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THE VOCAL REPERTOIRE OF THE EURASIAN STONE-CURLEW (*BURHINUS OEDICNEMUS*)

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ABSTRACT.—We collected behavioral observations and recordings of adult Eurasian Stone-curlews (*Burhinus oedicnemus*) in central and northern Italy, and of chicks in northern Italy. Eurasian Stone-curlews are highly vocal during spring and summer, and vocalize routinely, but less frequently, during fall and winter nights. Adult Eurasian Stone-curlews have a complex and relatively wide vocal repertoire composed of at least 11 different call types and some subtypes. Two of these calls (*Kurlee* and *Gallop*) are the most used and important; the *Kurlee* call is uttered year-round, while *Gallop* is uttered usually during the breeding season with a peak in spring. Adult vocalizations are structurally diverse; call syllable duration spans from < 0.1 to > 1.1 sec and average center frequency is between 2,190 to 3,037 Hz. The highest frequency is associated with a high intensity alarm call; some adult vocalizations can be compared to the loud rhythmically repeated calls which often occur in several species of Charadrii and Scolopaci. Five call types are used in well-defined circumstances suggesting specialized functions; the remaining calls are used mostly in combination with other call types, particularly *Kurlee* and *Gallop* calls. There are preferred and typical call combinations, which cannot be explained as random choices. We identified two main call types for chicks, which are completely different from adult calls and are developed before hatching. Juveniles up to 70 days of age utter these calls without major changes. We discuss preliminary data on vocal ontogenesis, as well as correspondences and differences between our findings and the existing literature on the adult repertoire. *Received 16 January 2012. Accepted 15 July 2012.*

Key words: Burhinidae, call functions, call syntax, Eurasian Stone-curlew, vocal ontogenesis vocal repertoire.

Vocalizations of non-passerines are typically simpler than those of passerines, especially of oscines. However several species use fairly complex calls with territorial and sexual functions, including chickens (Collias 1987), grebes (Nuechterlein and Buitron 1998), and owls (Galeotti and Sacchi 2001, Lengagne 2001); these calls are functionally analogous to passerine songs. Repertoires are large and complex in some groups (e.g., Galliformes; Marler and Slabbekoorn 2004). The size of avian vocal repertoires is variable; some species of both passerines and non-passerines have small and others have large repertoires, however, few species have been intensively studied. Marler and Slabbekoorn (2004: 132) indicate ''You have to be intimate with the entire behavior of a species… throughout the life cycle, to give a reliable estimate of call repertoire size; and assembling such a catalog is by no means straightforward. There are always problems about where boundaries between call categories should be drawn…'' Knowledge of the vocal repertoire is important for understanding a species' communication system (Marler and Slabbekoorn 2004) and for investigating display evolution.

Miller and Baker (2009) indicate Charadriiformes are attractive for investigating evolutionary change in vocal displays because: (1) their phylogeny is quite well resolved (Paton and Baker 2006, Livezey 2010 and references therein), (2) many species have loud and diverse vocal repertoires (e.g., Miller 1996, Sung et al. 2005), and (3) their vocalizations often show little geographic variation, suggesting they are not learned (Miller 1996; but see Adret 2012). However, analysis is hindered by the poor available information regarding acoustic repertoires and structure of several species, especially those belonging to the most ancient families such as the Burhinidae (Miller and Baker 2009).

The Eurasian Stone-curlew (*Burhinus oedicnemus*) is a secretive and cryptic species with nocturnal habits, which largely relies on acoustic communication during the entire annual cycle (Cramp and Simmons 1983). The species' habits make the study of its vocal behavior difficult, which explains the sparse literature. Cramp and Simmons (1983) and Vaughan and Vaughan-Jennings (2005) provide the most recent and detailed but incomplete

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accounts of the species' calls. For example, many calls have only an onomatopoeic description without spectrographic documentation, and there are almost no data on the chicks' voice except for anecdotal reports. Additional spectrograms and descriptions are in Rasmussen and Anderton (2005) and Bergmann et al. (2008), but the overall repertoire is incomplete and no indications of possible functions are provided for several calls. Our objective was to document the vocal repertoire of the Eurasian Stone-curlew throughout the life cycle and throughout the year. The data reported are important to advance knowledge of the vocalizations of Charadrii and for future comparative studies.

METHODS

Adults.—Data on the seasonal pattern of Eurasian Stone-curlew vocal activity were obtained from field notes by the authors and experienced volunteers from 2000–2010 in the Grosseto area (southern Tuscany, Italy; 42° 45′ N, 11° 06′ E), which hosts consistent nesting and wintering populations (Tinarelli et al. 2009, Giovacchini et al. 2012). These opportunistic observations (n = 692) reported date and time, locality, number of birds, call type and, when possible, behavior of calling birds. We believe that, even though the data were not collected following a predetermined schedule, the results are representative considering the extended study period, large study area, and number of observers (n = 19). It is difficult even for experienced people to consistently classify all call types by ear, and we used field notes only to examine the seasonal pattern of (1) overall vocal activity, and (2) the easily distinguished call type (*Gallop*). Twenty-six observations were not considered in the *Gallop* call analysis because the call type was not specified.

We recorded 213 adult Eurasian Stone-curlews around Grosseto, Italy throughout the year from 2004–2011. Recordings were made at night from 1730 to 2300 hrs and before dawn from 0400 to 0600 hrs CET. A few adults (n = 15) were recorded in Taro River Regional Park (Parma, Italy; 44° 74″ N, 10′° 17″ E) during the reproductive season; the total number of recordings of adults was 228 (mean ± SD duration = 132 ± 129 sec). We used a Marantz PMD 222 cassette recorder or a Fostex FR2 digital recorder, with an Audiotechnica AT815B shotgun microphone or a Telinga 22″ parabolic dish plus Sennheiser ME62 microphone. We digitized recordings using a standard audio chip of a personal computer (PC) with 48 kHz sampling frequency and 16-bit accuracy. Spectrograms were made in SeaWave Version 1.1 software (Pavan 2003) with the following parameters: FFT size = 2,048 points, window type = Gaussian, overlap = 87.5% (frequency resolution = 23 Hz, time resolution = 5 msec).

We primarily recorded spontaneous vocalizations of undisturbed wild adults (n = 164). An additional 64 recordings were made as a part of a monitoring study to assess the species' winter abundance around Grosseto (Giovacchini et al. 2012). We played back two different call types (*Kurlee*, *Gallop*) at night during the latter study at 140 different locations in December and January from 2004–2007. Each call was played for 1 min, followed by 3 min of listening time. We performed two of these 4-min sessions at each location and recorded and analyzed all vocal responses by Eurasian Stone-curlews. We used playback because it helps elicit behavioral or vocal responses (Marion et al. 1981, Tinarelli et al. 1991, Bibby et al. 2000, Giunchi et al. 2009).

We assessed how frequently each call was used with two measures (Table 1): (1) percent of birds that uttered each call over the total birds recorded (if a bird uttered multiple call types, it was scored for each category), and (2) percent of time each call was used over the total time spent calling. Call duration was calculated with the following criteria: when a given call was uttered alone or alternated with other different call types or uttered repeatedly at irregular and generally long intervals, the duration was the actual call duration. When the same call type was repeated several times at a regular rate creating a call series, the call duration referred to the entire series (call durations + silence between calls, which is generally short). Thus, a call series requires at least three calls uttered at a regular rate. This procedure was also used for calculation of total time spent calling. Call identification and classification were performed following at least two of these criteria: (1) a temporal gap between preceding and subsequent calls, sufficiently large to suggest the considered vocalization was not part of a more complex utterance; (2) a clear and evident difference in spectrographic morphology; (3) evidence of a functional and/or behavioral effect; and (4) correspondence with a well-known call category already described by different authors. These criteria are not fully objective,

TABLE 1. The vocal repertoire of the adult Eurasian Stone-curlew (% of birds = percentage of birds which uttered one or more times one particular call type over the total birds recorded; % time = percentage of time for each call type and call series over total time spent calling, excluding silences; duration = call duration expressed as mean ± SD and calculated considering call series duration).

Call type	Spontaneous vocalizations			Playback vocalizations			Playback + spontaneous vocalizations		
	% birds (n = 164)	% time (total time = 2,903 sec)	Duration (sec)	% birds (n = 64)	% time (total time = 1,536 sec)	Duration (sec)	% birds (n = 228)	% time (total time = 4,439 sec)	Duration (sec)
Kurlee	41.5	36.4	5.5 ± 3.91	51.5	18.6	5.0 ± 3.78	46.1	28.6	5.3 ± 3.86
Gallop	11.6	35.0	34.8 ± 36.99	60.9	67.7	28.8 ± 22.47	25.4	49.3	30.4 ± 26.88
Strangled Call	28.1	8.9	3.4 ± 5.26	21.9	6.9	9.5 ± 19.24	26.3	8.0	4.6 ± 9.61
Bitonal Whistle	25.6	6.1	1.9 ± 2.56	29.7	3.8	2.2 ± 2.41	26.7	5.1	2.0 ± 2.49
High-frequency Trill	13.4	6.2	5.3 ± 3.88	7.8	1.0	4.9 ± 3.27	11.8	4.0	5.2 ± 3.67
Simple Whistle	19.5	2.3	1.1 ± 1.46	17.2	0.8	1.1 ± 1.01	18.9	1.7	1.1 ± 1.36
Whit Call	15.2	1.7	1.5 ± 1.13	9.3	1.1	2.1 ± 0.77	13.6	1.4	1.7 ± 1.07
Polytonal Whistle	11.0	1.3	0.7 ± 1.15				11.0	1.3	0.7 ± 1.15
High-frequency Whistle	9.1	1.2	1.6 ± 1.56				9.1	1.2	1.6 ± 1.56
Intro Trill	3.7	0.8	1.5 ± 0.91	4.7	0.1	1.0 ± 0.42	3.9	0.5	1.3 ± 0.81
Answer-to-Chick			0.3 ± 0.23						0.3 ± 0.23

but we believe they are useful to reduce the subjectivity rooted in every classification of bird calls.

