Craneworld

Die Welt, wie Kraniche sie sehen.
The world, as seen by cranes.

3.2 Frequenzanalyse von Kranichstimmen (in Englisch)

Individual recognition of cranes, monitoring and vocal communication analysis by sonography
A broad application of modern bioacoustic techniques

(Presentation at the IV. European Crane Workshop in Verdun, 11. - 14. Nov. 2000)

Abstract

The purpose of this work is to provide a method for individual recognition of crane pairs and crane individuals for long-term monitoring and gathering of individual life history facts without the need to capture and band them. Results in various regions and with various crane species will be described. In addition to the monitoring capability the method opened the possibility of analysis cranes' vocal communication and regionally specific "language" structures. The method is practically applied also in projects for the protection of endangered crane species, predominantly the Whooping crane, and here also in the raising and training of captive reared cranes for release into the wild and ultraleight airplane-led migration.

Dr. Bernhard Wessling mit Aufnahmeequipment

Introduction

Systematical sonographical studies on cranes had rarely been conducted in previous years, first by Archibald [1]. His goal and achievement was a taxonomical assessment by similarities and dissimilarities of the unison call as displayed by the various species of the cranes all over the world. No hints were given if any individual characteristics were detectable.

A second study [2] on the sandhill crane (grus canadiensis) was performed in order to evaluate individual and regional similarities and differences of their voice. Due to the use of the "guard calls" [3] and rather insensitive sonographical techniques (electromechanical, as available at that time), not only the recording method (a significant disturbance) was inappropriate for our goals, also the manual evaluation technique of the analogous sonograms is not effective. Moreover, the guard call was mostly expressed by the single crane in absence of its mate, so that pairs can not be identified, and hence the results of the study questionable. The unison call was not analysed by Weekly due to its complexity not manageable by this sonographical technique.

A third study [4] was devoted to sex determination of the Whooping Crane (grus americana) again by using the guard call. No hints were given concerning individual recognition possibilities, neither were the studies made on pairs, nor over many years.

Generally, earlier sonographical studies on unison calls of cranes have been sporadic and with low resolution, at most focused on showing the qualitative frequency picture of the calls.

Dr. Henne, Leiter des Biosphärenreservates Schorfheide-Chorin, bei der Beringung eines Kranichs

E. Henne in Germany, Brandenburg, had attempted in creating a collection of recordings on magnetic tapes for sonographical identification of cranes and their life history, and has started to record unison calls in certain crane territories in 1988. However he did not succeed in developing an analytical method for analysing his unique records [5].

One single older study was found where sonography was used to identify birds individually by acoustical methods: the Woodcock [6]. However in this case, it is the form of the song, not a characteristic frequency, which distinguishes the individuals.

The authors were recording birds whose territories were certainly too distant from each other to have birds changing locations. They showed, that an individual identification should in principle be possible, but did not perform it in a given region with several neighbouring territories, nor over several years.

In a more recent work (published after the development of the technique described here), C. Walcott [7] et al. used a commercially available program for analysing bird calls based on "Canary 1.2" and a multivariate factor analysis running on Macintosh and applied it on banded common loons. They were mainly able to recognise the loons and to follow them when they changed their territory, however, the program also produced some uncertainties [8] due to its concept (it automatically looks for empirically determined characteristic frequencies of the introduction, of lengths of tacts, etc., but would not be able to analyse unison calls where two birds are calling simultaneously).

The method

developed a lightweight system consisting of a transportable minidisk

I recorder, fed by a long range microphone (Sennheiser 486) with highest sensitivity and resolution plus an intermediate amplifier ("booster"), digital filing on minidisk and analysis by two different computer based Fast Fourier Transformation analyses.


Ein Teil des notwendigen Equipments

In the area where I developed the method (Hamburg, nature preserve "Duvenstedter Brook"), it is preferred to wait for the cranes to display their early morning call (up to 1 œ hours before sunrise), but also calls expressed in certain situation like territorial fights, copulation and others.

The hardware is completed by a megaphone (linked to a CD player) for recording work outside of this area when is limited time for recording. An appropriate unison call played over the megaphone, provokes the territorial pair (and sometimes also others) to answer. The method allows to record many calls at various places, from distance, without the need of penetrating the territory or come even close to the nesting area. Usual and practical distances are between 250 and 500 m, but recordings from a distance of 1 km or more have also been successfully made and analysed.

