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Guidelines for capturing and radio-tracking Great Bustards

Prepared for the Memorandum of Understanding on the Conservation and Management of the Middle-European Population of the Great Bustard under the Convention on Migratory Species by

Juan C. Alonso
Research Professor
Museo Nacional de Ciencias Naturales
Consejo Superior de Investigaciones Científicas

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Author's address:
Juan C. Alonso
Museo Nacional de Ciencias Naturales (CSIC), José Gutiérrez Abascal 2, 28006 Madrid, jcalonso@mncn.csic.es

Front cover picture:
Great bustard male chick released in Madrid, Spain, after being marked. © Juan C. Alonso

Introduction

The Great Bustard *Otis tarda* occurs in highly fragmented populations across the Palaearctic region, from the Iberian Peninsula and Morocco, eastwards, to China (Del Hoyo et al. 1996). It is considered *Globally Threatened* and qualifies as *Vulnerable* in the Red List of Threatened Species (IUCN 2006), due to the possible negative impact of land-use changes in eastern Europe, Russia and central Asia, which might cause a rapid population reduction (BirdLife International 2004a). The population trend was clearly declining worldwide in the last century due to hunting, agricultural intensification and infrastructure expansion, a tendency that still persists today. In Europe it is also classified as *Vulnerable* (BirdLife International 2004b). Over the last 50 years Great Bustards have become extinct in several European and Asian countries (Cramp & Simmons 1980, Chan & Goroshko 1998, BirdLife International 2001).

Scientific research of the biology and ecology of great bustards was identified as one of the priorities to stop these declining trends in the Action Plans established some years ago (Heredia et al. 1996, CMS 2000). Individual marking is a useful method to study wild animals in the field (reviews in Bub & Oelke 1985, Bub 1991). Specifically, radio-telemetry is currently acknowledged as a necessary means for answering many biological questions (Amlaner & McDonald 1980, Kenward 2001). Compared to other marking techniques, radio-tagging has obvious advantages for recording behaviour and demography, being essential to obtain true and reliable estimates of e.g. dispersal and mortality rates (Table 1). These advantages may be summarized in two: (i) radio-tracking makes animals accessible to systematic sampling, thus reducing many sources of bias, and (ii) it does this for specific individuals for which other attributes can be recorded during capture for tagging and through subsequent monitoring (Kenward 2001).

Table 1. Some benefits of radio-tracking *vs* alternative marking methods

Study objective	**Radio-tracking**	**advantages**
Natal and breeding dispersal	essential	no alternative method to track all birds and establish true dispersal rates
Mortality	essential	only way to establish true mortality rates
Migratory and seasonal movements	required	allows continuous tracking; satellite telemetry necessary for long-distance migration
Home range and space use	required	enables easy location and continuous tracking
Longevity	required	facilitates tracking until battery depletion
Viability modelling	required	allows estimation of demographic parameters
Census	useful	facilitates location of birds or flocks by tracking marked individuals

Under the auspices of the Convention of Migratory Species (CMS) a Memorandum of Understanding for the Conservation of the Middle European Population of Great Bustard (MoU) was concluded and became effective on June 2001. At the 1st Meeting of the Signatory States in Illmitz, Austria on 17-18 September 2004, the range states adopted their Medium Term International Work Programme 2005-2010 (MTWIP), which identifies the priority actions to forward the implementation of the MoU in the following areas (1) cooperative research and monitoring, (2) measures to implement the action plan and (3) issues for which guidelines should be developed.

Amongst other issues, the MTIWP identified the preparation of guidelines on capturing and handling birds for research in order to reduce possible negative impact of otherwise very much needed research activities on the small populations in Middle Europe. These guidelines were considered necessary because the Middle European population of Great Bustard sometimes suffer serious losses during winter migration and migration routes and winter movements are poorly known based on land based surveys. In addition, lack of reliable demographic information also hinders the evaluation and further development of conservation measures for the protection of the species.

