

# **Guidelines for the attachment of tracking devices to birds**

Latest Draft: April, 2023

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Draft

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## 1. Introduction

The continued miniaturization of electronic tracking devices has allowed a remarkable expansion of our knowledge of bird movements across their full life cycle, which, until recently, was a challenging area of study. With the diversity of technology available, some guidance can be useful in helping researchers select the appropriate tracking device for a specific species or application. These guidelines will refer to the most common tags used for land birds, including passive integrated transponder (PIT) tags, data loggers, radio transmitters, and satellite transmitters.

There is conflicting evidence regarding the impacts of tracking devices on birds. See Geldart et al. (2023) for a summary of available research demonstrating the impacts of attaching a variety of tracking devices to birds. Briefly, reported tag effects are often context-specific and can be somewhat controlled through careful consideration of methods applied in relation to lifestyle characteristics of the study animal and the data that one aims to collect. Methods of attaching tracking devices vary considerably with tag type, study species, and the research questions being addressed. This document will provide guidelines and standard operating procedures for some of the most common methods used across a variety of taxa.

Any use of wild animals in research should adhere to the ethical principles described in the Canadian Council on Animal Care (CCAC) *Guidelines on: the care and use of wildlife* (2003), including application of the “Three Rs” of humane experimental technique: Replacement, refinement, and reduction. From the CCAC guidelines:

- 1) **Replacement** - Animals may be used only if the researcher’s best efforts to find a replacement by which to obtain the required information have failed. Though it is unlikely that studies of movement ecology could replace animals altogether, consideration should be given to using more common species in place of species of conservation concern, if possible.
- 2) **Refinement** - The most humane, least invasive techniques must be used. Further, any refinement methods employed should be published to make them widely available to the scientific community.
- 3) **Reduction** - The fewest animals appropriate to provide valid information and statistical significance should be used.

This document incorporates these tenets to promote best practices for the attachment of tracking devices to birds, with the aim of reducing potential negative impacts and enhancing bird welfare.

## 2. General considerations

### 2.1 Background reading

The body of published literature concerning the attachment of tracking devices to birds has grown substantially since the start of the 21<sup>st</sup> century. Researchers are strongly encouraged to use the literature cited within these guidelines as a starting point for background reading, while also reviewing the latest literature to ensure experimental design is based on the newest science available. In particular, the following articles are valuable resources in the design of studies using tracking devices:

BARRON, D.G., J.D. BRAWN and P.J. WEATHERHEAD. 2010. Meta-analysis of transmitter effects on avian behaviour and ecology. *Methods in Ecology and Evolution* 1: 180–187.

BODEY, T.W., I.R. CLEASBY, F. BELL, N. PARR, A. SCHULTZ, S.C. VOTIER and S. BEARHOP. 2018. A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. *Methods in Ecology and Evolution* 9: 946–955.

BRIDGE, E.S., J.F. KELLY, A. CONTINA, R.M. GABRIELSON, R.B. MACCURDY and D.W. WINKLER. 2013. Advances in tracking small migratory birds: a technical review of light-level geolocation. *Journal of Field Ornithology* 84: 121–137.

BRLÍK, V., J. KOLEČEK, M. BURGESS, S. HAHN, D. HUMPLE, M. KRIST, ET AL. 2019. Weak effects of geolocators on small birds: A meta-analysis controlled for phylogeny and publication bias. *Journal of Animal Ecology*. Advance online publication. DOI: 10.1111/1365-2656.12962

CASPER, R.M. 2009. Guidelines for the instrumentation of wild birds and mammals. *Animal Behaviour* 78: 1477–1483.

COSTANTINI, D. and A.P. MØLLER. 2013. A meta-analysis of the effects of geolocator application on birds. *Current Zoology* 59: 697–706.

GEEN, G.R., R.A. ROBINSON and S.R. BAILLIE. 2019. Effects of tracking devices on individual birds – a review of the evidence. *Journal of Avian Biology*. Advance online publication. DOI: 10.1111/jav.01823

GODFREY, J.D., D.M. BRYANT and M.J. WILLIAMS. 2003. Radio-telemetry increases free-living energy costs in the endangered Takahe *Porphyrio mantelli*. *Biological Conservation* 114: 35–38.