The recorded files are transferred into a PC after the field work. The files are recorded in Mono, and are transferred into the computer with 20 kHz sample rate.

The analysis is performed in two steps:

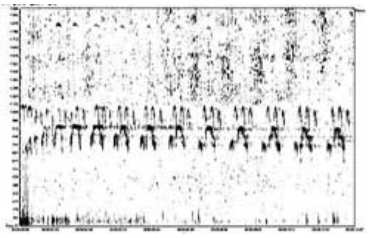
Figure 1

1. using the program "SoundForge 4.0", which generates a qualitative sonogram (Figure 1) between 0 and 2000 Hz - in contrast to earlier sonogram practice to show the full bands of overtones up to 3 or 6 kHz; the program is not made for voice or speech analysis; therefore, the resulting sonogram is not a data file, but only a screen picture which can be printed, but not be used for pattern analysis. It shows a qualitative picture of the call, it helps to identify noise, other disturbing bird calls (like geese, ducks, cuckoo) and to cut the files into useful pieces free from such complications.
2. based on "mathematica 4.0" (Wolfram Research), with a specially developed script [10] (protocol), a so-called "powerspectrum" is calculated (which is the plot of the intensities at certain frequencies, derived from the addition of all intensities at these frequencies over the time of the recorded call); these results are data, or better: lists of data, which can be analysed and compared. This analysis is preferably made between 600 and 1200 Hz at a very high resolution, and can be changed according to needs (e.g., there are cranes which call below 600 or above 1200 Hz). (With this program also sonograms are created which are now available as 3-dimensional lists of data - frequency, time, intensity - for further analysis in the powerspectrum, but not yet in the sense of a pattern or image analysis.)

The "powerspectrum" was considered by me to be a "vocal fingerprint" based on the fact, that the properties of the sound generating organ (the trachea) will determine the frequency spectrum of the generated sounds of an adult crane (after complete development of the voice).

▲

Results (1): identification of crane individuals / pairs

An identification of cranes and crane pairs would be feasible, if (a) call characteristics are stable enough within one season and from year to year (b) the are different enough to differentiate them from calls expressed by other cranes or crane pairs. In 1998, about 200 files from 7 pairs in their territories and outside of it, one adult unpaired male, and a few calls of unpaired youngsters had been recorded from late March to May.

The main result is that the sonogram and the "acoustic fingerprint" for a given pair are very stable and can be safely recognised (Figure 2, Figure 3, Figure 4).

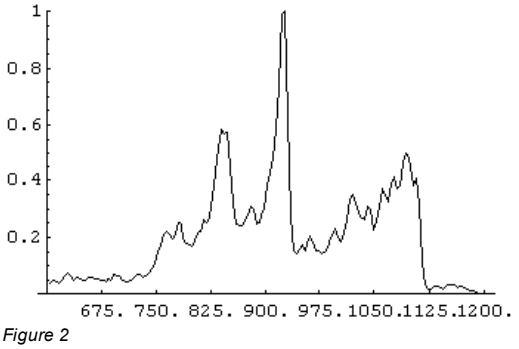

Figure 2

Calls from the same pair only differ by less than 5% (as calculated by spectrum comparison) during a season or from year to year.

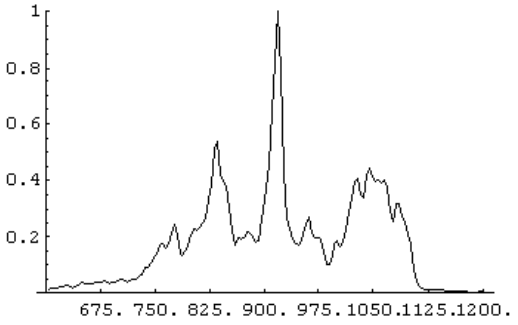

Figure 3

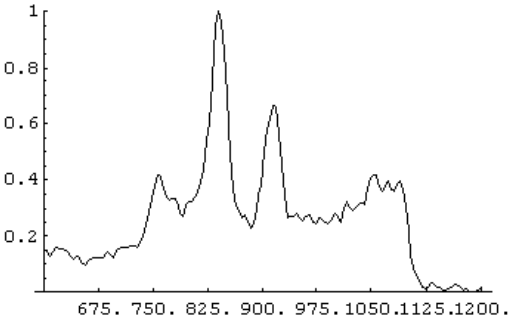

Figure 4

All calls, all the fingerprint spectra show enough different features from pair to pair so that they can be differentiated, cf. Figure 5 and Figure 6 with 2 - 4. These differences are much greater than 5%.