On behalf of the MoU BirdLife International asked Prof. Juan C. Alonso, as an acknowledged expert in this species, to compile these guidelines. Since 1987 he has been leading the *Project Great Bustard* in Spain (www.proyectoavutarda.org), where the main stronghold for the species survives (with an estimated total of ca. 25000 birds, Alonso et al. 2003, 2005a). From the start the main objective of this project was to acquire a profound knowledge of the species and systems studied, which later could be applied to their conservation. The research line was the relationships between individual behaviour, population ecology and conservation biology. Therefore, one of the main methods used has been long-term studies of individually marked birds, which has required an enormous amount of effort in capturing and marking birds (several hundreds up to present), as well as tracking many of them to obtain significant samples of their behavioural features. This way the *Project Great Bustard* has produced results of both, theoretical and applied interest on various aspects of the species' ecology and behaviour, e.g. migration (Alonso et al. 1995, 2000, 2001, Morales et al. 2000), juvenile and natal dispersal (Alonso et al. 1992, 1998, Martín et al. 2002, 2007), breeding success (Morales et al. 2002), and metapopulation structure (Alonso et al. 2004). Besides, interesting results for age and sex identification were obtained (Martín et al. 2000, Alonso et al. 2006).

The present document contains the above mentioned guidelines, which consist of a review of existing experience with various methods of capturing, handling, fitting radio transmitters or other marking methods, identifying the advantages and risks involved with each method. The guidelines aim (a) to share available experience and best practices with researchers in the MoU area, and (b) to inform the decisions of the competent national authorities to assess correctly the risks involved when capturing great bustards for research purposes.

Capturing great bustards

Juvenile birds

Juvenile birds should be captured in late July to early August, when they are 3-10 weeks old and still dependent on their mothers, by chasing them down. After one or two flights young birds usually separate from their mother, lay down and remain motionless, hidden when possible in the ground vegetation, trying to go unnoticed. Chicks <3 weeks old tend to remain hidden on the ground rather than fly, and thus are usually easier to catch but too small to be marked. Chicks >10 weeks old are frequently impossible to catch by this method, because they are experienced enough to fly after their mother and do not tend to hide by laying down any more.

In any case, birds weighing less than 1 kg should be released unmarked, at least with the wing-tags or radio-transmitters recommended below, since juvenile mortality is still too high at that age (Martín et al. 2007), and the weight of tags and transmitters could increase natural mortality rates. In our study the average weight at capture was 2131 g in males (n= 186, maximum weight = 3800 g) and 1433 g in females (n= 175) (Martín et al. 2007).

After marking a chick, we recommend to release it in the same spot where it was caught to facilitate that it is rejoined by its mother as soon as possible. If the place where it was caught is too far away from where the family was initially spotted, and there are doubts that the mother followed the chick's flights, it is safer to release the chick close to the initial family location. The whole capture process, from starting chasing to release, should not last more than 30 minutes, and from capture to release, not more than 10-15 minutes.

This method is considered safe and harmless for the species, if carried out by people with previous experience in handling wild birds. It is desirable that researchers planning to capture young bustards for the first time learn how to do it from experienced teams. We did not observe any apparent negative effects of the marking procedure on the birds. In order to make sure that marking was harmless; we compared counts of young great bustards throughout the summer and did not find significant differences between the mortalities of marked and non-marked birds (Martín et al. 2007). Thus, we assumed that our marking method did not negatively affect the birds, as has been also shown or assumed for similar radio-tagging methods with other species (Combreau, Launay & Lawrence 2001, Grant 2002, Rohner et al. 1996). Ideally, teams trying to capture young bustards for the first time should have some training with people having done it before.

Adult birds

Rocket nets

After testing several methods of capturing adults, the most effective was using rocket nets. However, this technique needs an experienced team to select the place for the nets, handle the explosives, and several trained persons to safely remove the birds from the net. The whole operation should be carried out within the shortest possible time (from the net shooting to release of the last bird not more than ca. 30 minutes), to avoid problems related with capture myopathy, which doesn't affect young birds but may affect some adults after capture. To minimize these risks, the birds should be quickly removed from the net, immobilised with special jackets, and their heads should be covered to ensure they remain calm during radio-tagging.