GÓMEZ, J., C.I. MICHELSON, D.W. BRADLEY, D. RYAN NORRIS, L.L. BERZINS, R.D. DAWSON and R.G. CLARK. 2014. Effects of geolocators on reproductive performance and annual return rates of a migratory songbird. *Journal of Ornithology* 155: 37–44.

MCKINNON, E.A. and O.P. LOVE. 2018. Ten years tracking the migrations of small landbirds: Lessons learned in the golden age of bio-logging. *The Auk* 135: 834–856.

STREBY, H.M., S.M. PETERSON, C.F. GESMUNDO, M.K. JOHNSON, A.C. FISH, J.A. LEHMAN and D.E. ANDERSEN. 2013. Radio-transmitters do not affect seasonal productivity of female Golden-winged Warblers. *Journal of Field Ornithology* 84: 316–321.

## **2.2 General guidelines for bird safety**

When using wild birds in research, the safety and welfare of study subjects is one of the highest priorities (after human safety). Researchers must follow *The Bander's Code of Ethics* (available online: <http://www.nabanding.net/banders-code-of-ethics/>; North American Banding Council 2001).

The use of tracking devices on birds carries some assumed risk, so researchers should work to minimize negative effects wherever possible, both for the welfare of the birds and for the integrity of the results (Wilson and McMahon 2006; Casper 2009; Fair et al. 2010). Researchers should use the smallest possible tracking device that can gather the type and amount of data required to meet study objectives, and the device should be attached with the least invasive method based on tag type, study species, and desired attachment duration. Capture and recapture (if applicable) should be planned in advance, and birds should be closely

monitored throughout handling for signs of distress. Clear humane endpoints should be established for suspension or cessation of tagging procedures if an animal is in distress (CCAC 2022).

### **2.3 Researcher skills and training**

The attachment of tracking devices requires a high level of comfort with handling birds, as methods often require manipulation of wings and legs to allow proper tag fitting. Any researcher proposing a tracking study should thus be competent with handling birds, and have bird-banding experience. Further, the research team must have experience, through training or previous studies, in the application of the specific methods proposed prior to commencing the study.

### **2.4 Standardizing methods**

Researchers should aim to standardize methods with other similar studies or species whenever possible to facilitate data compilation for future meta-analyses.

### **2.5 Pilot studies**

Application of tracking devices to a new species, or use of a new attachment method on a previously studied species, should be first tested through a pilot study that includes an appropriate control group to facilitate detection and quantification of any tagging effects (Casper 2009; Geen et al. 2019). Any negative effects should be thoroughly documented and reported in any manuscripts resulting from the study, along with detailed descriptions of methods to ensure the published literature accurately represents the potential impacts of the use of tracking devices on a species (Hill and Elphick 2011; Geen et al. 2019).

### **2.6 Selecting appropriate study subjects**

Selection of study subjects should be considered at both the species- and the individual-level, and will be guided by the research questions. Research addressing knowledge gaps for a specific species will likely have little flexibility in the selection. However, if working with Species at Risk that may be particularly sensitive to disturbance, it is worth considering whether the questions could be answered by replacing that species with a similar species with lower conservation concern (Canadian Council on Animal Care 2003; Casper 2009). If possible, broader questions should be addressed using well-studied species with well-established methodology.

At the individual level, consideration should be given to age, sex, breeding status and timing, and body condition. These choices will again be influenced by the specific research questions, but should also consider animal welfare. For example, researchers may want to avoid tagging birds very early in the breeding season to avoid handling potentially gravid females (Canadian Council on Animal Care 2008). Researchers may also want to avoid attaching tracking devices to nesting females, as the time necessary to attach the device may leave an unattended nest susceptible to predators (Casper 2009). However, complete avoidance of tagging females can add bias to the results if males and females present different behaviours or migration strategies (McKinnon et al. 2018). It is also generally advisable to avoid tagging animals in poor body condition unless they are the specific target of the study; however, selecting only the healthiest individuals can also add bias to the results (Authier et al. 2013).