Chicks.—Calls and vocal interactions between adults and their offspring were studied in Taro River Regional Park, where > 80 pairs of Eurasian Stone-curlews breed, mainly in a dry gravel riverbed (Caccamo et al. 2011). Some chicks (n = 10) were recorded in unconstrained conditions by a hidden recordist ~10–15 m from birds using the Telinga parabola. Most chicks (n = 66) were recorded in a wood enclosure (35 × 35 × 37 cm) after we banded them (we placed a Sennheiser M67 shotgun microphone 30 cm from the enclosure, connected to a Sony Mini Disc MZ-R30 or a Fostex FR2-LE digital recorder). The wood enclosure was placed in the chicks' nest territory, so chicks could hear adults. Some chicks (n = 14) were recorded twice, on average 9.4 days apart (range = 9–12 days). The age of recorded chicks was 10–30 days (Dragonetti et al. 2012). We recorded two chicks > 30 days of age (ready to fledge) while they were in an external aviary of CRASM-WWF (recovery center for wild animals) of Grosseto Province (recording distance = 3 m). The number of calls analyzed for each chick varied between 25 and 150.

Audio tracks were digitized at 44.1 kHz sampling rate with 16 bit accuracy and stored on a PC. Recording sessions lasted 15 min on average. Tracks were digitized and spectrograms made as for adults, except we used 1,024 FFT size and 75% overlap, producing 23-Hz frequency resolution and 11 msec time resolution. Power spectra of chick calls were obtained using the function meanspec in the Seewave package (Sueur et al. 2008) in the R environment (R Development Core Team 2011). This function returns the mean frequency spectrum of a sound sample; parameters of the meanspec function were: sampling frequency = 44,100 Hz, FFT window length = 1,024 and range of frequency axis = 1–10 kHz.

We included recordings of pipping eggs (n = 5) collected just before hatching in Taro River Regional Park and in the Grosseto area. Recordings were made with a Telinga parabolic dish, Sennheiser ME62 microphone, and Fostex FR2 recorder placed ~2 m from the egg. This allowed us to minimize interference of unwanted sounds and background noises.

Quantitative Acoustic Analysis.—We used only good quality recordings (signal to noise ratio > 3) of spontaneous vocalizations and discarded recordings or parts of them containing background sounds which could interfere with the analysis (e.g., Orthoptera stridulation, frog calls, owl calls). The selected recordings were submitted to bandstop filtration from 0–1 kHz to clean background noise (e.g., wind and road sounds). We randomly selected three calls for each available call type for each recording; call types were identified by examining the spectrographic morphology and the specified criteria. We selected five samples for *Gallop* and *C-call*.

We used the Seewave package (Sueur et al. 2008) to measure first and third frequency quartiles, peak frequency (frequency with the maximal energy), center (median) frequency, and duration of each call type using the functions: specprop (for quartiles and center frequency), fpeaks (for peak frequency), and timer (for call duration; amplitude threshold = 1). We did not analyze three rare vocalizations (*Intro Trill, Answer-to-Chick, S-call*) because the sample size was too small.

RESULTS

Adults.—Eurasian Stone-curlews use calls throughout the year with a minimum in January, a peak in early spring and a second peak in summer; substantial activity also occurred in autumn (Fig. 1). We identified 11 main call types (Table 1; Figs. 2–5) of which some have >1 subtypes. All calls, where not specified otherwise, were uttered on the ground and in flight. The *Kurlee* call is the most common vocalization; long bouts of *Gallop* call also were common, especially after playback. *Strangled Call*, *Bitonal Whistle*, S*imple Whistle*, *High-frequency Trill*, and W*hit Call* were less common, and the remaining types were rare and sampled only in particular contexts. Many winter recordings were made after playback, but birds also vocalized spontaneously in winter, mainly after sunset, when they left their diurnal roosting areas to forage.

There are three variants (Fig. 2A) of the *Kurlee* call: (1) *Rolled Kurlee*, a three-part version with a trilled central part; (2) *Bitonal Kurlee*, like the former but lacking a trill; and (3) *Strangled Kurlee*, a less common three-part type with a middle strangled portion. Quantitative data (Table 2) suggest the three subtypes share most frequency characteristics, except for *Strangled Kurlee* which has a slightly reduced interquartile range. However, there are differences between central elements of the *Rolled* and *Strangled* subtypes (Fig. 3), as shown by the power spectra of the central elements of two sample calls. The *Rolled Kurlee* is characterized by a well-defined peak frequency correspondent to the pulsating (trilling) elements, while the *Strangled Kurlee* has a wide band spectrum which obscures the trilled elements. The *Bitonal Kurlee* was recorded alone in 37% of cases (n = 395); this form occurred in the other 63% of *Kurlee* bouts with other *Kurlee* forms, at the beginning (50%), end (9%), or within (4%) the bout. *Strangled Kurlee* and *Rolled Kurlee* were usually preceded or followed by *Bitonal Kurlee* or other call types. The *Kurlee* call is uttered year-round; we recorded it in breeding areas and after playback and at winter or autumn roosts. It selectively stimulated chick response.

The *Gallop* call (Fig. 2B) is variable in number of syllables and frequency range. Some authors categorize the bisyllabic variant of *Gallop* as a separate vocalization (Table 3); however, we often recorded mixed bi- and polysyllabic *Gallop* calls (Fig. 2B). Frequency parameters of the bisyllabic variant are slightly higher than those of the polysyllabic call (Table 2). The *Gallop* call, when given spontaneously, is uttered usually during the breeding season with a peak in spring (Fig. 1B) and sustained activity in summer; it is rarely uttered at pre-migratory fall roosts. Playback of this call often elicited a strong response of the same call type (Table 1). *Gallop* call bouts uttered spontaneously during the breeding season are at times preceded or followed by other call types, such as *Strangled call*, *Bitonal Whistle*, *Whit Call*, *High-frequency Whistle*, and *Kurlee*.

The *Strangled Call* is a strangled soft drawn-out sound ending with a sharp high-frequency note (Fig. 2C). It can be heard at close quarters and often is repeated in series of variable length. This call is given on the ground and not in flight. It is given year-round, either spontaneously or after playback. The *Strangled Call* is usually (65% of recordings, n = 185) given in combination with other call types (Fig. 2D): in 35% of cases, it ended a *Kurlee* bout, in 7% it opened a *Kurlee* bout, in 6% it ended a *Gallop* bout, in 6% it was within a *Kurlee* or a *Gallop* bout, and in 11% of cases it was combined with other call types. Most of the remaining recordings were from winter roosts, after sunset, and when the birds were leaving the roost when vocal activity is low.

The *Bitonal Whistle* (Fig. 4A) has morphology similar to the *Bitonal Kurlee*, but the frequency is