Other nets

Smaller transportable nets have been used to capture 6 females at their nests in Saratov, Russia in 1999-2000 (Watzke et al. 2001, Watzke 2007). A net of 25 m^2 fired automatically over the breeding female, and also a ring-mounted net of a diameter of 2.5 m thrown by night over the female were used, after replacing the eggs with wooden dummy eggs. A female was caught in 2006 in Hungary with a small manually triggered net (Lorant 2007). Similar nets of this type or others including bow-nets installed at the nest have also been used to catch little bustards in France and Spain, and houbara bustards in Morocco and some Arab countries (Launay et al. 1999, Seddon et al. 1999, Hingrat et al. 2000, Combreau et al. 2001). The use of such nets also needs experienced people, and causes disturbances to the incubating females which may result in nest desertion. If used with caution it may be effective for catching females, but obviously not males. The method requires previous nest location.

Large nylon nets hung vertically between two trees or bushes have been successfully used to capture Kori bustards in Namibia (T. Osborne, pers. comm.). Koris apparently do not see the net when driven by car or foot into it, and get entangled. We tested this method in Spain without success.

Nylon snares

Nylon snares have been successfully used to catch houbara bustards (Launay et al. 1999, Seddon et al. 1999, Hingrat et al. 2000). Displaying males step on the laces and get entangled. However, after getting caught by the laces birds continue jumping and trying to escape until researchers arrive and immobilize them. We have tried this method once with great bustards without success, but discarded it because we think the bustards are too heavy and could get seriously injured when trying to escape from the laces.

Oral tranquilizers

Alpha-chloralose and other oral tranquilizers have been successfully used to capture several bird species. Although we had previously caught storks and cranes using this method, we tried catching great bustards without success.

Marking methods

The recommended method is the use of radio-transmitters combined with wing-tags. The transmitter allows locating the birds through radio-tracking and the wing-tag facilitates a quick visual identification of the marked bird in a flock, and enables further recognition when the transmitter batteries are exhausted. This is particularly important in a long-lived species, in order to maximize the benefits of having already caught and marked the bird, considering all risks involved in capturing and marking a species classified as vulnerable.

Some authors have called attention on various possible negative effects of capturing and marking procedures on animals, which would be subject to higher mortality, behaviour alterations, or worsening of their physical condition (Hessler *et al.* 1970, Greenwood & Sargeant 1973, Craighead & Dunstan 1976, Lance & Watson 1977, Snyder 1985, Small & Rusch 1985, Perkins 1988, Kenward 2001). Others suggest, in contrast, to increase the sample of marked individuals to assure that it is representative of the species studied (e.g. Cochram & Ior 1963). Most authors admit that radio-tagging, as well as any other capture and marking method, including netting birds for ringing, implies certain mortality risks. However, these should be compensated by the benefits derived from the application of the research results to the conservation of the species studied, provided the mortality risks remain low and controlled by the researcher.

Wing-tags (or patagial tags)

Patagial tags (also called wing-tags or wing markers) have been used to mark birds of several species (Anderson 1963, Mathisen 1966, Parry 1967, Southern 1971, Blackman 1973, Morgenweck & Marshall 1977, reviewed in Bub & Oelke 1985). They are particularly appropriate for great bustards, a large, ground-dwelling species that inhabits open grasslands with high horizontal visibility. Wing-tags have been usually made of soft plastic (e.g., Saflag, Dantex, Herculite, etc.). Such soft wing-tags have been also recently used to mark great bustards in Germany (Eisenberg 2007) and Great Britain (D. Waters, pers. comm.). Some authors have found that these soft materials do not reliably hold up after a few years, or that the original colour faded, making many tag colours impossible to distinguish. Furthermore, in the case of soft wing-tags the numbers or letters are usually painted with permanent ink markers on the plastic, and could become difficult to read after some years.

We prefer wing-tags of rigid coloured PVC (Gravoply) like those we have used in our study (www.proyectoavutarda.org, see Fig. 1). If they are bent in the upper part to adapt to the wing shape and properly attached to the wing they do not flap when the bird flies, and do not fade even after 10 years. Wing-tags may be lost but this is very infrequent. We have used the same material to make colour rings for common cranes, and could distinguish the colours of the ring after several years.

The Gravoply plate is 1.5 mm thick, and has two layers of different colour (e.g., green-white, brown-white, yellow-black, etc.), and by engraving a letter, number or symbol on the upper layer we obtained combinations of colour symbols on a background of a different colour (e.g., a green 'A' on white background, or a white '3' on green background, etc.). The recommended size of the visible part of the tag is ca. 60x60 mm, and the width of the number or letter ca. 10 mm. Thinner symbols are difficult to read from normal observation distances.

