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BIOACOUSTICS IN ZOOS: A REVIEW OF APPLICATIONS AND PERSPECTIVES

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In recent years a bioacoustic approach has been generated as a separate group of non-invasive methods in zoo and agricultural practice. Animal sounds have a potential to provide extensive information about internal state, sex, subspecies, reproductive state, social status, stress and welfare of animals, and there are now many positive results in the area. This approach is based on the vocal behaviour of animals and on the structure of their calls. Here we review both some successful applications of this approach and some scientific reports providing information that can be potentially applied in zoo practice.

Application 1: Identification of species, subspecies and their hybrids

Zoos try to prevent the breeding of individuals of unknown subspecies, and sounds are a promising means of identifying subspecies and their hybrids. This application has been reported as appropriate for the following taxa: Hylobatidae and Cervidae (Mammalia); Phasianidae (Aves).

It has been shown that bioacoustic methods may be useful for determination of subspecies status in black gibbons *(Hylobates concolor leucogenys* and *H. c. gabriellae)* (Demars and Goustard, 1978). Some time ago Moscow Zoo used tape recordings of black gibbons' songs to confirm the subspecific status of animals being transferred from the zoo. Geissmann (1984) reported that hybrids between pileated gibbon *(H. pileatus)* and white-handed gibbon *(H. lar)* may be distinguished by their songs because of the inheritance of species-specific song parameters.

Deer provide some particularly good examples of hybridization occurring between apparently distinct species both in captivity and in the wild. Long *et al.* (1998) showed that the status of hybrids between red and sika deer *(Cervus elaphus* and *C. nippon)* may be confirmed by their rutting vocalizations and alarm calls.

In common pheasant *(Phasianus colchicus),* twelve subspecies are difficult to distinguish by their external appearance, and then only in the case of males. Phokin (1983) reported that the subspecies may be recognized in one-day-old chicks by their vocalizations.

Application 2: Determining reproductive state

Some zoos and private keepers use animal sounds as indicators for determining reproductive state. This application has been reported as appropriate for the following taxa: Cheirogaleidae, Cercopithecidae, Sciuridae and Felidae (Mammalia). The approach is based on the fact that females of some mammals utter a special call on the day of oestrus, which is not heard during other reproductive phases. Among these species are, for example: grey mouse lemur *(Microcebus murinus)* (Buesching *et al*,, 1998), lion-tailed macaque *(Macaca silenus)* (Lindburg, 1990), gelada baboon *(Theropithecus gelada)* (Moos-Heilen and Sossinka, 1990), Siberian chipmunk *(Tamias sibiricus)* (Gillett, 1988), puma *(Felis concolor)*, jaguar *(Panthera onca)* and leopard *(P. pardus)* (Peters, 1978).

Cheetah *(Acinonyx jubatus)* females do not produce any specific call during oestrus, but the males do so in response to urinal scents of oestrous females introduced into their enclosure. Keepers at Moscow Zoo use these males' sounds to decide the time for a pairing. These sounds also provide the potential for assessing the 'quality' of a male: as a rule, if a male does not produce the specific calls, he is unable to reproduce (Volodina, 1994; Volodina and Volodin, 1996).

Application 3: Transmission of conspecific sounds in order to increase or decrease some behavioural activities

Transmission of recordings of conspecific calls can be used to stimulate reproductive behaviour and reproduction, or to decrease aggression. This application has been reported as appropriate for the following taxa: Phasianidae, Tetraonidae, Laridae (Aves), Cervidae (Mammalia).

Tichonoff *et al.* (1988) showed that the transmission of species-specific courtship calls enhances courtship vocalizing, copulatory behaviour and egg fertilization of the farmed game birds *Coturnix japonica, Phasianus colchicus, Tetrao urogallus* and *Lyrurus tetrix.* Prenatal acoustic stimulation of embryos gives positive effects on synchronization of hatching. Transmission of comfort calls increases foraging activity and decreases aggression by chicks in high-density housing conditions. Some of these effects were also reported for ring-billed gulls *(Larus delawarensis)* (Fetterolf and Dunham, 1985) and domestic hens (Guyomarc'h and Guyomarc'h, 1981).

In the red deer (*C. elaphus)*, transmission of male rutting vocalizations advances the occurrence of oestrus in females (McComb, 1987).

We believe, however, that in the case of rare or endangered species of mammal, the transmission of conspecific calls should only be used with great care, because animals' reactions to them are unpredictable - they may react extremely strongly, or alternatively they may become habituated and learn to ignore them.