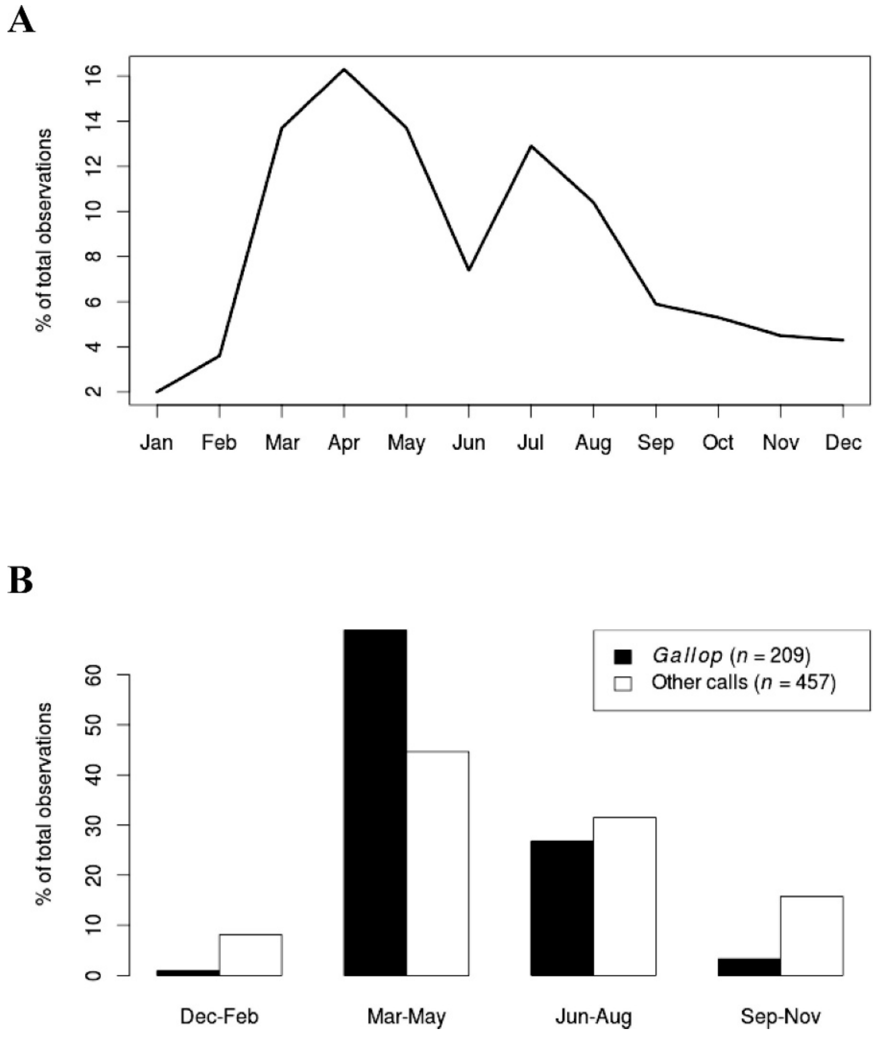

FIG. 1. (A) Seasonal pattern of Eurasian Stone-curlew vocal activity derived from (n = 692) field notes between 2000 and 2010 in southern Tuscany, Italy. (B) Comparison between the seasonal pattern of *Gallop* call and all other call types (percentages calculated over the total observations of each group). Data are from field notes (n = 666) between 2000–2010 in southern Tuscany. Call type (*Gallop* vs. other call types) and period of the year (four periods: Dec–Feb, Mar–May, Jun–Aug, and Sep–Nov) are not statically independent ($\chi^2 = 48.31$, df = 3, $P < 0.001$; test calculated on the actual number of observations).

higher and the duration is about one half of the *Bitonal Kurlee* (Table 2). We show a rare variant of this call (Fig. 4A) with three instead of two tonal steps. The *Bitonal Whistle* was recorded as a spontaneous vocalization and after playback. It was uttered alone in 73% of cases (n = 231), but in 27% of cases, mainly in breeding areas, it was recorded at the beginning of *Kurlee* and *Gallop* bouts. Stone-curlews utter this call either in flight or on the ground throughout the year. The *Bitonal Whistle* in a few cases was recorded after the *High-frequency Trill*. This call often was recorded when humans were nearby, after sudden loud noises (e.g., gunshot), when a high danger had passed (e.g., after a red fox, *Vulpes vulpes*, intrusion in the breeding area), and after a car passed nearby.

The syllable structure of *High-frequency Trill* (Fig. 4B) recalls the *Gallop* call morphology, but the rhythm is different; the element repetition is

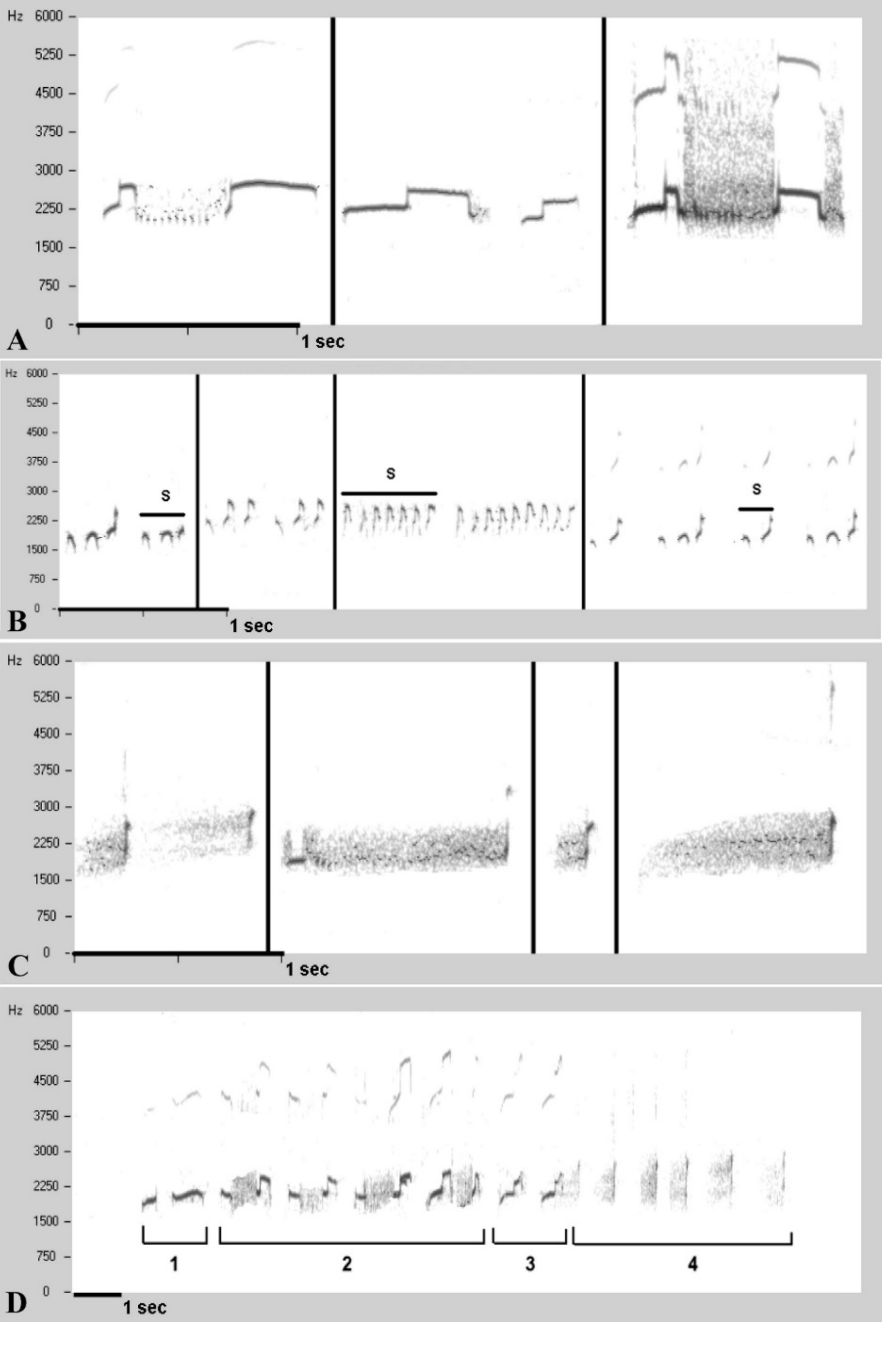

FIG. 2. The most common call was *Kurlee* and it had several recognizable variants. (A) The three subtypes of the *Kurlee* call. Left: *Rolled Kurlee*; center: two examples of *Bitonal Kurlee* from the same bird; right: *Strangled Kurlee*. (B) Four samples of *Gallop* call from different birds. Note the variability of morphology, frequency and syllable number. The last sample on the right shows a mix of bisyllabic and polysyllabic *Gallop* calls (S = call part submitted to quantitative analysis, see Table 2). (C) Four samples of the *Strangled Call* from different birds. The calls within vertical bars are by the same bird. Note the variability of call duration. (D) A typical bout of *Kurlee* calls introduced and closed by other call types. 1 = *Simple Whistle*; 2 = *Rolled Kurlee*; 3 = *Bitonal Kurlee*; 4 = *Strangled Calls*.

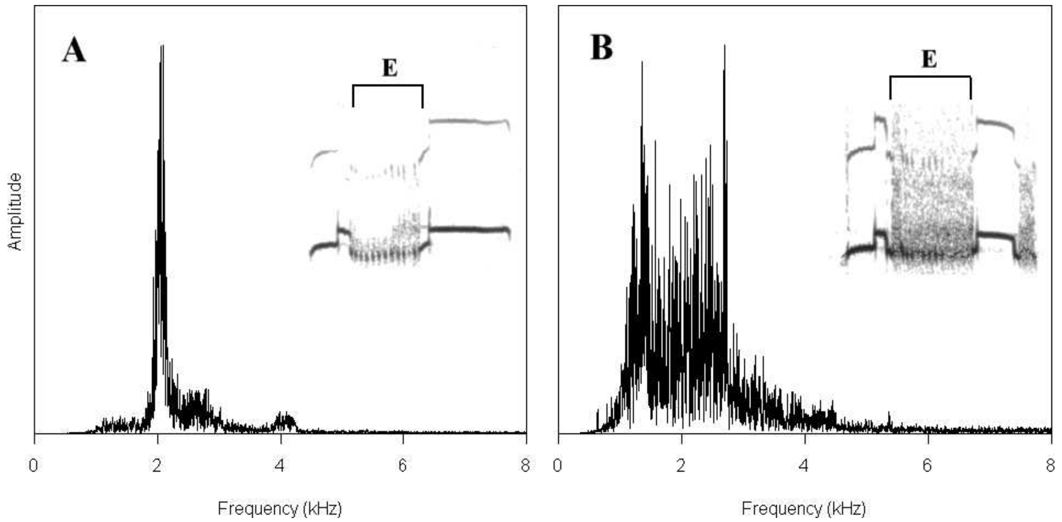

FIG. 3. Power spectrum of the central element (E) of the *Rolled* (A) and *Strangled Kurlee* (B). Frequency of the rolling sound is clearly found in A at about 2 kHz with a small harmonic component at 4 kHz, while in B it is obscured by a wide frequency band (the hissing/strangled sound).

faster, irregular, and syncopated (Fig. 2B vs. Fig. 4B). This call has the highest frequency parameters within the reported Eurasian Stone-curlew repertoire (Table 2). The call was uttered on the ground, in flight, or at times when flushed by humans. This call was given only in a specific circumstance: the presence of potential ground predators. It was recorded associated with distraction display and in response to the presence of a red fox in the nesting area. This call was also occasionally given in apparent response to the approach of humans or presence of wild boars (*Sus scrofa*) in the nesting area.