The tag is attached to the wing patagium by piercing it with a rivet like those used for the sheep ears using special pliers (Allflex). While piercing it care should be taken to avoid damaging any blood vessels, muscles or tendons. The total weight of tag plus rivet is ca. 10 g. We recommend covering the tag with thin brown paper painted with black imitating the plumage design of the birds to reduce as much as possible the visibility of the tag to predators during a few days after marking (see front cover picture). The paper will usually fall off after some days, showing the design of the tag. Wing-tags should have an address label to enable anyone finding a dead marked bird to contact the researcher responsible for the tracking project.

Fig. 1. Wing-tags used to mark great bustards by Alonso and co-workers in the *Project Great Bustard* in Spain (www.proyectoavutarda.org)

Dorsal tags

Dorsal tags similar to wing-tags made of rigid plastic described above have been used successfully for adult males (Fig. 2). They are not recommended for young or adult female bustards, because they would appear too bulky on them, and in the case of adult females, also because they would probably make them more vulnerable than wing-tags during incubation. The plate is glued to the top of the backpack transmitter in a vertical position, thus showing the engraved letter or number to both sides of the bird. These tags are easily read from a distance, and apparently do not disturb the bird when flying,

as they are quite aerodynamic. The main advantage of dorsal tags over wing-tags is that piercing trough the patagium is not necessary, which means less time necessary for marking.

Fig. 2. Adult male great bustard marked with backpack transmitter and dorsal tag before release

Radio-transmitters

Radio-tagging is a sophisticated technique for studying wildlife behaviour that has developed during the last decades (Amlaner & McDonald 1980, Bub & Oelke 1985, White & Garrot 1990, Kenward 2001). After testing several types of radio-transmitters and attachment procedures we strongly recommend backpack-mounted units, fitted to the bird with an elastic harness. Below we describe the various fitting methods and transmitter types we have tested (see also Table 2).

Patagial tags

Radio-transmitters were glued to wing-tags of rigid plastic like those described above but of smaller size. These were attached to the patagium as described above. This method obviously limits maximum transmitter weight and thus transmitter lifespan. We tested this transmitter type in 1991, and discarded it for its short lifespan and also after observing a high percentage loss after a few weeks to few months after marking (>80%, Alonso et al. 1996a). The relatively heavy transmitter fell off probably tearing the patagium, which however didn't affect the survival of the bird. We do not recommend this tag type for great bustards.

Wing-band mounts

The transmitter is attached to a flexible plastic wing-band similar to those used in raptor tagging which surrounds the humerus and is sewn with conventional staples behind it. The staples would eventually break and the wing-band should fall off with the transmitter. We indeed observed a percentage loss of wing-band transmitters of ca. 20% (Alonso et al. 1996a), in many cases even after battery exhaustion. Although we used wing-band transmitters in just a few birds, we suspect that their loss was primarily due to the fixing system used. The weight of the transmitter should not exceed 20-30g, and therefore its

lifespan is also limited to perhaps ca. 2 years, the main reason to consider this transmitter type also suboptimal.

Ponchos or necklaces

There are various types of necklaces described in the literature (Kenward 2001). We used some of these, and also a modified version of the 'poncho'-attachment described by Perkins (1988). Necklaces weighing ca. 20 g have also been used in Germany and UK, to mark females released from artificial rearing programs (Eisenberg 2007, D. Waters, pers. comm.). In poncho-mounts the transmitter was attached to a reinforced, flexible, ca. 10 x 10 cm plastic sheet. A 3.5 cm diameter hole was cut off the upper part of the plastic sheet through which the bird's head could easily pass, so the transmitter hung from the bird's neck and the antenna was directed upwards and slightly curved backwards. Since the plastic material used was not elastic, a cut was made at one side of the neck hole to allow for neck growth without damaging it. Both sides of the cut were then rejoined through 2-3 elastic rubber strips.

The main advantage of ponchos or necklaces is that both are easier and quicker to attach than backpacks. However, they cannot be used for male chicks because their neck has still to grow considerably. Ponchos or necklaces can be used on adult females, but again, their use is not possible on adult males, which inflate their necks during display. The disadvantage is again that the weight of the transmitter, and therefore its lifespan, is also limited (the recommended maximum weight of poncho or necklace transmitters is 30g, which allows for ca. 2 years transmission). Furthermore, the percent loss of this type of transmitter was higher (up to 15%, Alonso et al. 1996a) than that of backpacks (zero losses at present, Alonso et al. unpubl. data). This might be considered an advantage if one could predict the time when the transmitter would be lost, but this is not possible. In Germany necklaces were usually lost after 1-3 years (Eisenberg 2007).