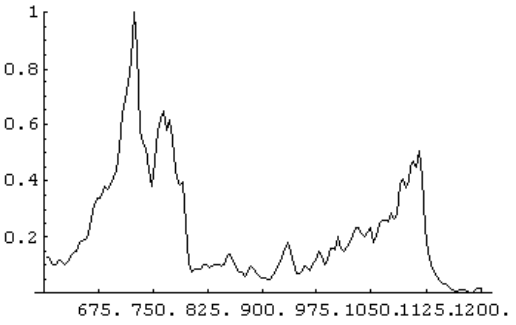

Figure 5

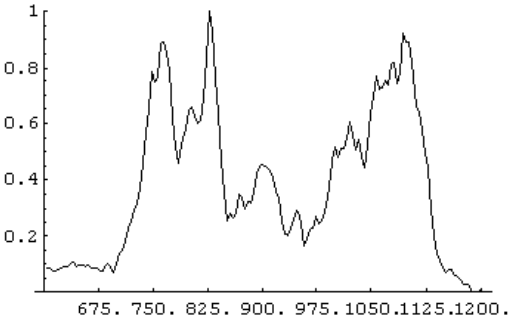

Figure 6

As (especially in the beginning) no ring banded cranes were available for making sure that certain recordings are definitely originating from a known pair, I tested the method by analysing the loon yodels recorded by C. Walcott et al [7]. The calls were safely identified, and even the confusion raised by changing the yodel character after territory changes could be resolved [11].

In the meantime, unison calls and other calls have been recorded and analysed from 7 crane species:

- Common Crane in Hamburg, Brandenburg, and in a bigger study area in Mecklenburg (comprising around 120 breeding sites in 635 km² with 92 nesting pairs (in 2000), from which in a first attempt 28 pairs have been characterised), altogether more than 50 different pairs
- Red crowned Cranes (in captivity: Baraboo, ICF; Vogelpark Walsrode, Germany; wild on Hokkaido, Japan, and in the Demilitarised Zone in Korea), in total over 60 different wild pairs, 5 of which are banded (recordings from banded cranes in winter 99/00, to be compared with later recordings)
- Whooper cranes in captivity (Baraboo, ICF, and Patuxent, Washington - almost 20 pairs), in the wild in Aransas National Wildlife Refuge (USA) 27 pairs, and in the breeding area in Wood Buffalo National Park (Canada), 10 pairs
- sandhill cranes (captive ones in Baraboo, ICF, and some wild ones in ANWR)
- White-naped Cranes (wild, DMZ in Korea), more than 30 pairs
- Siberian Crane (in captivity: ICF, Baraboo, and Vogelpark Walsrode, 8 pairs)
- Black-necked Cranes (captive in Hokkaido and Vogelpark Walsrode, 2 pairs)

Results(2): life history facts, (a) Hamburg

With these results, it was possible to conclude (in difficult cases, the sonogram should always be consulted, too), that in the nature protection area in Hamburg / Stormarn in the season 1998.

- 7 pairs (including a new one) were present, 6 of them territorial (and breeding: M1F1, through M6F6), 1 non-territorial: M7F7
- without any doubt, 3 pairs were territorial in an inaccessible hardly observable wetland and breeding in close vicinity at corners of a triangle with sides 75, 150 and 200 m long (however, this year with no success), where doubts had been expressed the year before as visual observations had indicated a third pair, which was not accepted as fact by many other observers (M1F1, M4F4 and the third pair M6F6)
- also, where doubts had been expressed the year before in an even less observable area, as

to whether the observation of a new pair in close vicinity of another older one was correct, the presence of 2 distinct pairs could be confirmed, and they were breeding in close vicinity (less than 100 m apart) (pair 3 and 5)

- it was possible to prove that pair 5 was looking for a territory in the vicinity of its 1998 territory by analysis of a video tape taken by another observer (where he was lucky to get a unison call) in 1996
- an unpaired (adult male) crane was trying to mate the female of the not territorial pair (pair 7) and to separate this pair (however with no success until the end of the breeding season).
- out of a group comprising 4 young cranes, I was lucky to record a single unison call expressed by 2 of these 4 young cranes (later pair 10).