Possible negative effects on a species or individual should be thoroughly researched during the experimental design phase to ensure familiarity with challenges that have been reported in the literature. However, it can sometimes be difficult to achieve a sufficient sample size to attain statistical power in tracking studies, so researchers should use caution when interpreting

results, especially with regards to measuring tagging effects (Costantini and Møller 2013; Scandolara et al. 2014). Control and experimental groups should also be chosen carefully, to ensure both represent a random sample of the population (Authier et al. 2013).

## **2.7 Reporting**

Recent meta-analyses have shown that many tracking studies are published without sufficient detail to properly assess tag effects (Barron et al. 2010; Bodey et al. 2018; Geen et al. 2019). Bodey et al. (2018) recommends the following details be included in the reporting of any tagging study to allow further analyses of effects:

1. Study species
2. Number of devices deployed and individuals tagged, including all instances where tags failed or individuals did not return
3. Mean mass of study individuals
4. Method of attachment used in repeatable detail
5. Mass of devices deployed
6. Total length of tag deployment

Further, all negative impacts should be described in any publications that arise from that study, along with a detailed description of methods. By reporting undesired consequences of tracking methods, future studies on tracking using similar methods on similar species can reduce the chances of making similar mistakes.

## **3. Permits**

The use of any auxiliary markers (including tracking devices) must be reviewed and approved by the appropriate provincial/territorial and/or federal governments prior to implementation. In almost all cases, auxiliary markers must be used in conjunction with federal metal bands that uniquely identify each individual, thus researchers must hold an appropriate permit for the capture and banding of the study species. Banding permits must include authorizations for the tracking device and attachment method to be used. If required, the project should be reviewed by and approved by the institution's Animal Care Committee. Information on permits and permit applications are available by contacting the Bird Banding Office (BBO; [bbo@ec.gc.ca](mailto:bbo@ec.gc.ca)) or an equivalent program for other regions (e.g. Bird Banding Laboratory (BBL); [bbl\\_permits@usgs.gov](mailto:bbl_permits@usgs.gov)) .

## **4. Tag selection**

### **4.1 Tag types**

There are several types of tracking devices that can be attached to birds and general knowledge of the function, benefits and drawbacks of each type can help with selection. A summary of tag types is provided in Table 1.

#### **4.1.1 Passive Integrated Transponder (PIT) tags**

PIT tags use Radio Frequency Identification (RFID) technology to individually identify animals. They are amongst the smallest (weighing as little as 0.1 g), and least costly tags available. PIT tags are “passive” in that they are powered by the electromagnetic field emitted by an RFID tag reader and only emit a signal with their individual ID when within range of the reader. This also means their operational life is effectively unlimited (Gibbons and Andrews 2004). They have traditionally been implanted in animals, but can be attached to bird bands for a less-invasive deployment. The drawback of PIT tags is that the animal must be in close proximity to a reader,

generally within 30 cm, to be activated and read. Therefore their use is often limited to studies examining behaviour around a specific feature where a reader can be installed, e.g. nests, bird feeders, narrow movement corridors, etc. (Bonter and Bridge 2011). Tag readers with data-logging capabilities can be constructed by researchers at a relatively low cost, making PIT tags and RFID technology one of the most financially-accessible tracking technologies available (Bridge and Bonter 2011).

#### *4.1.2 Radio transmitters*

Radio transmitters send periodic pulses that are detected by a receiver system, where the detection range is determined by the design of both the tag and the receiver. These tags generally have a long external antenna that is necessary to achieve reasonable detection ranges. Beyond just relaying location, radio transmitters can also be fitted with sensors that will detect changes in posture, activity, or elevation (Warnock and Takekawa 2003).