Although necklaces and ponchos might be useful for short-term studies, their weight limits their lifespan, and thus we prefer backpacks.

Tail-mounted transmitters

They have been used in Germany during the last years to mark males released after artificial incubation (Eisenberg 2007), and in UK also in a few birds in 2005-06 (D. Waters, pers. comm.). These transmitters usually weigh ca. 15-20 g and thus their battery life is limited. In addition, the birds usually moult their tail feathers at an age of 100-130 days, i.e. before late October, and therefore these transmitters are only useful to track birds during 3-4 months (Eisenberg 2007). Considering the effort spent on catching young great bustards in the wild, or rearing them from artificially incubated eggs, this transmitter type is not recommended.

Backpacks and harness material

This popular and widely used attachment method (Kenward 2001) is also the recommended one for great bustards of both sexes and all ages. Of the several harnessing

ways described, we prefer the harness passing through transverse tubes across the front and back of the transmitter, and crossing at the ventral part, by the sternum of the bird.

After testing several harness materials (plastic, silicone, Teflon ribbon, over-braided rubber tubing, and metal wires covered with these), we strongly recommend using clothing elastic band of ca. 15mm width. All tubing materials tested were in general less flexible than desirable. According to manufacturers, Teflon (available from Bally Ribbon Mills and some tag suppliers) is biologically inert and does not change with time or cut. It is said to be best for long-life attachments, with the only disadvantage that free ends must be sealed to prevent unravelling. However, after having attached many transmitters to great bustards, we can assure that the expensive Teflon does not last longer than the much cheaper elastic band we use. Teflon ribbon generally worked well, but we observed that it frequently got somewhat stiff after several months use and in many cases lateral cuts were appreciated at the folding points of the harness.

The obvious advantage of the elastic harness is that it allows the chick's body to freely reach its final adult size, even in the case of males. The elastic band we use stretches up to ca. three times its normal length and keeps elasticity during many years. It also fits to the body very well and we observed no injuries to either feathers or skin after several years. The damage observed to young great bustards fitted with elastic harnesses in the British reintroduction project in 2004 was due to the too thin and less elastic band used, as well as to the excessive tightening of the harness. We recommend an elastic band of ca. 15 mm width.

We have used various types of backpack transmitters (Table 2), and recommend the 2xAA-battery model which lasts 4-6 years, with the following technical specifications: slow pulse rate (35 bpm), 30-40 ms pulse length, reinforced antenna base, heavy gauge, and 20 degrees antenna exit angle upwards. A heavier model (3xAA) may be used for adult males, which may last up to 8-9 years. As a rule, it is recommended that the weight of backpack transmitters should not exceed 3% of the bird’s weight (Amlaner & McDonald 1980, Kenward 2001).

Methods intended to reduce risk to animals by detaching or loosening tags may cause problems, and reliable time-release mechanisms are not yet available (Kenward 2001).

Satellite transmitters

PTTs and more recently, GPS tags which are much more accurate (location resolution ca. 20-30 m) have been used on great bustards in Spain (1997, Alonso et al. 2002), Russia (1999-2000, Watzke et al. 2001, Watzke 2007), Hungary (2006, Lorant 2007), and UK (2007, D. Waters, pers. comm.). They are ideal for long-range migratory species but very expensive (ca. 3000 euros per unit plus ca. 2-3 euros/day tracking costs). Therefore they may be recommended only to study migratory populations like the Russian one, or when funding is not a restriction. As an alternative, VHF backpacks combined with aerial tracking using small aeroplanes should be considered.