In the next 2 years, several unique conclusions could be drawn, where visual observation failed; in 2000, nine pairs were present, where visual observation only concluded 4 or 5:

- **pair 1**
  vocally known since 1996 (identity proven for 96 also - video analysis - probably the oldest pair, territory occupied since 81); no juv from 1996 - 1999; 2 juv in 2000 after selection of new nesting site for 2nd breed (visually, a new pair would have be assumed);
- **pair 2**
  most successful in last years; raised only in 2000 only 1 chick; probably 2 chick each year from 96 - 99 (assuming identity for 96/97), also here, this pair changed the territory;
- **pair 4**
  took a breeding pause in 2000: arrived late March, no copulation observed, it was very inactive and seldom in the territory;
- **pair 6**
  first present in 1997; first breeding attempt in 98 (failed), 2 attempts in 99, one in a new territory (both failed); in 2000, M6 arrives with F11, a new female; their breeding was successful;
- **pair 5**
  took its territory first time in 1998 (1997 unoccupied, previously owned by **pair 3**, which took neighbour territory after F of that territorial pair was killed in 95); in 99, not present - territory taken by **pair 7** (new in 98, no territory); back in 2000 (but now, pair 7 was missing)

  However, it is proven from video analysis, that pair 5 was searching for territories in the preserve in 96 (and observed in 97)

In 2000, 3 new pairs were looking for territory and probably established (each one undertaking no breeding attempt):

- **pair 8**
  first identified in a territorial fight with pair 2 in their second nesting place in 1999;
- **pair 9**
  also identified in 1999 calling from the area, where is now their territory;
- **pair 10**
  first identified and present in 1998 (!), when it appeared in a group of 4 youngsters, landed in a pond and unison called!

Figure 7, Figure 8 and Figure 9 (PDF) display a qualitative overview over the distribution of the crane territories and the changes observed by sonography.

Results(2): life history facts, (b) Brandenburg

With these tools and experiences in hand we replayed and digitalized analogous recordings on magnetic tape, taken by E. Henne over many years in Brandenburg, in an area of comparable size like the one in Hamburg with 7 - 9 territories, several of which had been very close together, and analysed them with the same method. Including 1998, the files are comprising 37 "crane-pair years".

The analysis (summarised in table 1) showed a remarkable stability of the crane pairs in their territories over years, although the places were rather close to each other. In all 6 territories, for 2 and more (up to 6) subsequent years it could be documented that the same pairs were present: 34 times, territories were occupied the next year, too, 29 times by the previous pair.

We found that in the nesting place Bb not only in 1997, as was observed by Henne, 2 pairs were breeding, but also - visually undetected - in 1994 and 1995, and these were the same ones as in the later years. The sonography had detected the presence of the second pair where the visual observation had failed for 2 years. Whereas one pair (No. 7) was missing there in 1997, it appeared again in this joint territory in 1998. Also it was shown, that - as in Ss and Fb - the apparently continuous use of a territory / nesting site may indeed be a sudden replacement of one pair by a new one, or a stepwise replacement with a phase of one to several years of tolerance at a close distance.

Pair No."3" bred in territory Zb from 1993 to 1996, it was joined in this territory by pair "4" for one year (1994).

In one territory (Ss) however, in contrast to the others, 3 different pairs of males and females were breeding between 94 and 98. Pair 9DB (male D and female B) bred in 1994, pair 8AC in 1995, pair 8AB (i.e. with the same female as in 1994 in DB!) in 1996 and 1997.

We conclude, that pair bonding and partner loyalty is quite strong in the Eurasian Crane, as is their loyalty with their territory. It seems to be more common than concluded from visual observation, that cranes tolerate another pair close to their nesting site, allow it to breed there for some years, whereby the latter pair may become the only pair after some time (disappearance of the first pair, like 1997 in Bb).

During the time and for the territories observed by Henne, three times a crane formerly bound with a mate has changed his mate (1991/94 Fb; 1994/ 95 and 1995/96 Ss). This would be equivalent to a rate of about 10%, and (as shown in Ss) not necessarily because of the death of the partner. Also, a territorial pair with longer tradition may be displaced by a new one and find a different territory nearby.

