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SETTING HARNESS SIZES AND OTHER MARKING TECHNIQUES FOR A FALCON WITH STRONG SEXUAL DIMORPHISM

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Abstract.— Backpack radio-tags can be used to monitor survival of raptors for several years after fledging, but may reduce survival if a poor fit results from subjective judgements. We present an attachment method that can use bird measurements to predict harness sizes. Relationships between body mass of Saker Falcons and harness size predicted the size for smaller falcon species. Harnesses were fitted when birds had reached full size in the nest, which required age estimation at a previous visit to predict a fledging date. Equations based on wing length provided objective ageing of nestlings. A pump-pressured water gun aided capture of young falcon and toggle-loops restrained the feet during marking. Saker Falcons with radio-tags and others marked only with leg bands and implanted transponders had the same recapture rate (7%) in autumn, indicating similar survival. This retrap rate should be adequate to estimate harvest rates and population sizes for Saker Falcons.

Resumen.—Los emisores de mochila pueden ser utilizados para estudiar la supervivencia de las rapaces a lo largo de varios años tras el abandono del nido. Sin embargo, una fijación deficiente, basada en apreciaciones subjetivas, puede reducir la supervivencia. Presentamos un método de fijación facilmente estandarizable, en el cual se usa la relación entre el peso de los pollos de halcón sacre y la medida de los bucles del harnés para predecir las medidas necesarias para halcones de mediano y gran tamaño. Las mochilas se fijaron a los pollos cuando éstos habían alcanzado su tamaño máximo en el nido, lo cual requiere una visita previa para estimar la fecha vuelo. Las ecuaciones basadas en la longitud del ala proporcionan un método objetivo para determinar la edad de los pollos. Una pistola de agua facilitó la captura de los pollos a una edad cercana al primer vuelo. Se utilizaron lazos para immovilizar las patas durante el marcaje. Las tasas de recaptura en otoño fueron las mismas para los sacres marcados con emisores que para aquellos marcados únicamente con anillas y microtransponders implantados. La tasa de recuperación observada del 7% debe ser adecuada para estimar las tasas de extracción y los tamaños poblacionales para el halcón sacre.

Long-life radio tags have advantages for modelling populations of uncommon species, especially raptors (Buehler et al. 1991, Kenward et al. 1991, Bowman et al. 1995), by providing survival estimates more rapidly than banding and without recovery bias that tends to underestimate juvenile survival (Kenward 1999, Kenward et al. in press). However, long-life radio-tags require attachment to raptors as harness-mounted backpacks, which themselves have reduced survival in some studies (Johnson and Berner 1980, Small and Rusch 1985, Marks and Marks 1987, Marcström et al. 1989, Paton et al. 1991, Foster et al. 1992). On the other hand, Buzzards (*Buteo buteo*) fitted as nestlings with backpacks survived as well as buzzards with small tail-mounted radios, and better than contemporary estimates from band recoveries (Kenward et al. in press). A possible explanation for differences in tag effect between studies is that problems stem from variation in harness design (Buehler et al. 1995) and subjective decisions about an appropriate fit.

We addressed these problems in research on the world's second largest falcon, the Saker (*Falco cherrug*). Northern populations of this falcon breed in the palaearctic from Austria to Manchuria and migrate south to Africa and the Indian subcontinent in winter (Baumgart 1978, Cramp and Simmons 1980). The species has been trapped extensively on migration for falconry for centuries (Riddle and Remple 1994), which motivated a study by the National Avian Research Center in the United Arab Emirates to estimate harvest rates and sustainability.

The aim was to use radio-tags with 2-3 yr transmission for estimating survival of Saker Falcons before dispersal and on their return in subsequent years to natal areas in Kazakhstan. The variable size of a strongly sex-dimorphic species made it important to develop objective criteria for fitting backpack radio-tags without adverse impact on survival. Alternative markers, including leg bands and microtransponder implants to detect when other markers had been removed, were fitted to assess harvest rates from trapping, but also served to compare survival to autumn of birds with and without radio-tags.