Table 2. Main characteristics of transmitters and fitting methods used in the *Great Bustard Project* by J. C. Alonso et al. (see www.proyectoavutarda.org)

Fitting method	Age / sex	Manufacturer & model	Pulses per minute	Antenna length (cm)	Weight (g)	Estimated lifespan (months)	Transm. size (mm)	Reception distance (km)[1]
Patagial tag[2]	juveniles of both sexes	Telonics CHP-4P	55	25	18	19	48x15x15	1-2
	juveniles of both sexes	Biotrack (TW2) 1 x AA x 1/3	30-35	25	24	8-12	45x15x15	2-3
Wing band[2]	juveniles of both sexes	Biotrack (TW2) 2 x AA x 2/3	30-35	30	40	30-42	44x29x16	2-3
'Poncho' & neck-collar	only juvenile and adult females	Biotrack (TW3) 2 x AA x 2/3	35-40	25-30	30	30-42	38x29x16	2
	only juvenile and adult females	Telonics 225	50	30	50	16-20	41x24x20	2-2.5
Backpack[3]	juveniles and adults of both sexes	Biotrack (TW3) 2 x AA	30-35	30	60	36-48 (>27)	70x30x18	2 - 3
	juvenile males	Biotrack (TW3) 1 x C	30-35	30	80	36-48	70x35x30	2 - 3
	juveniles and adults of both sexes	Biotrack (TW5) 2 x AA	30-35	30	60	48-60	70x30x18	2 - 3
	adult males	Biotrack (TW5) 3 x AA	30-35	30	100	72-96	70x45x18	2 - 3
	juveniles of both sexes	Biotrack (TW5) 1 x AA x 1/3[4]	30-35	30	10	7-9	25x15x15	1.5-2
	juveniles of both sexes	Microwawe[4]	1	30	50	$\geq$24[5]	100x30x20	satellite

[1] usual maximum reception distance from the ground; from top of hills or other elevated points this distance increases up to 10-20 km e.g. for TW3 Biotrack transmitters; from aeroplanes, the reception distance may increase up to 30-40 km when the bird is on the ground and >100 km for flying birds
[2] these attachment methods are not recommended for great bustards
[3] elastic band is recommended in all cases for the harness
[4] our satellite transmitters had small VHF transmitters attached, to facilitate the location of the bird with conventional receivers from the ground
[5] depending on power source (batteries, solar panels)

Other marking methods

Metal and colour rings

Numbered metal rings are being used to mark most great bustards released from artificial incubation and captive rearing programs in various European countries (e.g., Germany, Hungary). Several types of coloured metal or plastic rings with alphanumeric individual codes have been also used e.g. in Germany in 1982-92 and from 1999 to present (Eisenberg 2007). However, neither the conventional numbered metal rings nor the colour rings with numbers or letters are recommended, particularly in juvenile birds, because their tibias and tarsi will continue growing and ring diameters appropriate for adult size would stay too loose on juveniles and might cause some problems. There is a small risk that rings on the tibia or tarsus may cause some damage to the bird if they slip down and embrace, respectively, the tibio-tarsal joint or the fingers. However, the main reason for discarding this method of marking great bustards is that metal rings are meant to allow identification of the birds only when they are found dead, and this may also be achieved through the address labels of wing-tags or radio-transmitters. Colour leg-bands with alpha-numeric codes are very difficult to read at observation distances birds usually tolerate, and combinations of colour rings allowing individual identification are also extremely hard to see as the vegetation is usually higher than the legs. We do not recommend them in great bustard studies.

Neck collars

The use of neck collars to mark great bustards is not recommended. In males they would prevent neck inflating during display, and for females we prefer wing-tags.

Implants, transponders and microchips

Some of these have been used in certain projects (e.g., the reintroduction project in UK), but they are not necessary if other marking methods are used. Implants and transponders usually give only short-term data, and have reduced detection ranges.

Tracking marked birds

Ground tracking

Receivers, scanners, and directional antennas are available from several manufacturers of wildlife telemetry materials. Cheaper receivers from more popular radio-equipment companies may also be used, but direction finding will probably be more difficult.

Reception distance with conventional wildlife tracking receivers varies usually between 2 and 5 km ground to ground for the 2xAA transmitter model recommended above. From elevated points this reception distance may increase to ca. 20 km.

All marked birds should be located with a variable frequency depending on the objectives of the study, but frequently at least once per month or even once per week throughout the marked birds' lives will be desirable. To reach scientifically supported conclusions researchers will need large sample sizes, and since in radio-tracking studies the sample unit is usually the individual, a reasonably large number of different birds should be tracked in order to calculate the averages of the behavioural patterns studied. Many radio-tracking studies end up with just a few data of a small number of individuals, during one or two years. In the case of long-lived species, particularly if they are protected, these studies should be prolonged as much as possible in order to exploit to the full the fact of having captured and marked individuals, considering the risks involved in such operations.

