycle with long intervals.

It is well established that birds use different types of alarm signals (= calls) to warn mates, conspecifics, or other species in relation predator risk (Klump, Shalter 1984; Fucken, Popp 1996; Kumar, Bhatt 2000). The elements of the alarm signal of the White-spectacled Bulbul resemble the type I of simple alarm calls described by Kumar (2004) for the Red-vented Bulbul but the alarm calls of the *P. xanthopygos* have a narrower frequency range (1.4 to 4.47 kHz) than of *P. cafer* (0.94 to 7.00 kHz). Figure 2 shows that *P. xanthopygos* exerted monotypic elements in groups of usually 1 to 7 or sometimes even more elements. We could not identify any differences in its functional meaning (context of different behaviours or predators) but the alarm type depends clearly on the strength of the threat, e.g. the alarm signal with the most elements and the final trill were given in serious danger when the predator is about to attack the nest. A territory of the White-spectacled Bulbul could be divided into two sections: the breeding area in centre and the foraging area around it (Aslan 2005). The first type of alarm signal was given when a predator enters the breeding area. In such a situation, the White-spectacled Bulbul first used syllables with one to three elements (Figure 2A); if the danger persists, the signal becomes stronger, and the Bulbuls uttered syllables with four and five elements at shorter intervals (Figure 2B); and the last type was producing when the parents became aware of the predator which was about to attack their nest. At that time, both males and females dived on predators using strong alarm signals repeatedly, which was a combination of syllables with two to seven elements and ending on a trill (Figure 2C) and means as a song phrase at the end of the signal (Kumar 2004).

Both sex of the White-spectacled Bulbul used a clear localisation signals (=calls), which was mainly advertised during the breeding and sometimes also during the non-breeding season. Localization signals are frequently used by both sexes and during the whole year (Catchpole, Slater 1995) but the meanings of these calls are not always clear (Collias 2000; Marler 2004). We could argue that localization signals (location and feeding) of the species provided knowledge about location and food places and allowed individuals to identify each other, and therefore interceding breeding activities and social coactions between mates and offspring. There was a weak difference in the frequency range of these signal types and their length depends on repetition. However, they differ in shape, element numbers and gap lengths between syllables. The frequency range of the contact signals of the *P. xanthopygos* lies between 1.3 to 3.6 kHz and is similar to those of *P. cafer* (1.8 to 3.7 kHz) (see Kumar 2004).

The greeting signal was only exerted by males and the resting by both sexes. The greeting and resting signal do not only differ by their function but also their physical characteristics like element shape, number, interval length between elements and syllables and frequency range. In this species only the females incubate, and the males meanwhile guard the territory. During incubation breaks, females search for their partners to forage and on such occasions when they meet, males exerted this strong melodious greeting signal (=song). This vocal greeting signal was also described for some other *Pycnonotus* species from South Africa (Lloyd et al. 1996) and India (Kumar 2004). In addition, this greeting signal was described as a complex call by Kumar (2004) but there are some differences between these calls of two species e.g. differences exist in the frequency range, element shape and number. It was stated by Kumar (2004) that the function of these calls was to maintain social contact between individuals which is also supported by our own observations. In songbirds such greeting signals were mentioned to be frequently used by juveniles at the first year during the process of song learning (Kroodsma, Miller 1996). Kumar, Bhatt (2000) found no age or sex specific variation in the production of greeting calls in the Red-vented Bulbul. Our result also supports this finding since our males produced this type of vocalization also outside the breeding season.

In conclusion, vocal production in birds is not just male singing behaviour in relation to sexual selection. Birds usually have a variety of ways for vocal experession and communication. In this study, we found that White-spectacled Bulbul use different vocal signals in different contexts and these signals are separated by physical characteristics. Results from this study suggest that the White-spectacled Bulbul could be a model species to study both acoustic communication system and behaviour of birds. It is tolerable to human existance in urban areas, allowing easy observation and easily kept in cages for further experiments.

Acknowledgements

The study supported by The Scientific and Technological Research Council of Turkey (TUBITAK) under project no: 212T111 and Akdeniz University Scientific Research Projects Coordination Unit under project no: FDK_2014_91. We thank H. Hoi and A. Kumar for their valuable comments on the draft manuscript. We also wish to thank numerous students and volunteers helped us to collect data during the study.

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