METHODS

<u>*Handling and measuring*</u>.— We marked falcons shortly before they left the nest, so that they were close to full size when they were measured and fitted with radio-tags. For carriage from the nest and processing, their legs were restrained with a loop of cord on which a sliding, spring-loaded toggle could be closed with one hand. Toggle-loops (Fig. 1) were brightly coloured to aid detection if dropped and formed a convenient loop for weighing. We covered the heads of especially aggressive individuals with a cloth during processing.

Young Saker Falcons were classed subjectively before further processing as female if they were relatively large and male if they were small. Most studies of sex differences in strongly sex-dimorphic raptors have used subjective sexing (e.g., Newton 1979, 1986). To obtain objective measures for comparison with subjective sexing, we also measured mass, head-length, beak-depth at culmen, minimum tarsus width, foot span across the pads of the center and hind toe (Fig. 1) and wing length from flexed carpal joint to the longest feather of a wing held flat. Differences between subjective sexes of young falcons were most marked in the last week before fledging, when wing length was >250 mm. At this age, mean mass of 51 "males" was 854 (S.E. = 7) g, compared with 1102 (S.E. = 11) g for 61 "females" ($t = 19.6$, $P < 0.001$). The next strongest "sex" separator was footpad span, at 84.2 (S.E. = 0.4) mm and 93.4 (S.E. = 0.4) mm, respectively ($t = 17.4$, $P < 0.001$). Only 1 of 51 nestling "males" exceeded the lower limits of mass and foot-pad span (925 g & 87 mm) for 61 "females".

In 1993, we found that young falcons were likely to fly from the nest when all visible down had been shed, which occurred when wing length was about 300 mm for "males" and 320 mm for "females". To predict when they would reach these flight thresholds, we estimated growth rates in 1994 by measuring wing length of 16 nestling falcons 4-5 times in the nest over a period of 18 days. The falcons were all at least 8 days old, and thus in the period for which wing growth of other raptors is effectively linear (Bechard et al. 1985, Newton 1986).

In a northern study area, where young Saker Falcons were reared in tree nests, completion of radio-tagging was constrained by travel to 4-5 d each year. We chose dates to mark as many birds as possible close to leaving the nest, with a risk that the oldest young might fly when the nest tree was climbed. In 1993, only 31 of 43 well-grown falcon nestlings (72%) could be captured. Mean wing lengths were 271 mm (S.E. = 9 mm) for "males" and 295 (S.E. = 5) mm for "females", with lengths for 2 birds (6%) at or above thresholds for flight.

In 1994-5, we used a pump-pressurized water gun to help catch the older birds. At 2-5 m from a nest, about 200 ml of water was sprayed to fall on the head and wet the main flight feathers of any young falcon thought capable of flight. Wetting affected the birds in 2 ways. Spraying the head seemed to discourage them from flying. One young "male" on a branch 1 m from the nest ran back and lay down in the nest when sprinkled with water; this bird had probably already flown to and from the nest tree. If birds looked very likely to fly from nests, their main flight feathers were sprayed quite heavily with water to reduce their lift. With wetting, in 1994 the capture rate rose to 31 of 38 young (82%), despite wing lengths being significantly longer than in 1993 (2x2 analysis of variance, $F_{1/56} = 6.99$, $P < 0.01$), at 284 (S.E. = 5) mm for "males" and 309 (S.E. = 3) mm for "females", with 5 young falcons (16%) at or above the flight thresholds. The water gun was not used for falcons at cliff nests in southern and eastern Kazakhstan, where it would have been hard to replace falcons in the nest if they flew prematurely.

Harness-mounted radio-tags.—We attached radio tags (Biotrack, Wareham, BH20 5AX, UK) with 6-mm straps of Teflon ribbon (Bally Ribbon Mills, Pennsylvania 19503, USA), using a method modified from Dunstan (1972). The 22 g tags (1.6-2.9% of bird mass) had 300-mm whip antennas (3 mm tapering to 1.5 mm), and lateral 4-mm diameter tubes about 30 mm long for the harness. An 800-mm length of ribbon was knotted twice in the middle and the knots coated with cyanoacrylate ("Super") glue. The knots were pulled immediately into the tube on one side, by winding the ribbon round pliers, before the glue set and held the ribbon in place (Fig. 2a).