Historically, a researcher would use a series of tags that each operated on its own frequency to allow identification of individuals (beeper tags), but newer radio transmitters allow many tags to operate on the same frequency by transmitting a digitally coded ID with their pulse (Lotek Wireless Inc. 2018). Coded tags have facilitated the development and expansion of the Motus Wildlife Tracking System, a collaborative network of automated telemetry stations used by many researchers in North America and internationally, to study long distance movements and migration (Taylor et al. 2017). Currently, the smallest coded tags that work on the Motus network are ~0.2 g which have a lifespan of 10-45 days, depending on their programming. The lifespan of a radio transmitter is generally determined by the size of the battery and the frequency of pulses, but since the battery also contributes most of the weight to radio tags there is usually some trade-off between lifespan and weight. However, there are now solar-powered and hybrid (battery- and solar-powered) radio transmitters available that could offer 'lifelong' tracking of tagged animals. Radio tags are moderately expensive, and there is a wide range of costs associated with manual and automated stations depending on the supplier and design of the station. More information about the Motus Wildlife Tracking System and related equipment can be found at <https://docs.motus.org/motus-guides/>.

#### *4.1.3 Satellite transmitters*

There are two satellite systems that can be used to detect animals, depending on the type of satellite transmitter employed: Advanced Research and Global Observation System (Argos), and Global Positioning System (GPS). Platform terminal transmission (PTT) tags use the Argos system, which will relay an animal's location from the ground to the Argos satellites, and ultimately to a researcher's computer without any need for tag recovery. These tags generally offer location accuracy in the range of 250 m to 1.5 km ([www.siritrack.co.nz](http://www.siritrack.co.nz)). Alternately, GPS tags receive signals from GPS satellites to determine a tag's location, and can offer resolution in the range of  $\pm 5$  m, depending on how many satellites are in range (Lotek, Wireless Inc. 2018). Satellite transmitters that use only GPS technology do not transmit locations to the researcher, so need to be recovered to access the data, and in that way they function as archival tags (see section 4.1.4 below for further considerations). GPS tags are the simplest and lightest (down to 1 g) satellite transmitters (e.g. PinPoint GPS tags, Lotek Wireless). Notably, VHF radio beacons can be added to GPS tags to help with relocation or to allow remote download of the data. In addition, other sensors (e.g. altimeters, accelerometers) are increasingly being incorporated into GPS tags to allow collection of multiple types of data beyond just locations. GPS and Argos technology can also be combined (i.e. GPS-PTT tags), allowing high-resolution location data to be gathered by GPS satellites, and those data transmitted to the researcher through Argos satellites. Satellite transmitters can also incorporate solar cells for longer-term operation. All of these features come with added weight and cost; for example solar powered satellite tags can cost up to several thousand dollars each and weigh up to 16 grams.

#### **4.1.4 Data loggers**

Data loggers, or archival tags, measure and store data that can be accessed by a researcher once the logger is recovered. These tags have been used extensively in marine bird research to gather data on temperature, dive depth, and swim speed (Wilson et al. 2002). In studying land birds, the most commonly used data loggers are geolocators, which provide coarse locations of a tagged animal over the course of a deployment based on the light levels recorded (Bridge et al. 2013). Geolocators have the benefit of being able to gather data throughout the annual movements of a bird without the need of any external receiver, as satellite tags do, but with a substantially lower cost per-tag. Currently, the smallest geolocators weigh less than 1 gram, which allows tracking of smaller birds than is possible with satellite tags. One limitation of geolocators is the resolution, as data can have location error of over 100 km. Additionally, it is not possible to locate animals around the equator where hours of daylight are constant throughout the year (Niles et al. 2010). Despite these limitations, geolocators are still frequently used to collect data on large-scale migratory movements, particularly in studies of small (under 20 g) birds for which satellite transmitters are still too large.

Another drawback, which has already been mentioned, and is relevant to all archival tags, is that the tags need to be recovered to access the data, so several tags likely need to be deployed for every tag recovered (Bridge et al. 2013). This is an important consideration from the animal welfare perspective because we must accept that some tags will not be removed from birds, thus they will likely cause lifelong impact. Consideration for optimizing recapture must be factored into studies proposing the use of archival tags to minimize that impact. Further, the use of these devices must be carefully considered in balance with the value of the data collected and its importance for answering specific research questions.