The *Simple Whistle* call (Fig. 4C) is a pure tone with little frequency modulation. Its duration was variable and 79% of calls (n = 118) were recorded alone, while 21% opened *Kurlee* bouts, or less frequently, *Gallop* bouts. Sixty-five percent of these calls were uttered at winter roosts after sunset; in this context the short variant (Fig. 4C) was most common, and most calls were uttered alone. This call was recorded in spring and summer in breeding areas, and at winter roosts, especially before the birds left for foraging sites or, in a few cases, after playback stimulation.

The *Whit Call* (Fig. 4D) is a short, staccato, high-frequency syllable, at times rapidly repeated in series; it is a less common vocalization (Table 1). Only 17% of *Whit Call*s (n = 79) were recorded alone, while the remaining calls were uttered among other calls: 35% ended *Kurlee* or *Gallop* bouts, 24% opened *Kurlee* or *Gallop* bouts, and 24% were uttered among other calls (*High-frequency Trill* and *Simple Whistle*). The call was usually uttered by birds on the ground; it was recorded in winter, spring, and early summer, but not in late summer and autumn. It was recorded in winter either after playback or at roosts as spontaneous vocalization. Seventeen percent of the calls uttered alone were recorded at winter roosts.

Samples of the *Polytonal Whistle* (Fig. 5A) had a short rapid modulated whistle with a characteristic high pitched end. It was recorded only at winter and autumn roosts when birds were ready to leave the roost. This call, in these cases and, particularly in December and January, was frequently uttered with other short vocalizations, such as *Simple Whistles* (short variant), *Whit Calls*, *High-frequency Whistles*, and *Strangled Calls*. We did not record the *Polytonal Whistle* in other seasons or other contexts.

The morphology of *High-frequency Whistle* (Fig. 5B) is less variable than others. The high-pitched end of this call type may be somewhat similar to the *Polytonal Whistle*, but quantitative analysis shows that duration of the *High-frequency Whistle* is almost double and peak frequency is lower than the *Polytonal Whistle* (Table 2). This call is rare, recorded in spring and, less frequently, at winter roosts in February. It was not uttered alone, but usually before or after *Kurlee* and *Gallop*

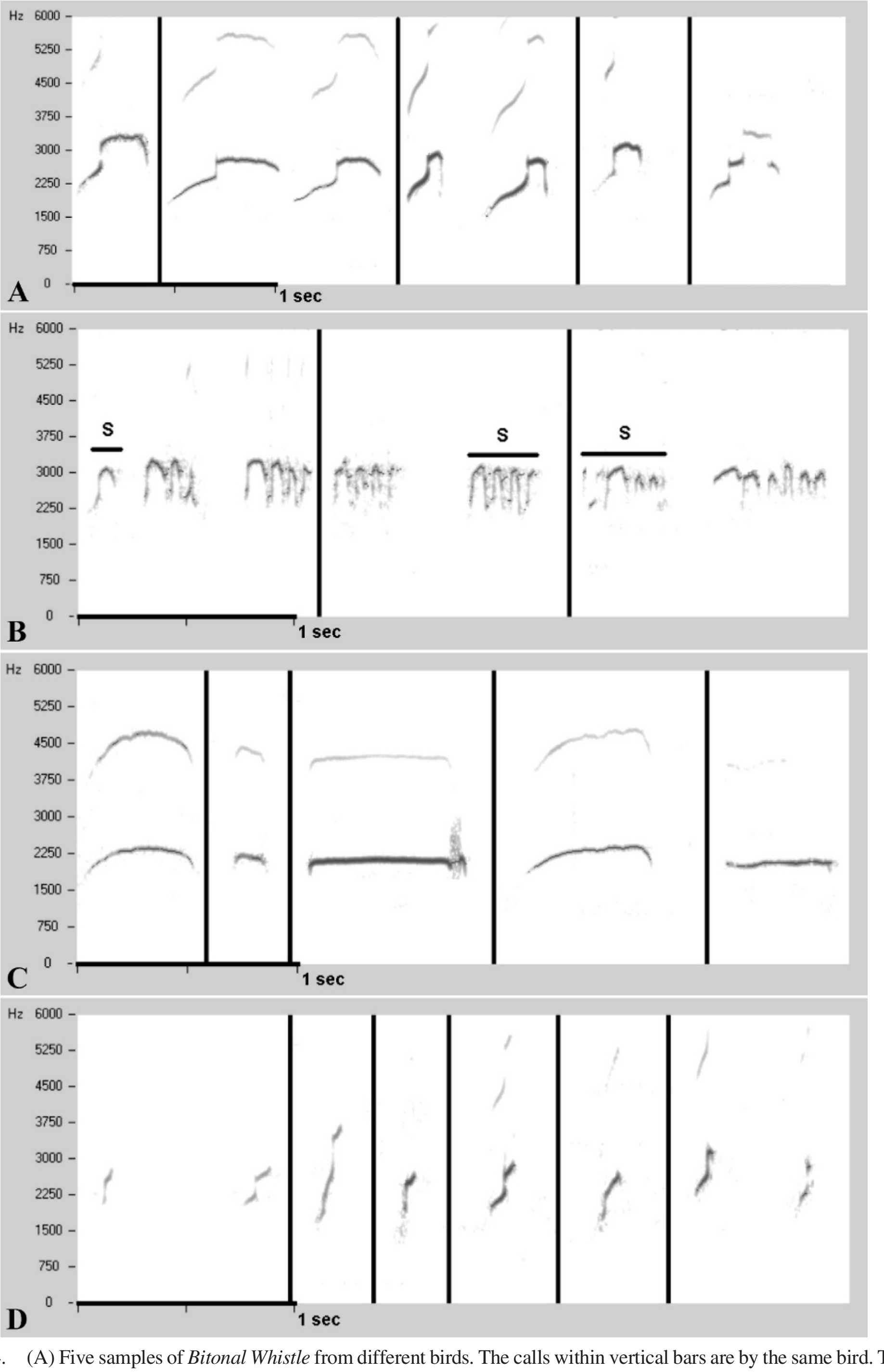

FIG. 4. (A) Five samples of *Bitonal Whistle* from different birds. The calls within vertical bars are by the same bird. The last sample on the right shows an uncommon variant of this call with three tonal steps instead of two. (B) Samples of *High-frequency Trill* from three different birds. The calls within vertical bars are by the same bird. Note the variability between and within birds. S = call part submitted to quantitative analysis, see Table 2. (C) Five samples of *Simple Whistle* from different birds. Note the high variability of this call type. The second sample from the left is a short variant typically uttered after sunset before leaving the roosts. (D) Six samples of *Whit Call* from different birds. The calls within vertical bars are uttered by the same bird. Note the variability between and within birds.