A 45-mm breast-strap was made by sewing 7-10 mm loops at the end of a 75-mm length of ribbon, keeping all thread knots on one side and smearing them lightly with the glue. The end of the ribbon at the back of the tag, that would form a body-loop round the thorax of the falcon, was then inserted through a loop in the breast-strap such that the thread knots on the strap would remain outwards, and then through the lateral tube on the other side of the tag to emerge from a 10-mm long, half-depth slot cut from the mid-upper surface of the tube (Fig. 2b). After threading through a 4-mm diameter by 7-mm long tubular crimp of 0.8-mm aluminium, the ribbon was knotted at its end to prevent withdrawal.

The front end of the ribbon, which would form the neck-loop, was similarly threaded through the front of the slotted tube, but without a knot. Both ends of the ribbon had been lightly coated previously on one surface with the glue, folded together and cut at an angle when dry, to form a stiff, narrow point that aided threading and prevented fraying. Each ribbon was marked with white typing-correction fluid at its emergence from the slotted tube, such that the circumference of the body-loop was 280 mm and the neck-loop 300 mm; the neck-loop was unthreaded before tag attachment.

With the legs of the young falcon held extended and parallel with the tail, the body-loop was passed forward over the feet and tail until both legs were completely through the loop. The tag was then held loosely in position on the back while the neck-loop was passed first through the feathers down one side of the neck, then through the breast-strap, and then back to the tag on the other side of the neck. No more than 50 mm of the ribbon was threaded through the slotted tube from the front, and 20 mm through the crimp parallel with the ribbon from the body-loop. Initially, it was important to keep the neck-loop loose, so that it did not pull the body-loop forward from the base of the legs, and to ensure that the neck-loop was adjacent to the neck, within the notch formed ventrally on each side by the diverging clavicle and flight muscles.

With both ribbons threaded, the crimp was closed until it lightly gripped both ends of Teflon ribbon, but could be slid in either direction under moderate pressure. The end of the body-loop was then drawn through the crimp until the tag could be pulled clear of the back by about 10 mm, as measured by the width of an inserted finger. The end of the neck-loop was then drawn through the crimp until its white mark was adjacent to the white mark on the body-loop, thus ensuring that the neck-loop remained about 7% longer than the body-loop. When fitted correctly, the front of the tag could lift about 30° relative to the line of the back and the breast-strap lay along the keel with its front at the point of the keel or just posterior to it. If the breast-strap had been pulled in front of the keel, the neck-loop was loosened, the body-loop moved back and tightened minimally before the process was repeated. The crimp was then flattened fully and thread sewn through both ribbons underneath the crimp (Fig. 2c). The free ends were cut, noting how much of each had been pulled beyond the white mark. The crimp was glued into the tube and the area coated with potting material. A leaf or slip of card between the tag and the falcon's back prevented adhesion to feathers.

Leg bands and microtransponders.—We also marked young falcons with leg bands (British Trust for Ornithology, Thetford, IP24 2PU, UK), and with 1.3 x 13 mm microtransponders (Avid, Norco, California 91760, USA) for identification at falcon hospitals in the United Arab Emirates. These veterinary treatment centers mark trained falcons with transponders for record-keeping (Riddle and Remple 1994), and therefore scan new arrivals for existing tags.

Microtransponders were injected subcutaneously to lie close to the keel near the posterior edge of the sternum, where on older birds they tend to become embedded in fat and thus not move far from the insertion point. With the young falcon lying on its back, each tag was dipped with its 25 mm insertion needle in surgical spirit, which was also wiped on the skin to sterilise it and to damp away downy feathers. The needle was inserted about 35 mm from the edge of the sternum and 1 cm from the keel, pointing towards the posterior tip of the keel. With the full extent of the needle inserted, the ejector was used to push the transponder part-way out of the needle, and then pushed further as the needle was withdrawn to keep the tag in place at least 1 cm from the needle hole. To minimize risk of tag loss or failure, the small entry hole was covered with surgical glue and tags were read after insertion.