#### **4.2 Tag weight**

It is generally accepted that all markers attached to a bird should weigh less than 5% of the bird's body weight - including the tracking devices, whatever material is used for attachment, and bands - to avoid negative tagging effects (Fair et al. 2010). The '5% rule' has been criticized, however, for being widely accepted with only limited evidence of its applicability (Bodey et al. 2018; Portugal and White 2018). Recent attempts to test whether this rule does actually minimize negative effects on tagged birds have been hampered by the almost universal acceptance of the rule, thus there are few opportunities to compare effects at different loadings (Barron et al. 2010; Bodey et al. 2018). Interestingly, Bodey et al. (2018) found comparable negative effects when birds carried tags weighing 5% or 3% of their body weight, whereas those negative effects disappeared when loading was less than 1% of body weight. While a '1% rule' may be impractical, these results do emphasize that researchers should minimize tag weight as much as possible. The BBO generally uses 3% as a maximum tag load, unless additional evidence and justification for a higher load is provided (ECCC, 2023).

However, tag weight is just one consideration amongst a myriad of factors that contribute to the magnitude of tagging effects on birds (reviewed in Geldart et al. 2023). Attachment location must also be considered; for example if a tag is attached on a leg (i.e. away from a bird's centre of gravity) it should weigh under 1% of the bird's mass (or under 2%, with justification). Further, wing shape and flight style should be considered, as birds with a high wing aspect ratio (i.e. long, narrow wings) or flapping flight generally show more negative impacts with heavier tags, as compared to birds with lower wing aspect ratio or gliding flight, respectively (Bodey et al. 2018).

All potential factors affecting magnitude of tagging effects should be considered with the “Three Rs” in mind (replacement, refinement, reduction; Canadian Council on Animal Care, 2003), to ensure overall impacts on the study animals are minimized. For instance, rather than exploiting the continuing miniaturization of tracking devices to track smaller birds while adhering to the 5% (or 3%) rule, researchers should instead use these technological advances to reduce the relative mass of tracking devices deployed on animals (Portugal and White 2018).

### 4.3 Species-specific modifications

When selecting tracking devices, consider the characteristics of the species which you are studying and whether modifications will be necessary (i.e. refinements, as per the CCAC). For example, birds with strong, seed-crushing bills may need thicker antennas on radio transmitters to prevent damage (Diemer et al. 2014), and birds with hooked bills may need reinforced tag bodies to prevent damage. Researchers should be sure to include species-specific needs in discussions with tag manufacturers and be prepared for tag weight to increase substantially if modifications need to be made.

**Table 1.** Comparison of different tag types

	<b>PIT tags</b>	<b>Radio transmitters</b>	<b>Data loggers</b>	<b>Satellite transmitters</b>
<b>Size</b>	Smallest	Small-medium	Small-medium	Small - large
<b>Cost</b>	\$	\$\$	\$\$	\$\$ - \$\$\$
<b>Power source</b>	Tag reader	Battery or solar	Battery	Battery or solar
<b>Lifespan</b>	Unlimited	Unlimited for solar, otherwise determined by battery size	Determined by battery size	Unlimited for solar, otherwise determined by battery size
<b>Detection range</b>	Within ~30 cm of tag reader	Variable based on equipment; up to 20 km	Near unlimited (no receiver needed), but no location resolution around equator	Effectively unlimited (detected by satellites), with high location resolution (up to $\pm 5$ m)
<b>Main limitation(s)</b>	Detection range	Detection range; data limited by extent of automated telemetry network	Low location resolution ( $\pm 100$ km); most tags must be recovered to access data	Cost often prohibitive; some require recovery of tag to access data
<b>Application</b>	Studying use of specific habitat features (e.g. cavities, nest provisioning)	Habitat use, short-range migration	Long-range migratory movements; connectivity studies	Any movements

## 5. Tag Attachment

Methods of attaching tracking devices to birds are numerous and varied, depending on the study species, tag type, and required attachment duration. These guidelines include detailed consideration of glue attachment, two styles of leg-loop harness, and a backpack-style harness; a summary comparison of those methods is given in Table 2, and detailed Standard Operating Procedures for each method are supplied in the appendices. Other attachment methods (e.g.

tail mount, suture, surgical implantation) are not covered in the current document though may be added in future revisions.