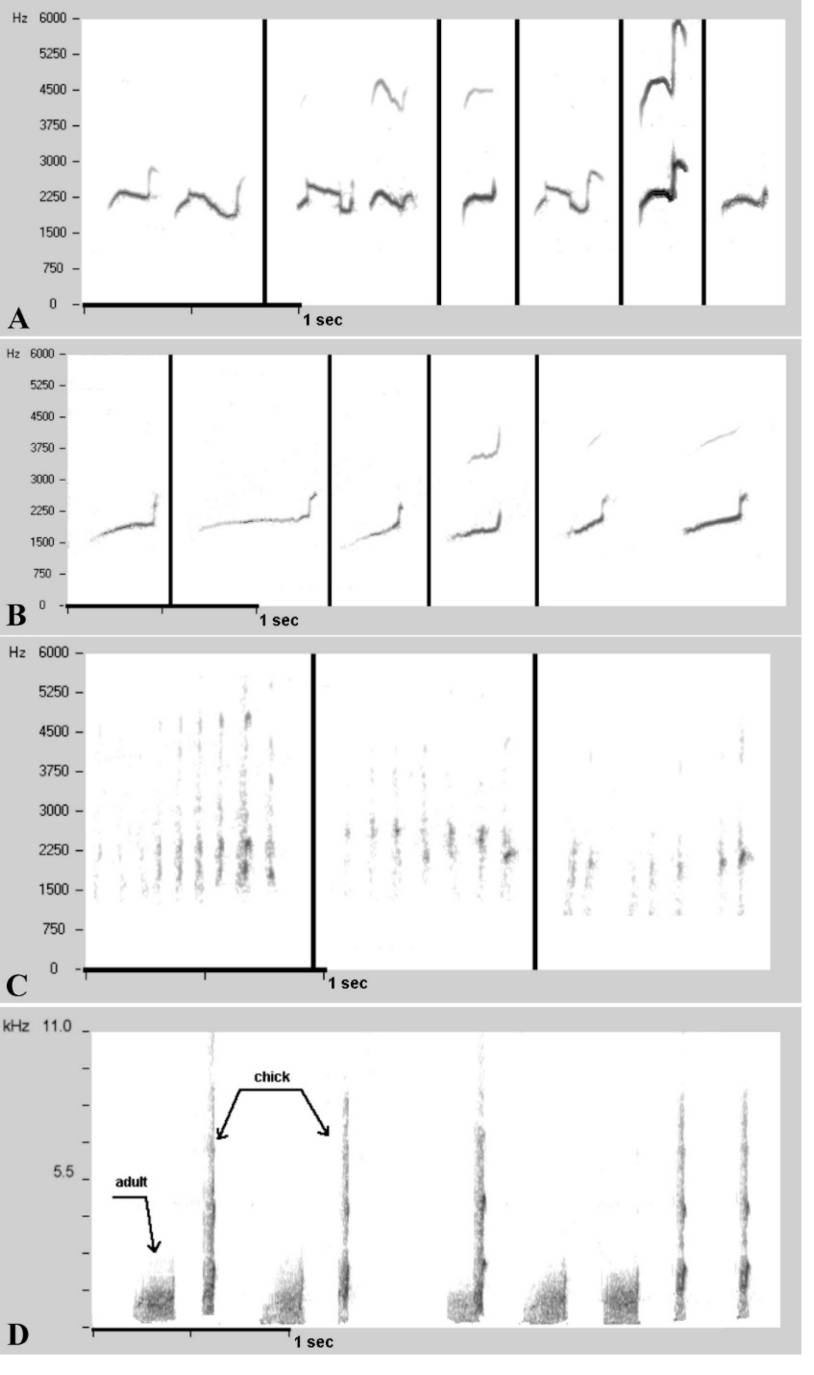

FIG. 5. (A) Six samples of *Polytonal Whistle* from different birds. The calls within vertical bars are by the same bird. Note the variability between and within birds. The main characteristics of this call type are frequency modulation and high-pitched end. (B) Samples of *High-frequency Whistle* from five different birds. The calls within vertical bars are uttered by the same bird. (C) Samples of *Intro Trill* from three different birds. (D) Five samples of *Answer-to-Chick* call from the same adult. The higher-pitched calls are chick vocalizations, defined as *S-call*.

TABLE 2. Quantitative acoustic analysis of calls of Eurasian Stone-curlews. Values are expressed as mean ± SD; *n* = number of recordings analyzed.

Call type and subtype	*n*	First quartile freq (Hz)	Third quartile freq (Hz)	Center freq (Hz)	Peak freq (Hz)	Call duration (sec)
Rolled Kurlee	35	2,102 ± 186	3,240 ± 768	2,446 ± 196	2,385 ± 268	1.097 ± 0.137
Bitonal Kurlee	34	2,096 ± 264	3,149 ± 784	2,424 ± 221	2,439 ± 230	0.724 ± 0.133
Strangled Kurlee	17	2,192 ± 84	2,882 ± 523	2,452 ± 129	2,468 ± 204	1.107 ± 0.218
Gallop (polysyllabic)	15	2,240 ± 117	3,182 ± 610	2,572 ± 280	2,473 ± 306	0.356 ± 0.093
Gallop (bisyllabic)	13	2,343 ± 157	3,825 ± 674	2,756 ± 306	2,685 ± 403	0.231 ± 0.037
Strangled Call	34	1,981 ± 145	2,948 ± 362	2,393 ± 172	2,340 ± 338	0.534 ± 0.273
Bitonal Whistle	31	2,547 ± 284	3,760 ± 1,141	2,891 ± 274	2,887 ± 272	0.315 ± 0.095
High-frequency Trill	20	2,686 ± 266	3,840 ± 980	3,037 ± 263	3,092 ± 507	0.312 ± 0.061
Simple Whistle	23	2,207 ± 309	3,097 ± 832	2,451 ± 396	2,395 ± 360	0.477 ± 0.215
Whit Call	20	2,202 ± 244	3,015 ± 527	2,472 ± 280	2,435 ± 325	0.116 ± 0.032
Polytonal Whistle	16	2,166 ± 166	2,701 ± 507	2,334 ± 191	2,303 ± 218	0.246 ± 0.068
High-frequency Whistle	13	1,965 ± 162	2,873 ± 599	2,190 ± 234	2,063 ± 246	0.468 ± 0.145
C-call (chicks)	25	2,112 ± 166	2,618 ± 402	2,350 ± 310	2,416 ± 411	0.170 ± 0.025

calls; in a few cases it was mixed with other calls, such as *Simple Whistle* and *High-frequency Trill*. This call was not recorded after playback.

The rarest Eurasian Stone-curlew vocalization is *Intro Trill,* a short, subdued call, audible only at close quarters (Fig. 5C). It often opened and occasionally closed *Kurlee* bouts and was recorded as a spontaneous vocalization as well as after playback.

An adult call (Fig. 5D) resembling the *Strangled Call*, but with lower pitch, lower volume, and without the final high-frequency element was also recorded. It is audible only at close range. We often found this vocalization in our experimental conditions during chick recordings. However, this same call, defined as *Answer-to-Chick,* was recorded several times in the wild, when adults were caring for and feeding their chicks, or near eggs that were about to hatch.

We could not categorize 8% of the calls (*n* = 1,490), despite our efforts to categorize as objectively as possible all Stone-curlew vocalizations, because they had an intermediate morphology between two or more different types. We defined these as *Mixed Calls* (Fig. 6). The *Strangled Call* is most frequent in mixed vocalizations (4.2% of all vocalizations).

Chicks.—Recordings of Eurasian Stone-curlew chicks revealed two main call types: (1) a brief strangled sound (*S-call,* Fig. 5D) with a broadband spectrogram, often uttered when parents and

TABLE 3. Eurasian Stone-curlew calls described in the literature and in this paper. NA = not available. Question marks indicate that correspondence between literature and our paper is difficult because spectrograms are not available.

This paper		Cramp and Simmons 1983		Vaughan and Vaughan-Jennings 2005	
Verbal rendering	Sonogram	Verbal rendering	Sonogram	Verbal rendering	Sonogram
Bitonal Kurlee	Fig. 2A (center)	Kur-LEE	Fig. 1	Kurlee	Fig. 1D
Rolled Kurlee	Fig. 2A (left)	Kur-LEE (2nd type)	Fig. 2	Kurlee	Fig 1A, B, C
Strangled Kurlee	Fig. 2A (right)	Kur-LEE (3rd type)	Fig. 3 (left)	Not described	NA
Gallop	Fig. 2B	Gallop-rhythm	Fig. 4	Tylliwick	Fig. 4A, B
Gallop (bisyllabic)	Fig. 2B (right)	Ker-vic	NA	Kervic	NA
Strangled Call	Fig. 2C	ChhhwhIK	Fig. 3 (right)	Shurr-ik	Fig. 5A, B, C
Strangled Call (variant?)	Fig. 2C (center)	Hissing (call 9)?	NA	Hiss?	NA
Bitonal Whistle	Fig. 4A	Klui (call 8)	NA	Klee	Fig. 3
High-frequency Trill	Fig. 4B	Not described	NA	Not described	NA
Simple Whistle	Fig. 4C	Whee (call 7)	Fig. 5	Pwhee	Fig. 2
Whit Call	Fig. 4D	Not described	NA	Whit call	Fig 7A, B, C
Polytonal Whistle	Fig. 5A	Not described	NA	Not described	NA
High-frequency Whistle	Fig. 5B	Wuii (call 7)	NA	Not described	NA
Intro Trill	Fig. 5C	Not described	NA	Not described	NA
Answer-to-Chick	Fig. 5D	Quig (call 11)?	NA	Caw-wik	Fig. 6A, B