Aerial tracking

When a radio-tagged bird disperses outside the range usually covered by ground tracking, aerial searches should be carried out with small aeroplanes, to which directional antennas are attached using special brackets available from some manufacturers. Maximum ground-to-ground reception distances (10-15 km from hilltops or other elevated points) may go up from aircraft to 40-50 km for birds on the ground, and even more for flying birds.

After locating any signal from the aircraft the fate of the bird should be confirmed through visual contact with the bird from the ground, in order to check whether it is alive or dead. Moreover, visual contact with each bird is usually required in most radio-tracking studies, which as a rule aim at studying specific behavioural patterns of the marked animals. In the case of great bustards, with the aid of aerial radio-tracking researchers should be able to locate all marked birds, even if they move, in some parts of this species' distribution range (e.g., in Spain aerial location success of dispersed birds was nearly 100%, Alonso et al. 1996b). In these cases the main problem commonly affecting dispersal studies, i.e. the emigration of individuals outside the study area, may be solved (Koenig *et al.* 1996). Otherwise, satellite tracking may be a better alternative to track the birds, for example in migratory bustard populations like those living in Russia.

Satellite tracking

Satellite tracking is much more expensive than ground or even aerial tracking, but also renders usually more locations per unit time. The number of locations can be programmed by the manufacturer, but again, usually visual contact with all marked birds will be desirable after satellite location, at least with a certain frequency (e.g., once per month). The cost of these periodical ground controls of marked birds should be added to the cost of satellite units plus transmission of data.

Concluding remarks: checklist for researchers and conservation authorities

Is radio-tagging of great bustards justified?

Wing- and radio-tagging may be considered excellent tools to study the behaviour of great bustards, as they are also for other animal species. They enable researchers to obtain data without bias and from individual animals; in particular, highly valuable information on migration, dispersal, home range use, mortality, and social relationships that would be impossible to get without individually marked birds.

However, capture and radio-tagging is only justified when (i) it is necessary to answer sound biological questions, and (ii) there is no other means of obtaining the required information.

Moreover, considering that great bustards are classified as globally endangered, and vulnerable or threatened in many parts of their distribution range, special care should be taken when planning or approving capture and marking campaigns.

Most researchers and conservation authorities admit that radio-tagging, as well as any other capture and marking method, implies certain mortality risks. However, these should be compensated by the benefits for the species derived from the application of the research results to conservation of the species, provided the mortality risks remain low and controlled by the researcher.

Who should capture the birds?

Careful planning of the scientific project and adequate training of the team that will carry out the captures and marking campaigns is absolutely necessary. Capturing any animal species needs an experienced team, and this is particularly important in the case of a protected species like the great bustards. Ideally, teams trying to capture bustards for the first time should have some training with people having done it before. Specifically in the case of adult birds, any capture and marking operation should be absolutely justified and carried out by personnel having captured bustards already or having learned how to do it from experienced biologists.

How many bustards should be marked?
What data should be obtained from radio-tracking great bustards, and for how long?

The number of marked birds should be proportional to the population size to be studied. If not endangered, a sample large enough to reach statistically supported results should be captured and tracked. In the case of very small and/or endangered populations, a reasonable number of individuals might be marked, but then particular emphasis should be put on the experience of the researchers carrying out the capture campaigns.

To reach scientifically supported conclusions researchers will need large sample sizes, and since in radio-tracking studies the sample unit is usually the individual, a reasonably large number of different birds should be tracked in order to calculate the averages of the behavioural patterns studied. Radio-tracking provides unbiased samples of many biological aspects, particularly dispersal and mortality rates, migratory routes, habitat or nest-site selection, etc. However, scientifically acceptable results should be based on large sample sizes, and locations of the same individual may not always be treated as statistically independent data. Therefore, tests of many hypotheses should be based in most cases on individuals (which are the sample units), rather than on locations. This is important when deciding how many individuals should be captured, marked and radio-tracked, as well as to calculate the costs of the project in terms of number of people, field days, cars, and study years.