In 4 cases (about 15%) a new pair appears in a territory originally owned by another pair (1991, 1995 and 1998 in Fb, 1993 Zb, 1995 Ss).

Surprisingly, these results are in good accordance with .preliminary conclusions drawn from a broad field study running now over 7 years with sandhill cranes [12]. Here, an increasing number of adult cranes pairs was banded (now 35 pairs), and some radio-tagged.

Of well over 100 crane-pair-years observed until now in only 12 cases mates had changed, in the other cases, the same pair returned to the territory, i.e. again about 10% "divorce rate". It was found that most of these divorces had not been due to one of the mates having died.

It is therefore not any more unlikely that partner loyalty may be a matter of the degree of the partners "fitting together" and a change of the mate a matter of choice by both sexes. This is supported by our observations in Hamburg, where a single adult crane tried for a whole spring season to win a mate bound with another male, however without success. Male 6, obviously a young individual, came back with a new female after the first 2 unsuccessful breeding attempts.

In another even broader study in Mecklenburg near Goldberg, we will build a database comprising around 90 pairs in 635 km² observation area for a long-term monitoring; 28 pairs have been acoustically characterised as a first step. 2 new pairs have been found in a densely populated small moor, 2 new occupied territories (visually unknown) in a forest. The sonographical monitoring will be part of the continuous visual observation going on there since many years, which is accompanied by banding and radio-tracking work.

International projects

In Japan (Hokkaido), we have begun to build the basis for a longer term monitoring with the resident red-crowned cranes. Recording of spontaneous unison calls at winter feeding stations showed the feasibility, as well as did a later recording (using provocation by playing calls from CD via megaphone) in 16 breeding territories in South and Northeast Hokkaido.

Even later, it was possible to record unison calls of pairs with at least one banded crane individual at winter feeding station. These pairs can be followed over the years even in winter, provided that they will call in the presence of a recorder [13].

The analysis of these calls was the basis for a comparison of Japanese red-crowned crane unison calls with those from mainland China. These calls have been recorded by me in winter 99/00 in the Demilitarised Zone between North- and South-Korea, where a significant portion of Chinese red-crowned cranes (and also white naped cranes) is-wintering.

After a detailed analysis [14] it is evident, that the call structure is completely different between the Japanese and the Chinese cranes of the same species. Call structure (degree of complexity), most prominent frequency of male and female, call length, female calls per male tact and other features are basically different. The two populations are separate since probably 300 years or more, which did not create the cranes to form a different species (recent gene analysis has shown that the population still are genetically to be considered one species) [15].

We therefore have to conclude that the call structure is influenced not only by genetic, but also strongly by social factors.

Red-crowned cranes (especially at their wintering feeding sites) seem to provide an excellent study field for beginning to understand the cranes' vocal communication codes ("language"). We have found several different vocal expressions, more than have been observed before (and also some very interesting ones in response to CD calls by megaphone). Observations are leading to the conclusion, that cranes inform each other about living objects on earth (with no or low degree of danger, but some degree of interest), like a "deer", and with a different sound about a living flying object representing a certain danger, like an "eagle".

We have recorded and analysed the respective sounds [16].

The certainly most important study is connected with the North-American Whooping Crane, the most endangered crane species with only 188 living individuals in the last surviving wild and self-reproducing population. Banding of young whooping cranes has been stopped about 12 years ago. In a first expedition to the wintering grounds in the Aransas National Wildlife refuge in Texas in 1999, 27 pairs have been characterised with the "acoustic fingerprint", 22 of them by unison call, 17 of them by their guard call, and 12 with both guard and unison call. For this purpose, more than 200 recordings have been analysed.

In another expedition to the breeding grounds in the Wood Buffalo National Park in North Canada (by Brian Johns, using my equipment), it was possible to record 10 pairs in their breeding territories.

The analysis of the calls and the comparison with the analyses of the winter calls showed, that 6 of the 10 recorded pairs were in the group of 27 characterised in the previous winter. So it was possible for the first time to follow wild birds from the winter territory to their summer territory and find out which bird lives together with his mate in which territory - without having them touched any time, or even disturbed in any way. These are the results:

spring 2000	
territory in ANWR	winter 99/00 pair number in WBNP
8	3
10	1
17	2
19	12
32	30
33	13

This can be the basis for a long-term monitoring of these endangered birds, providing the possibility of learning more about their life, helping to establish even better protection means.