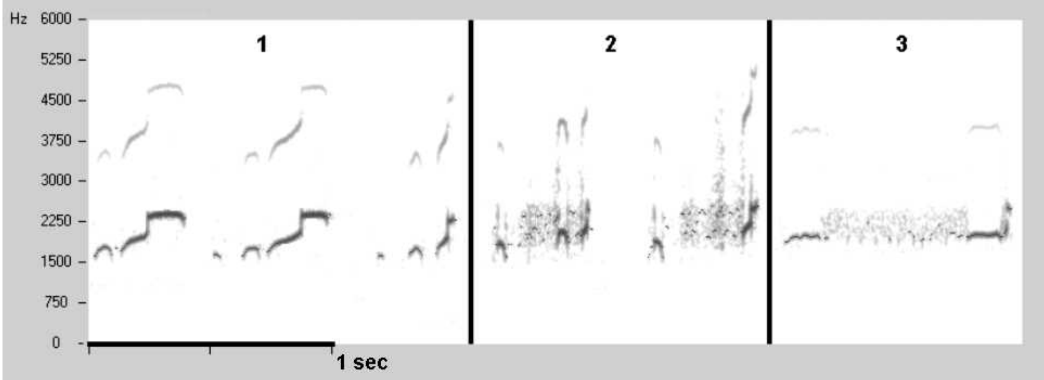

FIG. 6. Examples of *Mixed Calls*: 1 = *Bitonal Whistle* mixed with *Gallop* call; 2 = *Strangled Call* and *Gallop* call; 3 = *Strangled Call* and *High-frequency Whistle*.

chicks were at close quarters; and (2) a chirping sound (*C-call*, Fig. 7A) with a complex tonal-harmonic structure, mainly used by chicks during recording in our experimental conditions (wood exclosures). This last call has a variable morphology among different birds; the mean power spectrum calculated over a sample of 20 chicks shows two main frequency peaks at 2.7 and 3.3 kHz, while 95% of total power is below 8 kHz. Each of these calls was recorded both from chicks in our experimental conditions and from chicks in the wild. A *Distress Call* (not shown) was also recorded during the chick-banding procedure and immediately after catching some chicks during the night; it was a drawn-out hissing sound followed or preceded by a yelping whistle. The typical chick calls (*C-* and *S-*) are fully developed 1–2 days before hatching and they are the most-used vocalizations by chicks at age 45–50 days (Fig. 7B). Chicks at age ~35–45 days (approximate age of fledging) begin to utter other vocalizations: slightly prolonged whistling sounds with harsh and hissing quality, which recall the modulation of a *Kurlee* syllable; and strange nasal vocalizations, which seem like a failed try to utter a whistle and do not correspond to any adult calls (Fig. 7C). Chicks of age 45–55 days become able to utter a *Strangled Call* somewhat similar to the adult call (Fig. 7C). Our recordings suggest that chicks of age > 35–45 days begin a transition stage before attaining full adult vocal ability. We recorded a progressive increase during this period of the attempts to utter an adult *Kurlee* call and a progressive decrease in the use of *C-* and *S-calls*. Chick vocalizations (*C-* and *S-calls*) after 75–80 days were rarely uttered; at the end of this transition stage young were able to utter a nearly perfect *Kurlee* call (Fig. 7C). None of the other calls characterizing the adult repertoire were heard from young during this stage of vocal development.

DISCUSSION

We report for the first time a quantitative analysis of the seasonal pattern of vocalizations of Eurasian Stone-curlews. Previous reports referred only to the breeding period (Cramp and Simmons 1983) or included no quantitative data, especially for winter (Vaughan and Vaughan-Jennings 2005). Our data confirm that Stone-curlews are vocally active during spring and summer but also during fall and winter nights, although at lower levels.

We present the first description of acoustic structure and organization of vocalizations and the vocal repertoire for the family Burhinidae. Our recognition of 11 call types is similar to the published literature (Table 3), although it was difficult to make some comparisons with onomatopoeic descriptions and certain spectrograms.

Cramp and Simmons (1983) hypothesized a chiefly aggressive function for the *Kurlee* call, but our data accord with the multiple-functions interpretation by Vaughan and Vaughan-Jennings (2005), as we recorded the call in different situations (although mostly in the breeding period). We found evidence this call could act as a distant contact call, particularly between chicks and parents (Dragonetti et al. 2012) or between adults, as it is uttered frequently after sunset when birds are flying to foraging sites.

We did not follow the categorization of Cramp and Simmons (1983) and Vaughan and Vaughan-Jennings (2005), who defined the bisyllabic

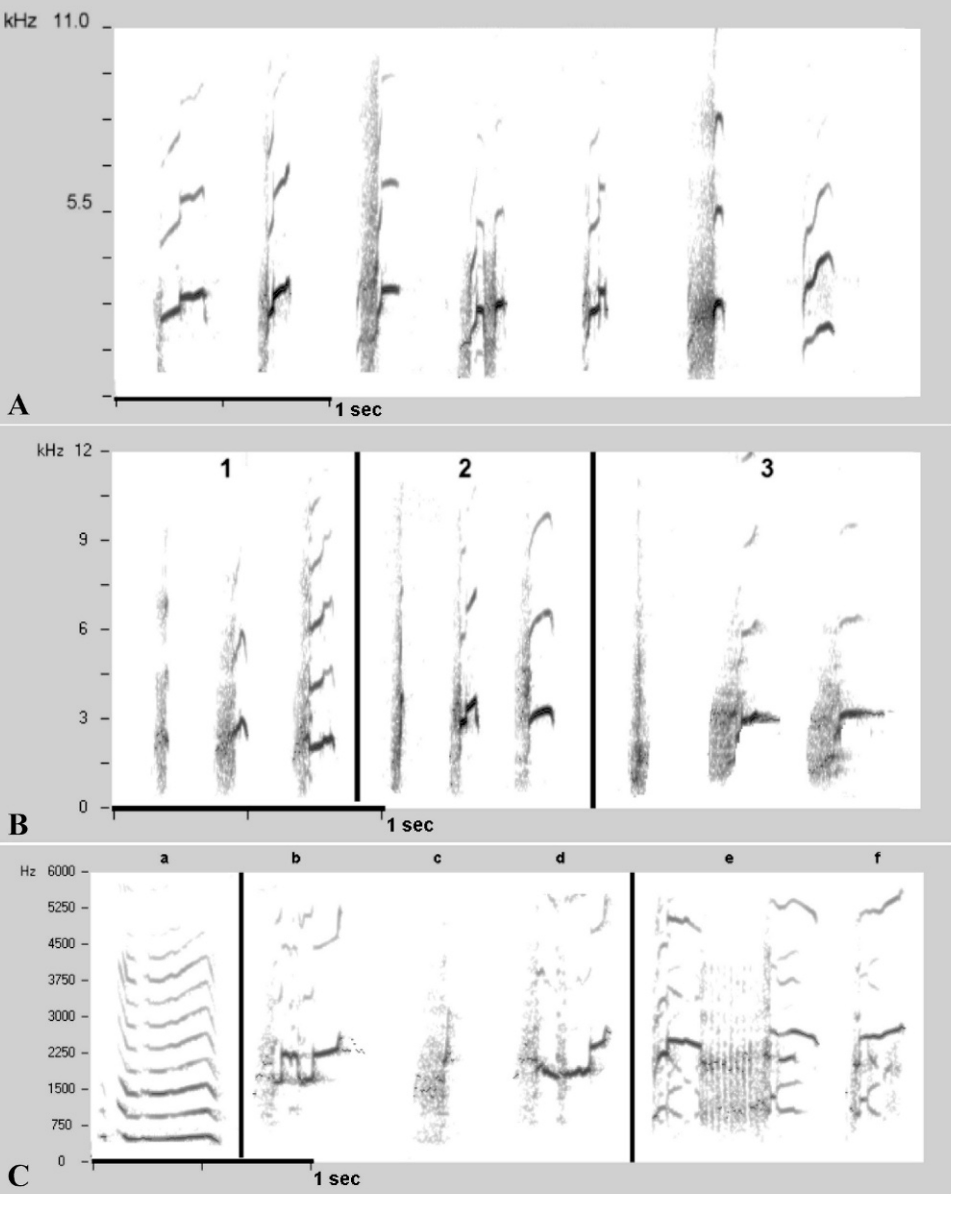

FIG. 7. (A) Seven samples of chick calls from different birds between 15 and 30 days of age. We define this call type as *C-call*. (B) Chick call repertoire at different ages: 1 = one day before hatching; 2 = 20-day-old chick; 3 = 50-day-old chick. The morphology of vocalizations does not change. (C) Voice-breaking and vocal development in Eurasian Stone-curlew: a = strange nasal call from a 39-day-old chick; b = whistling sound, with harsh and hissing quality, recalling a *Kurlee* modulation from a 44-day-old chick; c = *Strangled Call* from a 50-day-old chick (same bird as b), similar to the adult call, but still shorter and lower pitched; d = attempt to utter a *Kurlee* call from a 53-day-old chick (same bird as b), the result is still imperfect; e = a *Rolled Kurlee* from a 60-day-old chick; the call is quite similar to the adult one, but there are many subharmonic frequencies indicating a still imperfect control of the vocal apparatus; f = *Bitonal Kurlee* from a 60-day-old chick (same bird as e), the call is different from the adult template.

version of the *Gallop* as a separate call ('kervic' call); our data support the view of Bergmann et al. (2008), who considered this vocalization as a *Gallop* subtype. We found the *Gallop* call was uttered spontaneously with a high seasonal peak in spring and that it was not used during the winter. This call was the most effective of any in eliciting a response from playback, and responding birds matched the call type. Cramp and Simmons (1983) reported that *Gallop* and kervic calls are uttered by territorial birds meeting in spring; they are commonly heard during the breeding season and are associated with display, at times accompanied by dancing leaps. Vaughan and Vaughan-Jennings (2005) heard this call more often in spring and summer, and less often at autumn roosts. Our findings and the observations of Cramp and Simmons (1983) and Vaughan and Vaughan-Jennings (2005) support the idea that *Gallop* has a reproductive/territorial function and could be tentatively considered an analogue of the passerine song, like crowing of Red Junglefowl (*Gallus gallus*) (Collias 1987). The *Gallop* call can be referred to as the loud Rhythmically Repeated Call (RRC) uttered by males in association to conspicuous visual displays in several species of Charadrii (Miller 1996, Sung et al. 2005, Miller and Baker 2009) and Scolopaci (Miller 1983, 1996). Unfortunately we have no data regarding the sex of calling birds.