RESULTS

Age prediction.— Wing length was an excellent indicator of age. The regression of wing length on date (Fig. 3), after sex assignment based on final size and factoring-in of differences in elevation between individuals, was highly significant for 8 "male" nestlings (R = 0.995 with 6 d.f., P < 0.001) and 8 "females" (R = 0.988 with 6 d.f., P < 0.001) in the 5 measured broods, with a significant difference between "sexes" (t = 2.49 with 14 d.f., P < 0.05). Wing length increased each day by 6.7 mm day^{-1} (S.E. = 0.15) in "males" (l_m) and 7.3 mm day^{-1} (s.e. = 0.19) in "females" (l_f). To predict the Julian date when each young would be able to fly (F) from the wing measurement (d), we used the equations:

$F = d + (300 - l_m) \,.\, 0.149$ for "males";

$F = d + (320 - l_f) \,.\, 0.137$ for "females";

$F = d + (310 - l) \,.\, 0.143$ for all birds.

Estimation of hatching date requires data on the initial period of non-linear wing growth, which were lacking for Saker Falcons. We therefore used the 3 days observed between the y-intercept and date of hatching for buzzards, which have masses and wing lengths between those of the two falcon sexes. Hatch dates (H) were estimated as:

$H = d - 0.149 . l_m - 3.4$ for "males";

$H = d - 0.137 . l_f - 2.6$ for "females";

$H = d - 0.143 . l - 3.0$ for all birds.

<u>Harness fitting</u>.—With practice, a tag could be fitted in 10 minutes to a Saker Falcon that was ready to leave the nest. The circumference of the body-loop (c_b) increased with nestling mass (w) for "males" ($r = 0.39$, d.f. = 23, $P = 0.05$) and "females" ($r = 0.51$, d.f. = 33, $P < 0.005$); the neck-loop (c_n) gave similar results ($r = 0.38$, $P = 0.06$; $r = 0.51$, $P < 0.005$). When data from all birds were pooled (Figure 4), the regression of body-loop size on nestling mass ($R = 0.85$, d.f. = 56, $P < 0.001$) was not improved if "sex" was included as a covariate ($F_{1/56} = 2.9$, n.s.), but the relationship between neck-loop size and nestling mass ($F_{1/57} = 129.5$, $P < 0.001$) was slightly improved by including "sex" ($F_{1/56} = 6.6$, $P < 0.01$). The equations:

$c_b = 31 \times w^{0.30}$

$c_n = 29 \times w^{0.32}$

gave body and neck-loop circumferi of 235 mm and 251 mm at the mean mass of "males", with 254 mm and 273 mm for "females".

The equations also predicted the loop circumferi that were found to fit smaller falcon species. Thus, for 2 young ("male") Peregrine Falcons, masses of 680-690 g predicted neck and body-loops of 219 mm and 234 mm, compared with measured values of 215 mm and 230 mm. The 210 g of a full-grown ("female") Merlin (<u>*Falco columbarius*</u>) predicted loop circumferi of 154 mm and 161 mm, compared with measurements of 155 and 165 mm. The Merlin, 3 more peregrines of unknown mass and 2 Saker Falcons, were fitted with tags while carried hooded on the fist. This was done by placing the closed neck-loop over the head, ensuring that it passed through the feathers beside the neck, and then working the body-loop round the bird just in front of the legs. These trained birds preened the harness to lie completely under the feathers within about 24 hours, and had generally lost interest in the tag within 48 hours.

Records of tagged falcons.—The trapping of a live falcon on or after the first autumn, or the recovery of one that had died later, was evidence of survival through the first 2-3 months after dispersal. There were 6 reports from the first September or later for 89 falcons marked with radio tags in May and June during 1993-95 (7%), compared with 6 of 82 marked only with bands and micro-transponders (7%). Four of the 12 reports were of microtransponders, 3 detected in falcon hospitals and 1 in a trapped falcon examined in a bazaar; the 8 others were band recoveries. One further band was reported in Syria, from one of the 3 birds that was later detected by microtransponder (and without a ring) in a falcon hospital.

Survival of tagged falcons also was monitored by radio-tracking. Of 89 falcons tagged from 1993-95, 81 (91%) survived the 20-45 days between leaving the nest and dispersal from the natal area. The causes of death were predation by Eagle Owls (*Bubo bubo*) in 2 cases, by Imperial Eagles (*Aquila heliaca*) in 2 cases, by ground predators in 2 cases and unknown in 1 cases; the other bird was presumed killed by a predator or taken by humans, because its radio signal was lost a few days after leaving the nest, and it was not seen again with its family. There was no evidence of abrasion from harness straps in 2 dead falcons found intact enough to examine.