The growing knowledge about the importance of vocal communication for cranes has become an important part also of the project (carried out by the "Whooper Crane Recovery Team") to establish a third population (after the second one which is being established in Florida as a residential non-migrating flock) by release of captive reared cranes into the wild. The 3rd flock will be released in Wisconsin and it is planned to teach them to migrate with the help of ultraleight airplanes ("Operation Migration").

As a last test run before doing so with captive reared Whooper cranes, the team is flying the same way with captive reared sandhill cranes. For the first time in such raising and training for UL-led flights, calls recorded from wild (sandhill) cranes were used to communicate with the young cranes. 6 different calls have been provided by the author to be played using wrist-held small loudspeakers and powerful megaphones attached to the airplanes. The calls are interpreted to be used by the sandhills with the understanding of "attention", "danger", "continue flight", "come here / contact", and the guard and the unison calls.

The first experiences are very promising: the vocal imprinting seems to be much more powerful than pure visual imprinting (after hatching): whereby it was very complicate in earlier trial projects to bring the young cranes to follow the airplane in the first weeks (because they preferred to stay the ground together with the - costumed - caretaker), they now followed the subject or object making the "contact" call. It is easy to tell the cranes to follow the airplane or the caretaker, to go in or out of the fenced area. It was even possible to call a group of young cranes back to the training centre when they had been "kidnapped" by a wild crane pair.

Conclusions

The new sonographical method for identifying cranes provides a relatively simple and easy to handle tool for identifying and monitoring cranes and their life (partner and territory fidelity) It also allows to count how many different crane pairs are present in a certain area, much easier than by just visual observations.

The collection of recordings made by systematic visits to the areas in question especially early in the morning, but also statistically distributed over the days gives a picture of the minimum number of pairs (and individuals) present in the area under supervision.

Wherever it is not possible or not advisable to band (which is the majority of areas) this method is the only method which can be practically applied by almost every ornithologist or observer.

A long term monitoring of cranes leading to individual life history facts is possible.

All these advantages without even touching the cranes, from distances between their flight distance up to several kilometres.

Acknowledgements

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I thank George Archibald for his consults and his generous help in providing me the possibility to record at the ICF in Baraboo and for introducing me to the Whooper Crane Recovery Team, to the Japanese and Korean crane experts who helped me in my field work there (Yulia Momose, Prof. Masatomi, Kimiya Koga, Mr. Matsuo, Mr. Pae). My thanks go also to the Whooping Crane Recovery Team and especially George Gee who arranged the possibility for my recording in Patuxent, Tom Stehn who supported my recording in Aransas, and Brian Johns, who recorded in WBNP. Thanks also go to Operation Migration (Bill Lishman, Joe Duff) for their support for applying the vocal communication technique during the UL-led migration.

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4. G. Carlson, C. Trost The Condor 94 532 - 536 (1992)
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8. in 2 years, 2 different male loons occupied a territory which the factor analysis was not able to distinguish; in another year, a known loon invaded the territory of another known loon and displaced the former owner; the displaced loon established nearby but its "yodel" call changed so that it was not grouped any more in the same factor space as before, so would have been considered to belong to a different bird according to the program used; also the invador's yodel had changed, but less dramatically; several other examples confused the authors so that they concluded that changing the territory also changed the loon yodel; cf. footnote 11
9. thanks go to Frank Golchert, who consulted in purchasing of hardware and modified it according to my concept
10. thanks go to H. Hoffmann, a former "mathematica" support technician, who helped me to develop this special protocol
11. using my analysis, als apparently changed calls showed the same fingerprint as before territory change, and the confusion raised by "Canary 1.2" became obvious: the birds were partially "overblowing", so that the program did not find the correct frequency of the

introducting tone (which was to be found at double frequency as overtone only), and some other slight changes in the call structure not at all significant had nevertheless put the respective calls outside of the factor space

12. performed by the International Crane Foundation, Baraboo, Wisconsin, in Briggsville, WI; Jeb Barzen personal communication
13. K. Koga, B. Wessling, to be published
14. B. Wessling, to be published
15. K. Koga, personal communication referring to a Japanese publication
16. K. Koga, B. Wessling, to be published