1 Title: A report on a characteristic vocalization in *Corvus macrorhynchos osai* with an
2 indication of vocal learning.
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11 **Abstract**

12 In the process of vocal learning, animals give immature vocalization, such as babbling
 13 and subsong. Here I report a characteristic vocalization given by a subspecies of
 14 large-billed crow, *Corvus macrorhynchos osai*, that live in Kuroshima Island, Okinawa,
 15 Japan. This vocalization (type-K) is characterized by very rapid bill movements (ca. 13
 16 times/sec). The type-K was heard throughout the island, indicating that the population
 17 of the Kuroshima Island share this call type. In addition, a juvenile crow was observed
 18 giving immature type-K repeatedly. This observation suggests that this call type is not
 19 innate but acquired through vocal learning.

20

21 **Key Words:** vocal learning, corvid, crow, subsong, babbling, dialect, vocal
 22 development

23

24 **Introduction**

25 Vocal production learning, or vocal learning, is the ability to produce non-innate
26 vocalization through social learning and supposed to be essential for human language
27 (Jarvis 2006). In the animal kingdom, this ability can be found only in limited taxa:
28 songbird, hummingbird, and parrot in birds, as well as cetaceans, elephants, bats, and
29 pinnipeds in mammals (Petkov and Jarvis 2012).

30 In vocal learning animals, young individuals acquire new vocalization by
31 practicing it repeatedly in the course of development. This practicing behavior is called
32 “babbling” in humans (Lenneberg 1967). The babbling behavior is also reported in other
33 vocal learning mammals, such as pygmy marmosets *Cebuella pygmaea* (Elowson et al.
34 1998) and sac-winged bats *Saccopteryx bilineata* (Knörnschild et al. 2006). In songbirds,
35 the immature song produced by the juveniles during the sensorimotor phase is called
36 “subsong”. Subsong is soft, highly variable, and rambling vocalization, lacking
37 species-specific characteristics in the early stages. As the birds develop, the subsong
38 would become more stable, but still acoustically different from the adult song. This
39 stage of song is referred to as “plastic song”. During the subsong and plastic song
40 period, the juveniles are supposed to learn the motor skill to produce sounds that would
41 match their vocal template, which is learned during the sensitive phase (Nottebohm
42 1970, Nottebohm 1972, Wilbrecht and Nottebohm 2003).

43 Vocal learning often results in the variation of vocalizations between
44 geographically distant populations. The geographic variation of vocalization is also
45 referred to as vocal cultures or “dialects” (Catchpole and Slater 2008). The dialect in
46 animals was first reported in songs of white-crowned sparrow *Zonotrichia leucophrys*
47 (Marler and Tamura 1964) and is now widely reported in songbirds. Recent studies have
48 revealed the geographic variation also exists in bird and mammal calls, although calls
49 have been believed to be innate and lack flexibility compared to songs (Boughman and
50 Moss 2003).

51 As corvids belong to Passeriformes, it is not surprising that they have vocal

52 learning abilities. Their vocal learning ability is reported in some studies as well as lots
53 of anecdotes, although they do not produce songs comparable to those of songbirds.
54 Webber and Stefani (1990) reports A captive California scrub jay *Aphelocoma*
55 *coerulescens superciliosa* learned calls of Florida scrub jays *A. c. coerulescens*. In
56 ravens *Corvus corax* it is reported that their vocal repertoire is supposed to be formed
57 via cultural transmission, especially within sexes (Enggist-Dueblin and Pfister, 2002).
58 New Caledonian crows, *Corvus moneduloides*, give calls acoustically different
59 depending on the distance (Bluff et al. 2010). Corvids under captivity are also reported
60 to learn human vocalizations, suggesting their flexible vocal learning ability
61 (Chamberlain and Cornwell, 1971; Bluff et al. 2010).

62 Large-billed crow *Corvus macrorhynchos* is known anecdotally to learn human
63 vocalizations, indicating their vocal learning ability, but no scientific publication exists
64 (see Karasawa 1988 for anecdotes, for example). In addition, whether they acquire their
65 species-specific vocal repertoire through vocal learning is not clear. In a study of the
66 Indian population, the acoustic structure is different among subspecies but how such
67 acoustic differences emerge is not known (Martens et al. 2000). Fledglings of
68 large-billed crows give various unstable vocalizations and Kuroda (1969) considered
69 this vocalization was functionally comparable to the subsong of songbirds. However, no
70 study on vocal development in large-billed crows exists so far, especially focusing on a
71 particular call type.

72 Here, I report a preliminary observation of vocal learning in a wild population
73 of *Corvus macrorhynchos osai*, a subspecies of large-billed crow. *C. m. osai* live in
74 Yaeyama Islands, Okinawa. They are smaller in size than *C. m. japonensis*, a subspecies
75 of large-billed crow that lives in the mainland of Japan. The groups that live in different
76 islands are morphologically different, especially in bill length, depending on the habitat
77 they live in (Yamasaki 2010). However, their vocal behavior is not reported at all thus
78 far. Here I report vocal behavior in *C. m. osai*, especially focusing on a specific

79 vocalization that is not reported in any published literature of vocal behavior in
80 large-billed crows.