We suggest for the first time functions and meanings of other call types. The *Bitonal Whistle* is elicited by a wide spectrum of potentially alarming events. Vaughan and Vaughan-Jennings (2005) suggested it is an alarm signal when birds are flushed by humans, disturbed by an intruding bird or threatened by a bird of prey. These authors reported it is often uttered at night by flying birds, apparently as a contact or location call; we cannot confirm this interpretation. Cramp and Simmons (1983) reported that birds flushed by an intruder uttered a quick liquid 'klui' (no spectrogram available), probably referring to this same call. Our *High-frequency Trill*, which is not mentioned in the published literature, seems to be a high-intensity alarm call directed towards potential ground predators. The *Answer-to-Chick* call is a contact call between parents and chicks. Vaughan and Vaughan-Jennings (2005) report it is used not only as a contact call between parents and offspring, but also between adults, but we have no evidence supporting this interpretation. This vocalization probably corresponds to the low 'quig' call reported by Cramp and Simmons (1983) without spectrograms, which they considered as a 'feeding call' to chicks. The fourth specialized call is the *Polytonal Whistle*, which probably functions to coordinate flock movements and keep contact between flock members when leaving winter and autumn roosts. This call is not described in the literature.

Vaughan and Vaughan-Jennings (2005:68) wrote: ''The Stone-curlew's calls do not seem to be specialized in function.'' Our findings about these last four calls contrast with this statement. Further analysis of other vocalizations may help reveal more functions and meanings of the described calls.

Cramp and Simmons (1983) and Vaughan and Vaughan-Jennings (2005) generically reported that *Strangled Call* is connected to social and sexual displays in spring and autumn. Their conclusion contrasts with our findings, which show birds utter this call year-round, mainly in combination with other vocalizations, primarily after and before *Kurlee* bouts. We are not able to define precise functions or meanings for *Strangled Call* and for *Simple Whistle* call, which is also used in combination with *Kurlee* or *Gallop* calls, although less frequently than the previous vocalization. The *Strangled Call* is documented by Vaughan and Vaughan-Jennings (2005) from birds on the ground occupying or advertising territory and by Cramp and Simmons (1983) from birds possibly on alert or as a location call. Vaughan and Vaughan-Jennings (2005:67) wrote the *Whit Call* ''… is often heard among other calls, especially at the end of a bout of *Kurlee*,'' and our data confirm this observation. Our data suggest the *High-frequency Whistle* is possibly used in the reproductive context, as it was mainly recorded in spring and in combination with other call types. The *Intro Trill* is the least common Eurasian Stone-curlew vocalization, subdued and audible only at close quarters. These characteristics probably explain why it is not described in the literature. This call is uttered before or (less frequently) after a *Kurlee* bout. It was not combined with call types other than *Kurlee* in contrast to the previous calls uttered in combination with other call types.

A hiss call is described in the literature without spectrograms. This is probably a subtype of the *Strangled Call*, which can at times be relatively long (Fig. 2C), assuming a more hissing quality. We have not succeeded in identifying a few rare vocalizations described in the literature only with onomatopoeic words and lacking of spectrographic documentation, such as a rasping 'cu-ik' or 'cu-pik', a 'piping duuu' recalling plover calls, a yelping 'tuEE tuEE' (Cramp and Simmons 1983), a 'toy-it' call, and a 'kwaa' call (Vaughan and Vaughan-Jennings 2005).

Our repertoire is based on a subjective choice of the boundaries to demarcate different call types. This problem of subjectivity for the Eurasian Stone-curlew is exacerbated by: (1) the high inter- and intra-individual vocal variation that is shown in the selected spectrograms (also Table 2); and (2) the consistent percentage of *Mixed Calls*, where two or more different call types are merged together. This last phenomenon, also described by Vaughan and Vaughan-Jennings (2005), is difficult to explain; Nowicki and Marler (1988) likened the challenges birds have in the production of complex vocalizations to those of a musician playing a complex score on a musical instrument. Thus, *Mixed Calls* might be the result of a physical effort switching from one call type to the next, or simply an execution error, or an involuntary byproduct of poor motor control (Suthers and Zollinger 2008). We cannot exclude the possibility these vocalizations have their own meaning and/or function. We believe, despite difficulties in categorizing all call types, that the effort to classify the vocal repertoire is useful, because a morphological characterization, associated with a proper contextualization of the vocal activity, is the first step for investigating in depth the meanings of every call type.

Adult Eurasian Stone-curlews have a complex and relatively wide vocal repertoire. Two (*Kurlee* and *Gallop*), among our inventory of 11 call types, are clearly the most used and probably the most important. The *Kurlee* is probably multipurpose, and the *Gallop* is the one used for reproductive functions. Four calls (*Bitonal Whistle*, *High-frequency Trill*, *Answer-to-Chick*, *Polytonal Whistle*) have specialized function(s), and the remaining calls have unknown function(s) but share a common feature: they are rarely used alone, and mostly in combination with other calls, particularly with *Kurlee* and *Gallop* calls.

Does a syntax exist for the Eurasian Stone-curlew vocalizations? The ordering of syllables and phrases, often called song syntax, is widely recognized in the songbird literature (Kroodsma 2004, 2005; Doupe and Kuhl 2008) and there are examples for Charadridae (Sung et al. 2005). Our findings show there are preferred and typical call combinations, which cannot be explained as random choices. Some calls are preferentially uttered before others, and some are mainly used as a closing sequence. Possibly, meanings or functions could change following the different vocal combinations, as in 'chick-a-dee' calls of some parids (Ficken et al. 1978, Freeberg and Lucas 2002, Williams 2008) or alarm calls of Siberian Jay (*Perisoreus infaustus*) (Griesser 2008). The *Kurlee* call, which is suggested by some authors to be a multi-purpose vocalization, is almost exclusively uttered in combination with other call types. Alternatively, some call combinations could be favored because they are easier to produce without any specific meaning.

We identified two main chick call types, which differ substantially from adult calls. A comparison with the literature is difficult, because we have found only a few anecdotal descriptions and onomatopoeic transcriptions of Eurasian Stone-curlew chick vocalizations; possibly our *C-call* could be the 'coit' or 'kuit' reported by Cramp and Simmons (1983). Some of these calls are given before hatching and seem to change little even after 70 days, when the birds are fully grown. This lack of a relationship between body mass (size of the vocal apparatus) and vocalization has been reported for other species of birds, such as cranes (Niemeier 1979, Fitch 1999, Klenova et al. 2010). Adret (2012), however, showed these changes in Pied Avocets (*Recurvirostra avosetta*) can be slight and gradual, but our sample size is too small to test this hypothesis.

We also report for the first time preliminary data on the vocal ontogenesis of the Eurasian Stone-curlew. Our data suggest the ontogenesis of Eurasian Stone-curlew calls is a gradual process, which begins when birds are fully developed and ready to fledge. Young undergo a voice-breaking phase beginning at the age of 35–45 days (approximate fledging age; Cramp and Simmons 1983). This contrasts with the data reported by Adret (2012) for Pied Avocets, which showed the voice of captive birds began to break at ~9 months of age. Juvenile Eurasian Stone-curlews progress towards the adult vocalization during the period of voice breaking and give fewer chick calls. The ability to utter both new adult-like calls and chick calls has also been observed in Pied Avocets (Adret 2012) and in cranes (Klenova et al. 2009, 2010). However, unlike for cranes, chick and adult calls differ in Eurasian Stone-curlews. The development of adult vocal behavior, at least in this first phase, seems limited to a few call types

(*Kurlee* and *Strangled Call*), while the remainder of the adult repertoire seems to not be involved. Our sample sizes and period of observation are limited, but we note that Adret (2012) reported failure of captive Pied Avocets to acquire a full mature call repertoire even after one year, suggesting the need of an external model and/or social interactions for release of some vocalizations.

Quantitative analysis of calls showed that Eurasian Stone-curlew vocalizations have a relatively narrow peak and center frequency range (2,050–3,100 Hz and 2,200–3,000 Hz, respectively), while duration varies between 0.1 and 1.2 sec. These values are similar to those reported by Rasmussen and Anderton (2005). The two calls that we suggested to have an alarm function (*High-frequency Trill* and *Bitonal Whistle*) had the highest values for peak frequency, center frequency and third quartile. The *High-frequency Trill* has slightly higher values than the *Bitonal Whistle* and probably represents an alarm signal of higher intensity, directed towards a specific danger (ground predator). The limited available data on the Eurasian Stone-curlew call repertoire hinder further comparisons with other studies.