Many radio-tracking studies end up with just a few data of a small number of individuals, during one or two years. In the case of long-lived species, particularly if they are protected, studies should be prolonged as much as possible in order to exploit to the full the fact of having captured and marked individuals, considering the risks involved in such operations.

In any case, funding should be guaranteed for the whole project duration, not just for capturing and radio-tagging, and a research team should assure commitment to radio-track the marked birds through at least several years.

What marking method should be selected? Are recommended capture methods risky or harmful?

Prior to planning the radio-tagging project, permits for free frequency bands that can be used in wildlife tracking studies should be checked with the corresponding national authorities responsible for allocating these radio frequencies.

Before starting the project, the main type of transmitter should be chosen (VHF or satellite), depending on the main objectives of the study, and the movement range of the bustard population to be studied. In Iberian populations, VHF transmitters combined with some aerial tracking is usually sufficient, but in long-range migratory populations at least some individuals should be provided with satellite transmitters; other birds might be fitted with VHF units, to complement the necessary sample sizes of complementary behavioural features at either the breeding or wintering areas.

The recommended capture technique for juveniles is chasing them down when they are 3-10 weeks old. Chicks weighing less than 1 kg should be released unmarked, at least with the wing-tags or radio-transmitters recommended here. The whole capture process, from starting chasing to release, should not last more than 30 minutes, and from capture to release, not more than 10-15 minutes. This method is considered safe and in general, harmless for the species, if carried out by people with previous practice in handling wild birds, and, if possible, having learned the technique from experienced teams.

Capturing adult great bustards implies more risks for the birds, and should be carried out by experienced researchers, and in populations or breeding groups not severely threatened with extinction. The recommended method in such populations is the rocket

net, but the whole operation should be carried out within the shortest possible time (from the net shooting to release of the last bird not more than ca. 30 minutes). Adult captures in endangered populations should be carried out strictly by experienced personnel, and in justified cases. If the objectives of the study may be reached marking young birds, this method should be favoured.

The recommended marking method is a combination of wing-tags attached to the patagium and backpack radio-transmitters. Wing-tags are cheap and easy to make, and their high visibility in the steppe-like habitat makes them one of the best marking methods for great bustards. They are easy to read with conventional telescopes at usual observation distances even by non-experienced observers. As for radio-transmitters, their higher price and higher attaching difficulty is by far compensated by their obvious advantages.

We recommend using wing-tags of rigid coloured PVC with two layers of different colour, which do not fade, and enable engraving symbols on the upper layer. Dorsal tags glued to the backpack radio-transmitter are recommended for adult males.

Although the backpack harness system is probably the one that takes longest to get attached, it yields a ca. zero loss rates. It is the radio-tagging system that best suits great bustards, given that this species is mainly cursorial, with short time spent flying and thus can carry relatively higher transmitter weights than other bird species. Furthermore, backpacks never move around and keep antennas pointed upwards, so that reception is always optimal. Researchers should be aware that fitting harnesses to birds needs skill and should be done always by experienced people.

What transmitter specifications are recommended?

The recommended radio-transmitter is a 2xAA-battery-powered unit weighing ca. 60 g, with 4 to 6-year life, mounted as backpack using always elastic harness, even in adult birds. This unit will enable tracking young birds through their juvenile dispersal and immature phase to their establishment as breeding adults. After battery exhaustion, the wing-tag will allow identification.

A way to prolong the transmitter life is to make the units with as low a pulse rate as possible. For experienced users we recommend to use a beep-frequency of around 30 bpm. Lower bpm frequencies would make aerial location too difficult.

What radio-tracking method should be chosen (VHF or satellite)?

VHF telemetry should be chosen when the population is mostly sedentary or bustards are partial migrants that perform short to medium-range seasonal movements (up to 200-300 km). During the juvenile dispersal period, as well as when the birds perform long seasonal movements, at least some aerial tracking from aircraft will be needed to find dispersed individuals, since ground-to-ground reception distance is usually shorter than the average distances travelled by the birds.
When the population is migratory, and if the main purpose is e.g. to discover the main wintering areas, a few birds should be marked with satellite telemetry. But in most cases, it should be recommended that besides these satellite-marked birds, a larger additional

sample be marked simultaneously with VHF transmitters, to reach sample sizes adequate for statistical treatment.

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