Introduction

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Most species of Old and New World Vultures are globally threatened and accurate scientific studies related to their conservation are therefore essential. The range of available tracking and telemetry devices is becoming wider and they are performing more tasks better, as well as becoming more affordable. These changes open up opportunities to a wider community of researchers, but some of these will initially be inexperienced. Research groups on five continents have attached tracking and telemetry devices to vultures and condors using several methods, including thoracic and pelvic harnesses of various designs and patagial tags. The development of attachment techniques has mostly been conducted independently by a dispersed network of experts and rather little information has been documented and published about the relative advantages and safety of different techniques. The international conservation consortium SAVE (Saving Asia's Vultures from Extinction) has identified a growing need to monitor the success of population recovery efforts by safely tagging more Gyps vultures in Asia (SAVE 2020). In addition, the IUCN Vulture Specialist Group (VSG), the Raptors MoU Raptor TAG and others had independently recognised an urgent need to identify and disseminate expertise (CMS Raptors MoU 2018). To address these needs, and under the auspices of the VSG, we invited globally-recognised experts to participate in a three-day practical workshop at the International Centre for Birds of Prey, in Newent, United Kingdom, in August 2019. The key aims were to compare and document the various current attachment methods and to discuss ways to make the information available for wider use. At present, there is remarkably little published information of this kind with adequate practical detail, so accessible documentation of practical aspects would be an important step forward.

Tracking, using Platform Transmitter Terminal (PTTs), GPS-PTTs and GPS-GSM tags, contributes both to basic and applied research and conservation, such as the identification and monitoring of threats, exposure to spent lead ammunition and veterinary non-steroidal anti-inflammatory drugs (NSAIDs), deliberate poisoning, retaliatory poisoning directed at other species, electrocution on power infrastructure and collisions with wind turbines and power transmission lines. Tracking also allows nesting, roosting and foraging areas to be mapped and more appropriately managed. In addition, data from accelerometers and other sensors can be used to assess energetics, the speed and height of flight and the risk of collisions with man-made structures.

Deploying these devices is therefore of great potential value for conservation, and science. Researchers hope and intend that attaching them does not affect the birds' welfare or the aspects of survival, breeding success and behaviour they are trying to measure. However, it must always be remembered that placing any device on a living bird must run some risk of negative effects on its welfare, survival and breeding (Bodey et al. 2018). Hence, there should always be a good scientific or conservation reason for tagging birds. The new technology available allows many more detailed questions to be addressed as each year goes by, but everyone tagging birds should ask themselves whether it is justified if there is a risk to the individual birds or their conservation status and a danger that the data collected are biased and misleading because of undetected adverse effects.

So far, few robust comparative studies have attempted to quantify such effects for any bird

species, and we know of none for vultures and condors. For raptors, the comparative study by Sergio et al. (2015) of Black Kites *Milvus migrans* with and without harness-mounted satellite tags weighing 4% of body weight is the most thorough research of this kind that we know of. Although this study detected no adverse effects of the tags on the demographic rates of kites, it would be unwise to assume that this is the case for all species, devices and attachment methods.

We wish to encourage future comparative studies of vultures and condors, as well as large eagles, with and without devices to quantify any adverse effects, but we recognise that rigorous statistical comparisons between matched samples of birds with and without devices, like that of Sergio et al. (2015) on kites, are technically difficult and need to be long-term. It is therefore not possible at present to use studies of this type to establish whether any of the wide array of device attachment methods in use on vultures and condors offer significant advantages over others in minimising the risk of adverse effects. However, a more easily-achieved, short-term objective is to bring researchers together to make detailed descriptions of the methods they use for device attachment, to share expertise and to identify, document and disseminate good practice. That is the aim of this ***Practical guide to methods for attaching research devices to vultures and condors***. The guide is the result of the workshop held at the International Centre for Birds of Prey in August 2019.

Our experience of the effects of research interventions on wild birds is that much depends upon the details of the methods and equipment used and especially upon the skill and experience of the researchers. However, different groups of researchers rarely get the opportunity to study the details of alternative methods to their own, used by others, and to question them about the reasons behind differences in the selection of materials and methods. The brief Methods sections of published scientific papers are no substitute for such detailed discussions. The three-day ***Global Workshop on Methods for Attaching Tracking Devices to Vultures and Condors*** attracted tag attachment experts from around the world who demonstrated their materials and methods to each other by deploying real and dummy tags on live captive vultures and on stored bodies of dead birds. The demonstrations were recorded through images, videos and notes and later turned into illustrated step-by-step guides showing how to build and prepare harnesses and how to attach them to the bird. Demonstrations were monitored by experienced veterinarians, who made observations and measurements to assess the level of stress during handling. In addition, Neil Forbes, a veterinarian with long experience of birds of prey, gave a presentation on steps that can be taken to minimise adverse effects during the fitting of harness-mounted tags. Professor Rory Wilson (Swansea University, UK) gave a detailed presentation to the workshop participants about the evidence that all devices, large and small, and their attachment methods have effects on the energetic costs of locomotion of flying birds and therefore potentially on their fitness. An article based upon his presentation is not included in this guide because it is relevant to studies of all species of flying birds, not just vultures and condors. We hope that this work will soon be published in a widely-read scientific journal.

The guide includes a proposed classification of the principal methods used to attach devices to vultures and condors, including some that we do not yet have detailed descriptions for. There is a set of recommendations on how to handle and monitor birds during the deployment of devices in such a way as to minimise the risk of adverse effects. Then there are seven step-by-step guides to the preparation and fitting of devices, each of which was contributed by a different group of researchers.

This is the first workshop held under the auspices of the IUCN Vulture Specialist Group, and we hope more will follow. We hope that researchers studying vultures and condors will make good use of this guide and study its recommendations carefully. There is no substitute for practical demonstration and training by experts in this field, and we should emphasise that studying this document in itself will not be a substitute, but rather a reference point for further development. Equipment and know-how will continue to develop, so we feel sure that this guide and others should receive feedback and develop over time through revision and the addition of new methods.

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