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LITERATURE CITED

ADRET, P. 2012. Call development in captive-reared Pied Avocets, *Recurvirostra avosetta*. Journal of Ornithology 153:535–546.

BERGMANN, H. H., H. W. HELB, AND S. BAUMANN. 2008. Die Stimmen der Vögel Europas. Aula-Verlag GmbH, Wiebelsheim, Germany.

BIBBY, C. J., N. D. BURGESS, D. A. HILL, AND S. MUSTOE. 2000. Bird census techniques. Academic Press, London, United Kingdom and San Diego, California, USA.

CACCAMO, C., E. POLLONARA, N. E. BALDACCINI, AND D. GIUNCHI. 2011. Diurnal and nocturnal ranging behaviour of Stone Curlews *Burhinus oedicnemus* nesting in river habitat. Ibis 153:707–720.

COLLIAS, N. E. 1987. The vocal repertoire of the Red Junglefowl: a spectrographic classification and the code of communication. Condor 89:510–524.

CRAMP, S. AND K. L. SIMMONS. 1983. The birds of the Western Palearctic. Volume 3. Oxford University Press, Oxford, United Kingdom.

DOUPE, A. J. AND P. K. KUHL. 2008. Birdsong and speech: common themes and mechanisms. Pages 5–31 *in* Neuroscience of birdsongs (P. H. Ziegler and P. Marler, Editors). Cambridge University Press, New York, USA.

DRAGONETTI, M., C. CACCAMO, E. POLLONARA, N. E. BALDACCINI, AND D. GIUNCHI. 2012. A weak individual signature might not allow chick call recognition by parent Stone Curlews *Burhinus oedicnemus.* Bioacoustics in press. doi: 10.1080/09524622.2012.710394.

FICKEN, M. S., R. W. FICKEN, AND S. R. WITKIN. 1978. Vocal repertoire of the Black-capped Chickadee. Auk 95:34–48.

FITCH, W. 1999. Acoustic exaggeration of size in birds via tracheal elongation: comparative and theoretical analyses. Journal of Zoology (London) 248:31–48.

FREEBERG, T. M. AND J. R. LUCAS. 2002. Receivers respond differently to chick-a-dee calls varying in note composition in Carolina Chickadees, *Poecile carolinensis.* Animal Behaviour 63:837–845.

GALEOTTI, P. AND R. SACCHI. 2001. Turnover of territorial Scops Owl (*Otus scops*) as estimated by spectrographic analyses of male hoots. Journal of Avian Biology 32:256–262.

GIOVACCHINI, P., M. DRAGONETTI, F. CORSI, AND F. FARSI. 2012. Monitoraggio invernale dell'Occhione (*Burhinus oedicnemus*) in provincia di Grosseto con l'uso del playback. Rivista Italiana di Ornitologia: In Press.

GIUNCHI, D., E. CHIERICI, F. PICCIO, E. POLLONARA, AND N. E. BALDACCINI. 2009. Una valutazione di alcuni metodi di stima delle popolazioni nidificanti di Occhione. Pages 27–29 *in* L'occhione (*Burhinus oedicnemus*): biologia e conservazione di una specie di interesse comunitario—Indicazioni per la gestione del territorio e delle aree protette (D. Giunchi, E. Pollonara, and N. E. Baldaccini, Editors). Conservazione e gestione della natura, Quaderni di documentazione. Volume 7. Parco Fluviale Regionale del Taro, Parma, Italy.

GRIESSER, M. 2008. Referential calls signal predator behavior in a group-living bird species. Current Biology 18:69–73.

KLENOVA, A. V., I. A. VOLODIN, AND E. V. VOLODINA. 2009. The variation in reliability of individual vocal signatures throughout ontogenesis in the Red-crowned Crane (*Grus japonensis*). Acta Ethologica 12:29–36.

KLENOVA, A. V., I. A. VOLODIN, E. V. VOLODINA, AND K. A. POSTELNYKH. 2010. Voice breaking in adolescent Red-crowned Cranes (*Grus japonensis*). Behaviour 147:505–524.

KROODSMA, D. E. 2004. The diversity and plasticity of birdsong. Pages 108–131 *in* Nature's music. The science of birdsong (P. Marler and H. Slabbekoorn, Editors). Elsevier Academic Press, San Diego, California, USA.

KROODSMA, D. E. 2005. The singing life of birds: the art and science of listening to birdsong. Houghton Mifflin Co., New York, USA.

LENGAGNE, T. 2001. Temporal stability in the individual features in the calls of Eagle Owls (*Bubo bubo*). Behaviour 138:1407–1419.

LIVEZEY, B. C. 2010. Phylogenetics of modern shorebirds (Charadriiformes) based on phenotypic evidence: analysis and discussion. Zoological Journal of the Linnean Society 160:567–618.

MARION, W. R., T. E. O'MEARA, AND D. S. MAHER. 1981. Use of playback recordings in sampling elusive or secretive birds. Studies in Avian Biology 6:81–85.

MARLER, P. AND H. SLABBEKOORN. 2004. Nature's music. The science of birdsong. Elsevier Academic Press, San Diego, California, USA.

MILLER, E. H. 1983. The structure of aerial displays in three species of Calidridinae (Scolopacidae). Auk 100:440–451.

MILLER, E. H. 1996. Acoustic differentiation and speciation in shorebirds. Pages 241–257 *in* Ecology and evolution of acoustic communication in birds (D. E. Kroodsma and E. H. Miller, Editors). Comstock/Cornell University Press, Ithaca, New York, USA.

MILLER, E. H. AND A. J. BAKER. 2009. Antiquity of shorebird acoustic displays. Auk 126:454–459.

NIEMEIER, M. 1979. Structural and functional aspects of vocal ontogeny in *Grus canadensis* (Gruidae: Aves). Dissertation. University of Nebraska, Lincoln, USA.

NOWICKI, S. AND P. MARLER. 1988. How do birds sing? Music Perception 5:391–426.

NUECHTERLEIN, G. L. AND D. BUITRON. 1998. Interspecific mate choice by late-courting Western Grebes. Behavioural Ecology 9:313–321.

PATON, T. A. AND A. J. BAKER. 2006. Sequences from 14 mitochondrial genes provide a well-supported phylogeny of the charadriiform birds congruent with the nuclear RAG-1 Tree. Molecular Phylogenetics and Evolution 39:657–667.

PAVAN, G. 2003. SEAWave, Sound emission analyzer. Software Version 1.1, Laboratory of Bioacoustics, Pavia University, Italy. www-3.unipv.it/cibra/seawave.html

RASMUSSEN, P. C. AND J. C. ANDERTON. 2005. Birds of South Asia: the Ripley guide. Smithsonian Institution, Washington, D.C., USA and Lynx Edicions, Barcelona, Spain.

R DEVELOPMENT CORE TEAM. 2011. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org

SUEUR, J., T. AUBIN, AND C. SIMONIS. 2008. Seewave, a free modular tool for sound analysis and synthesis. Bioacoustics 18:213–226.

SUNG, H. C., E. H. MILLER, AND S. P. FLEMMING. 2005. Breeding vocalizations of the Piping Plover (*Charadrius melodus*): structure, diversity, and repertoire organization. Canadian Journal of Zoology 83:579–595.

SUTHERS, R. A. AND S. A. ZOLLINGER. 2008. From brain to song: the vocal organ and vocal tract. Pages 78–98 *in* Neuroscience of birdsongs (P. H. Ziegler and P. Marler, Editors). Cambridge University Press, New York, USA.

TINARELLI, R., R. PARODI, AND I. CANDON. 1991. Sperimentazione di un metodo per il censimento dell'Occhione (*Burhinus oedicnemus*). Supplemento alle Ricerche di Biologia della Selvaggina 17:385–388.

TINARELLI, R., G. ALESSANDRIA, P. GIOVACCHINI, L. GOLA, R. IENTILE, A. MESCHINI, S. NISSARDI, R. PARODI, F. PERCO, P. L. TAIAROL, AND C. ZUCCA. 2009. Consistenza e distribuzione dell'occhione in italia: aggiornamento al 2008. Pages 45–50 *in* L'occhione (*Burhinus oedicnemus*): biologia e conservazione di una specie di interesse comunitario-Indicazioni per la gestione del territorio e delle aree protette (D. Giunchi, E. Pollonara, and N. E. Baldaccini, Editors). Conservazione e gestione della natura, Quaderni di documentazione. Volume 7. Parco Fluviale Regionale del Taro, Parma, Italy.

VAUGHAN, R. AND N. VAUGHAN-JENNINGS. 2005. The Stone Curlew *Burhinus oedicnemus*. Isabelline Books, Falmouth, Cornwall, United Kingdom.

WILLIAMS, H. 2008. Birdsong and singing behavior. Pages 32–49 *in* Neuroscience of birdsongs (P. H. Ziegler and P. Marler, Editors). Cambridge University Press, New York, USA.