81

82 **Study site**

83 The Study site was Kuroshima Island (24°14' 22" N, 124°0'53" E), one of Yaeyama
84 Islands of Okinawa Prefecture, Japan. The island is very flat (>10m above sea level)
85 since it was formed when the coral reef rose. It is very small in size and has an area of
86 about 10.02 km², with a peripheral length of 12.62 km. Since the main industry of this
87 island is cattle-breeding, the island is for the most part covered with grassland. Although
88 the original habitat of large-billed crows is forest (Goodwin 1986), *C. m. osai* in
89 Kuroshima Island seems to have highly adapted to the open grassland (Yamasaki 2010).

90

91 **Methods**

92 From September 4th to 7th 2013 and from January 23rd to 27th 2014, I visited Kuroshima
93 Island and recorded vocalization of *C. m. osai*. I searched for vocalizing crows by
94 bicycle, and as soon as I spotted vocalizing crows, I started recordings using a
95 directional microphone (MKH416-P48U3, Sennheiser) and a linear PCM recorder
96 (DR-100MKII, Tascam). The recordings were made from 0700-1830. From Oct. 22nd
97 through Oct. 26th of 2020, I again visited Kuroshima Island and plotted the places
98 where the vocalization was heard onto a map. Unfortunately, however, I could not
99 record their vocalizations using a microphone due to the bad weather condition (rain
100 and strong wind). I, instead, tried to capture their vocalization via a digital camera
101 (OM-D E-M1 Mark II, Olympus) using its video recording function.

102

103 **Results**

104 In 2013, I noticed very strange vocalization given by the crows of Kuroshima (Figure 1,
105 Video S1). This vocalization consists of two phases: rattling phase and

106 rapid-bill-movement phase. The rattling phase is the introductory phase consisted of a
107 mechanical rattling sound. For the five vocalizations I managed to record, the rattling
108 phase lasted for 220-577 msec. In *C. m. japonensis* this phase is referred to as “rattling
109 call”, which is given independently (Kuroda 1990). The following rapid-bill-movement
110 phase was 849-1048 msec. In this phase, the crows move their bills very rapidly (ca. 13
111 times/sec) while vocalizing, resulting in a vibrato sound. When giving this call, the
112 crow’s head directed downwards (see Video S1). This call type was also recorded in
113 2014. This call type is not described in any publications, so I named it “type-K call” (K
114 after Kuroshima Island). Unfortunately, however, it was very difficult to record this call
115 since the crows did not give this vocalization very frequently. Thus, I only managed to
116 record one call in 2013 and four calls in 2014.

117 In 2020, the type-K was heard in 15 places of the island (Figure 2). At one of
118 these points, I observed one crow giving immature vocalization. This bird was young
119 and considered to be born that year, judging from its pink mouth cavity (Kitagawa
120 1980). It was wandering around cattle in front of a cattle shed while vocalizing. Its
121 vocalization contained an introductory rattling phase as well as adults’ type-K, but the
122 following rapid-bill-movement phase was replaced by several short notes of various
123 duration and frequencies (Figure 3, Video S1). The rattling phase was also produced
124 independently, resulting in a rattling call, but the short notes were always preceded by
125 the rattling phase. In Kuroshima Island I had never heard any vocalization composed of
126 rattling phase and other sounds, except for type-K. Therefore, I judged this juvenile’s
127 vocalization as immature type-K. This bird repeatedly gave similar vocalization, that is,
128 rattling call followed by various short notes, for more than five minutes after I found it.
129 It then flew into the cattle shed and I could not follow it anymore.

130

131 Discussion

132 The unique vocalization, type-K, has never been reported in any literature of

133 vocalization of *C. m. japonensis*, suggesting that this call is at least subspecies-specific.
 134 In addition, the juvenile immature vocalization implies that this call is not innate but
 135 learned. It is not surprising that the *C. m. osai* show vocal learning ability since it is
 136 known anecdotally that the large-billed crow learns anthropologic sound and human
 137 speech. Still, this is the first report showing the juvenile large-billed crows produce
 138 subsong-like immature vocalizations of a particular call type, indicating that their vocal
 139 repertoire is at least to some extent acquired through vocal learning.

140 In the rapid-bill-movement phase of adult type-K, it is supposed that they
 141 produce one single sound while moving bills very rapidly, resulting in the vibrato-like
 142 frequency modulation, since the sounds of the rapid-bill-movement phase are not
 143 separated but connected. In the juvenile type-K, on the other hand, the
 144 rapid-bill-movement was replaced by a sequence of short notes. It may be physically
 145 demanding for the juveniles to move the bill rapidly (at the speed of ca. 13 times/sec)
 146 while vocalizing. The juvenile might have imitated the rapid-bill-movement phase by
 147 repeatedly giving short notes since the adult rapid-bill-movement phase sounds like a
 148 very rapid repetition of short notes. As I only observed one case in this study, it is not
 149 clear how juvenile crow acquires rapid-bill-movement as it develops. How type-K
 150 changes as the crow develops would reveal the acquisition of complex body movement
 151 related to their vocalization.