## **5.1 Attachment methods**

### **5.1.1 Glue**

Gluing radio tags to birds is a preferred method for studies that require only short-term attachment (less than 6 months), though retention can be quite variable depending on species, moult schedule, and specific methods employed (Warnock and Warnock 1993; Warnock and Takekawa 2003; Mong and Sandercock 2007; Diemer et al. 2014). This relatively short attachment period generally limits the application of this method to studies that use battery-powered radio tags with lifespans comparable to the length of the attachment period. This attachment method is not appropriate for data loggers, satellite tags, or any other tag requiring longer-term attachment.

The assured detachment of glue-attached radio-tags minimizes the chance of any long-term effects on study animals (Anich et al. 2009), which is an attractive benefit when working with species of conservation concern; however, this method may impede the thermoregulatory abilities of study animals, so should be used with caution in extreme environments (Warnock and Warnock 1993). Past studies have highlighted some species that do not tolerate glue-attached tags well, specifically European Starling (*Sturnus vulgaris*), Northern Cardinal (*Cardinalis cardinalis*), and Bobolink (*Dolichonyx oryzivorus*), though the method has proven effective for many passerines and shorebirds (Raim 1978; Hill and Talent 1990; Sykes Jr et al. 1990; Johnson et al. 1991; Woolnough et al. 2004; Anich et al. 2009; Diemer et al. 2014). Gluing transmitters may also be effective for nightjars (E. Knight, pers. comm.), and hummingbirds, though more study is needed (Zenzal et al. 2014).

### **5.1.2 Leg-loop harnesses**

The figure-8 leg-loop harness, first described by Rappole and Tipton (1991), is an appropriate method of tag attachment for long distance migrants that will go through some body mass fluctuations over the course of the study. It can be used on a variety of small bird species, as long as they have external femurs (thus, this method is not appropriate for ducks, doves, swifts, and many shorebird species for example).

The harness described by Rappole and Tipton (1991) was pre-fitted and non-adjustable in the field, so some knowledge of proper sizing is necessary. Some guidance is supplied in Rappole and Tipton (1991) and Naef-Daenzer (2007), but those resources should be used only as starting points, and determining appropriate sizing will require some initial testing. Multiple harness sizes should be prepared and available during tagging, and records of bird mass and best leg-loop size should be kept for future reference. Alternately, harnesses can be constructed to be adjustable and individually-fitted, using crimp beads to secure the harness material once a proper fit is achieved. Application of tracking devices with a non-adjustable figure-8 leg-loop harness can generally be completed in under 30 seconds, with minimal negative effects on birds post-release (Suedkamp Wells et al. 2003; Davis et al. 2008; Rae et al. 2009; Gow et al. 2011; Bell et al. 2017). Though attaching an adjustable harness will take longer than a non-adjustable harness (>5 minutes per bird), and will require at least two people (one to hold the bird, the other to adjust the harness), there is evidence that this method can help to manage negative harness-related effects as it accounts for individual size variation amongst birds (Brlík et al. 2019). However, researchers should use care when applying adjustable harnesses, as harnesses that fit too tight could harm the study animals (especially when using non-elastic material as in Blackburn et al. 2016). Adjustable harnesses will also require tags to have some attachment points (tubes or eyelets), which will increase the weight of the tag.

Using harness attachments on nestlings has led to adults removing tagged individuals from the nest in some cases, so these methods are best applied to adults or fledglings, and used on nestlings with caution (Mattsson et al. 2006; Fisher et al. 2010). If harnesses must be applied to nestlings, the target sample size may be achieved by tagging a portion of the young from several nests (leaving some nest-mates untagged), rather than all young in a smaller number of nests.