Application 4: Vocalizations as indicators of social relationships

This application has been reported as appropriate for the following taxa: Hylobatidae, Cercopithecidae, Pongidae (Mammalia), Anatidae, Gruidae, Psittacidae (Aves).

In the Bronx Zoo, one pair of white-handed gibbons showed better duetting than others; later these ethologically compatible partners bred successfully (Gibbons and Lockwood, 1985).

It was found at Stuttgart Zoo that social position is reflected in contact calls in gelada baboons (Aich *et al.*, 1987). Similarly, in wild gorillas intragroup vocal repertoires correlate with the social ranking of individuals (Harcourt *et al.*, 1986).

Duets as indicators of established pair bonds were reported for greylag goose *{Anser anser)* (Fischer, 1965), snow goose (A. *caerulescens)* (Gurtovaya, 1990), Canada goose *(Branta canadensis)* (Phokin, 1985), red-breasted goose *(Rufibrenta ruficollis)* (Volodin, 1990b), ten species of crane (Archibald, 1974), and canary-winged parakeet *(Brotogeris versicolurus)* (Arrowood, 1988).

Application 5: Vocalization as an emotional indicator

For animals, the main problem of examining sounds as emotional indicators is how to measure an emotional state independently. But there are some findings in this area. This application has been reported as appropriate for the following taxa: Cebidae, Suidae, Felidae (Mammalia).

Thus, in squirrel monkeys *(Saimiri sciureus)* Jurgens (1979) found a relationship between the vocalizations evoked by electrical brain stimulation and the degree of aversion in the animals' emotional state. In his experiments the monkeys had the ability to switch off unpleasant electrical stimulation by moving into a different part of their enclosure, or to stay, if the stimulation provided a pleasant emotional state. The amount of time spent under stimulation was used as a measure of the emotional state of a vocalizing animal.

It was shown at Moscow Zoo that, throughout interactions between cheetahs, the enhanced uttering of tonal or pulsed sounds depends on the social role (Volodina, 1997b). A higher proportion of pulsed sounds is produced by the stronger animals, who can better control events in their environment. It was hypothesised that sounds with a pulsed structure are linked to an emotional state of self-confidence, whereas tonal sounds are produced by animals who are diffident or unsure of themselves. It was also shown that the tonal sound structure, together with a high degree of noise energy, is closely related to frustration in young leopards *(Panthera pardus orientalis)* and young cheetahs separated from their mothers (Volodina, 1994; 1997a).

The close relationship between certain call structures and pleasant or unpleasant emotional states suggests a potential use of sounds also as welfare indicators. Weary and Fraser (1995 a,b) showed that variations of sounds made by young domestic pigs during separation from their mothers, under various degrees of food deprivation, and during castration represent reliable indicators of the animals' needs. Norcross and Newman (1993) found that isolated housing can modify call parameters in common marmosets *(Callithrix jacchus).* Budde (1998) reported about some differences in structural nuances between the sounds of grey crowned cranes *(Balearica regulorum)* recorded from captive and free-living birds.

Application 6: Sex determination in birds without sexual dimorphism

In zoos sex determination in birds which lack sexual dimorphism may be a problem, because cranes, geese and ducks can easily form homosexual pairs. Also, curators need to know the sex of young and adult birds in order to plan their management with these species. This application has been reported as appropriate for the following taxa: Anatidae, Phasianidae, Gruidae (Aves).

This method of sex determination was initially developed by Tichonoff and colleagues (1988) as an alternative to manipulative methods for one-day-old poultry chicks and game bird chicks in industrial incubators. It was less traumatic and faster than the usual manipulative procedures. Bioacoustic sex determination was also reported by these authors for adult birds of various species of Anatidae.

Carlson and Trost (1992) of the Patuxent Wildlife Research Center (Maryland, U.S.A.) elaborated a method of sex determination in the whooping crane *(Grus americana)* by analysis of guard-calls.

The reliability of sex determination by vocal characteristics is dependent upon the parameters used, and is generally about eighty per cent. Sometimes it is possible to enhance reliability by behavioural observation.

At Moscow Zoo we found that in red-breasted geese males in homosexual alliances may be distinguished from females by the absence of the female's part of the duet in their vocal behaviour (Volodin, 1990a).

Conclusion

The bioacoustic methods reviewed above increase the options available for the non-invasive monitoring of captive animal populations. No doubt only a combination of disciplines can provide high-quality monitoring and management in zoo animals. However, bioacoustic methods may help in developing the most appropriate combination of techniques to solve a particular problem. Moreover, we now have better equipment than formerly for sound analysis, so these methods are becoming less and less expensive and more and more productive.

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