152 The function of type-K is not clear at all because most of the crows giving
 153 type-K in my observation were just sitting on a branch alone without showing any
 154 particular behavior. From the acoustic profile, I speculate that the type-K may function
 155 in the same way as the rattling call since it contains a rattling sound in the introductory
 156 phase. The function of rattling call is also unknown, but it is relatively soft vocalization
 157 and thus supposed to be used in short distance communication. Kuroda (1990) reported
 158 that he had heard the rattling call during fights. In one case of my observation, one crow
 159 was repeatedly giving type-K while snatching feed mixture from the cattle inside a

160 cowshed, together with more than 15 crows. Although I could not observe them closely
161 due to the distance, social interaction including fights over the food may have occurred
162 between them. If this was the case, it would support the idea that the type-K and rattling
163 call are similar in their function. The head downward vocalizing posture of type-K also
164 indicates that this call is not for long-distance communication, since such posture would
165 disturb sound propagation. How they use this call in their social interaction would be
166 revealed in future studies of long-term and close observation of *C. m. osai*.

167 Type-K call seemed to be shared by several individuals within the island. As I
168 have not identified the individual identities of the vocalizing crows, the vocalizations by
169 the same individuals may have been recorded repeatedly. In addition, given the small
170 island size, it is not difficult for crows to fly between the farthest points where type-K
171 had been heard. However, it is not natural to suppose that a single type-K calling crow
172 moved around all over the island as I moved. Rather, it is reasonable to suppose that
173 several individuals of this island give type-K. In fact, I had heard two individuals gave
174 type-K call at the same time. The observation of a practicing juvenile also supports the
175 idea that the type-K is shared within the island population through vocal learning.

176 I do not, however, know whether this call is also shared with populations
177 outside of Kuroshima Island. I preliminarily recorded vocalization of *C. m. osai* also in
178 Ishigakijima Island, Iriomotejima Island, Kohamajima Island, and Haterumajima Island.
179 In these four islands, type-K was not recorded. This may be due to the fact the degree of
180 difficulty to record crows' vocalization differed according to the islands because of the
181 size differences. Kuroshima Island is the smallest among them, and therefore easy to
182 record various vocalizations of *C. m. osai*. In order to find out whether this call type is
183 shared with other islands or not, a lot of thorough recording on other islands is strongly
184 required.

185 As the bird song dialect is supposed to be related to the site fidelity (Lemon
186 1975), the dispersion from the islands should also be considered. However, it is not

187 clear whether the crows of the Yaeyama Islands disperse to other islands or not. The
188 distance between the islands is within ca. 20 km (the distance from Kuroshima Island to
189 Ishigakijima Island is ca. 16 km, Kuroshima Island to Iriomotejima Island is ca. 10 km,
190 with Aragusuku Island in between). Given that the daily flight distance of *C. m.*
191 *japonensis* of the urban area is ca. 7km in the non-breeding season (Morishita et al.
192 2004), it is not impossible for *C. m. osai* to fly to other islands. Still, Yamasaki (2010)
193 points out the possibility of speciation of *C. m. osai* within the Yaeyama Islands based
194 on their behavioral and morphological differences. This suggests that the crow
195 population of each island does not disperse frequently. As the dialect in bird song is
196 considered to play important role in speciation (Slabbekoorn and Smith 2002), the study
197 of vocalization might uncover the speciation within the *C. m. osai*.

198 The study of vocal behavior of large-billed crows is unfortunately not
199 flourishing. This study is only descriptive, but I believe it is suggesting. I hope much
200 more studies would be conducted in the future to understand vocal communication in
201 large-billed crow, a highly social species.

202

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255

256 **Figure legends**

257 **Figure1. Sound spectrogram of type-K call given by an adult bird.** The call is
258 composed of a rattling phase (gray area with dark gray outline) and a
259 rapid-bill-movement phase (highlighted in dark gray).

260

261 **Figure2. A map of Kuroshima Island showing the points where type-K was**
262 **recorded.** The grey circles indicate the points where adult type-K calls were recorded
263 and the black shows the point where a juvenile crow gave immature type-K.

264

265 **Figure3. Sound spectrogram of immature type-K call given by a juvenile bird.** The
266 juvenile immature call was composed of rattling phase (gray area with dark gray
267 outline) and repetitive short notes indicated by the dark gray highlights and the capital
268 Ss. Note that the rapid-bill-movement phase in adult call was replaced by short notes in
269 juvenile vocalization, and the intervals, as well as lengths of short notes, were not stable.
270 The sound spectrogram was created after high-pass filtering (0.3 kHz).

271

272 **Electric Supplementary Materials**

273 Video S1. A video of an adult and a juvenile crow giving type-K.