A modified leg-loop harness was presented by Streby et al. (2015), which minimizes harness weight, allowing tags to be deployed on adult passerines weighing as little as 9 g with no negative effects observed. However, effects may vary between species, so caution may need to be used when applying this method to a new species (Taff et al. 2018). This attachment method can be particularly useful for attaching stalkless geolocators to small birds, as the harness elevates the tag slightly, ensuring that the back feathers do not cover the light sensor (Peterson et al. 2015).

Harnesses are ideal for studies requiring longer-term (over a year) retention that cannot be achieved with glue attachment techniques (Raim 1978; Johnson et al. 1991; Woolnough et al. 2004). Variable retention times can be achieved by using different materials, with shorter-term (up to 2 month) attachments achieved with elastic sewing thread, and longer attachments achieved with jewellery cord (Streby et al. 2015). Longer-term attachments should be used for geolocators and GPS tags, which generally need to be retrieved by the researcher to access the data.

### **5.1.3 Backpack-style harness**

The 'backpack-style', or 'wing' harness, first described by Brander (1968), uses plastic cord to create a neck and wing loops to mount a tracking device on the back, and is appropriate for long-term (>1 year) attachment of tracking devices to acrobatic bird species, birds that capture prey with their talons, and birds with short legs. Since most long-distance migrating shorebirds cannot wear leg-loop harnesses, Chan et al. (2016) developed a backpack-style harness that accommodates large fluctuations in body weight during migration. This harness is adjustable in the field and so all discussion in *Section 5.1.2* concerning adjustable harness also applies for this harness type.

## **5.2 Handling time**

Handling time varies between attachment methods, but the goal should always be to minimize handling time while maximizing data collection. Fastest tag deployment is achieved with pre-made leg-loop harnesses, which can be attached to a bird in under one minute (Rappole and Tipton 1991; Streby et al. 2015). Deployment time for glue attachment methods are usually determined by the drying time of the glue used. Warnock and Takekawa (2003) found no difference in the effectiveness of epoxy or Super Glue in attaching tags to shorebirds, though the latter tends to have a quicker drying time so is now typically used as the adhesive of choice for tag attachment (e.g. Mong and Sandercock 2007; Diemer et al. 2014).

Longest handling times are associated with harnesses that are individually-fitted to birds, as more time must be allotted to adjusting to ensure proper fit (Knight and Ng 2017).

## **5.3 Ensuring return to normal behaviour**

Researchers must be sure that birds are able to quickly return to normal behaviour after tag deployment, both for the integrity of the data collected and for the safety of the study animal. Wings and legs should be checked prior to release to make sure they can move freely, and feet

should be checked for perching ability (if applicable). Birds should be monitored after release until they resume normal behaviour, in case their mobility is affected and they are more susceptible to predators. If birds do not return to normal behaviour within 1-2 minutes, researchers should attempt to recapture the bird and remove the tag.

**Table 2.** Comparison of attachment methods

	Leg-loop harness		Glue	Backpack-style harness
	Non-adjustable	Adjustable		
<b>Preparation</b>	Constructed in advance	Partially constructed in advance, completed on site	None, or minimal if intermediate fabric is used between tag and bird	Partially constructed in advance, completed on site
<b>Handling time</b>	Short (~1 min)	Moderate (5-10 min)	Moderate (~5 min)	Long (~10 min)
<b>People required</b>	One	Two	Two	Two
<b>Sizing</b>	Size constraints defined by loop size; testing may be required to find proper size	Individually fitted at attachment	None, though larger birds may remove	Individually fitted
<b>Limitations</b>	Can't use on many non-passerines	Can't use on many non-passerines	Not tolerated by some species <sup>1</sup>	
<b>Retention time</b>	Long (>1 year) to permanent, depending on harness material	Long (>1 year) to permanent, depending on harness material	Short and highly variable (weeks to months)	Long (>1 year)
<b>Bird welfare considerations</b>	Abrasion risk with poor fitting, bird wears harness and tag for a longer time period	Abrasion risk with poor fitting, bird wears harness and tag for a longer time period	Possibility of skin abrasion/burning/tearing	Abrasion risk with poor fitting, bird wears harness and tag for a longer time period
<b>Useful for:</b>	Small species; species that physically remove tags; species that moult feathers during study period	Species with high size variation between individuals; species that physically remove tags; species that moult feathers during study period	Studies requiring only short attachment duration; Species that do not remove/damage tags or moult feathers during study period	Acrobatic species; Species that use their talons to capture prey; Species without external knee

<sup>1</sup> As described in Section 5.1.1

## 6. Tag removal

Research studies involving tag attachment should include some provisions for removal of tags (Casper 2009). This can be achieved easily with glue-attachment methods, where it is assumed the tag will be shed within a few months of deployment, at most (Warnock and Takekawa 2003). If using longer-term harness-attachment methods, however, more planning is necessary to ensure birds are not unnecessarily hampered by non-functioning tags.

If there is no need to recover tags, harnesses can be constructed to ensure detachment by using a degradable material. For example, Streby et al. (2015) constructed radio transmitter harnesses from 0.5 mm elastic thread that started to degrade in 40-70 days, at which point the

tags were shed. Powell et al. (1998) applied harnesses made of 5-kg test Dacron fishing line that generally detached within a year, whereas harnesses of 9-kg test line did not. Alternatively, a weak-link can be incorporated in a harness made of a sturdier material that will allow longer-term attachment while still detaching eventually (Kesler 2011).

Studies using geolocators or GPS tags without remote download capabilities will necessarily require recapture of individuals to access the data stored on those tags. If the study species is known to become “trap shy” after being captured, less invasive recapture methods should be used to maximize the chance of tag recovery (e.g. Friedman et al. 2008). Recapture should also be planned for an area where there is a high probability of encountering a bird at a later date (e.g. breeding grounds or known stopover sites).

## **7. Precautions**

### **7.1 Predators**

When attaching tracking devices to birds, researchers should be aware of the ways in which study methods can affect risk of predation. Within the first few days after attachment, birds may have increased predation risk as they acclimate to carrying a tag (Johnson et al. 1991; Warnock and Warnock 1993; Mong and Sandercock 2007). Though it may not be possible to safeguard birds against the risk over the acclimation period, researchers should maintain constant vigilance for predators in the vicinity during tagging, and, if a predator is observed, should be prepared to enact anti-predator measures as appropriate (e.g. more frequent trap checks, or suspending activities until the predator has left the area). Tracking devices can also increase the long-term predation risk of an animal if the tag makes it more obvious to a predator. For example, if the colour of the tag body stands out against the bird’s plumage (Scandolara et al. 2014) then camouflage may be compromised. Therefore, efforts should be made to match the tag’s exterior to the colour of the bird to avoid compromising its camouflage, and with the exception of solar-powered tags or light-level geolocators, adjust the feathers so that the harness and tag are hidden under the feathers.

### **7.2 Weather**

As per the *Bander’s Code of Ethics* (North American Banding Council 2001), trapping and banding, and thus tagging by extension, should not be conducted in adverse weather. Beyond the immediate forecast, consideration should also be given to the environmental conditions that a tagged bird may encounter over the duration of the study. Snijders et al. (2017) found that the negative tagging effects were more pronounced when environmental conditions were more challenging, and led to a lower likelihood of breeding in Great Tits (*Parus major*). Further, Barron et al. (2010) found a substantial increase in energy expenditure in birds carrying a variety of tagging devices, suggesting that great care should be used if deploying tracking devices on birds at times when it is difficult to maintain a positive energy balance; for example, if predictable climatic conditions will lead to lower food availability.

### **7.3 Equipment cleaning**

If a bird shows signs of illness or disease during the tagging procedure, any equipment used in the handling and restraining of that bird should be thoroughly cleaned and disinfected before being used on another bird, to minimize potential spread of disease.

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