DISCUSSION

Techniques for studying animals should not prejudice either the welfare of the individuals or the scientific quality of the results. This is especially important when advances in techology create new opportunities, as well as new risks. Thus, the power-life efficiency of radio-tags for raptors has increased 8-fold in the last 15 years, and reliability to the stage that 72% of buzzards in a recent study were monitored for more than 3 years (Walls and Kenward 1998). However, long-life radio-tags require mounting on harnesses, because tags on feathers are molted and tags on legs lose their antennas.

The risk from using harnesses can be minimized by a system that aids repeatable achievement of a good fit. This is obtained by (i) using a relationship between body size and harness size to estimate the loop sizes likely on a species, (ii) marking the maximum size likely on the loops to ensure a correct size ratio between them, (iii) making the loops totally adjustable at a single point so that their size ratio can easily be checked, and (iv) recording loop lengths and body size so that the fit can be reviewed and standardized after a few birds have been marked.

When working with a new study species, the most important initial step is to find the optimal combination of body-loop circumference and breast-strap length. A breast strap is important for preventing abrasion of the keel (Buehler et al. 1995), and also for positioning the body-loop around the thorax behind the main mass of muscle. Species that develop much breast muscle, including falcons and accipiters, need a relatively long breast strap so that the muscle is not constrained as the bird's condition changes through the year. The body-loop on Saker Falcons lay about 70% back from the front of the thorax, where a relatively small amount of slack was enough to prevent constraint of either the flight muscles or egg-laying. A short breast strap seems satisfactory on eagles and buzzards, which do not develop very wide muscles at the front of the thorax. However, in any species it is crucial that the body-loop cannot pass the anterior point of the sternum, nor should the breast strap be long enough for its junction with the neck-loop to move much forward of this point.

The initial choice of loop dimensions for a new study species could be based on body mass, but other objective and repeatable measurements might provide better predictions of harness fit. Thoracic measurements may be most appropriate, because they correlate more strongly than appendage measurements with body mass (Marcström and Kenward 1981). Length of the sternum is a candidate measurement on full-grown birds, but incomplete ossification prevents accurate measurement in juveniles. Until measures can be found to fit harnesses objectively to a new species, subjective fitting by a trained person remains necessary. Harnesses should never be fitted without training.

It is convenient to fit harnesses on raptors at the time of leaving the nest, because there is little further body growth. Tagging nestlings when they would be handled for banding avoids the extra effort, and risk of bias or injury, when juveniles are trapped to attach tail-mounted tags, after completion of feather growth. The same approach would suit other bird species that are close to full size on leaving the nest. However, expandable under-wing loops must be used to accommodate continued growth of some passerines (Hill et al. 1999), and glue-mounted tags seem most suitable for game-bird chicks (Kenward et al. 1993a).

If tags are to be mounted just before leaving the nest, it must be possible to predict the appropriate date. The rate of increase in wing-length is a convenient measure, because it is linear during much of the nestling period. This rate, which represents mainly the rate of growth of the primary feathers, was 6.7 and 7.3 mm day^{-1} in Saker Falcons categorized from other measurements as male and female respectively. The rate of feather growth in Saker Falcons was very similar to the 7.0 mm day-1 in Buzzards (unpublished data), and not much less than the 8.0 and 9.0 mm day-1 in male and female Goshawks (Kenward et al. 1993b). A growth rate of 7-8 mm a day can probably be used in pilot work to estimate optimal dates for radio-tagging of other large raptors.

Sexing criteria for Saker Falcons have yet to be confirmed by *post mortem* or genetic analyses, but mass and foot-pad span are likely to be important criteria. Harness fitting did not depend on correct estimation of sex, because sex fell out of the mass-based equation for objective fitting of body-loops to full-grown nestlings.

Estimation of sex was impractical when chicks were younger than about 20 days; their tagging date was predicted from the wing length of the largest, using the equation for males because these tended to fledge first. For estimating date of hatching, the problem of assigning sex to young chicks was reduced, because the divergence in estimates of hatch-date between sex-specific and unspecific equations was only 0.35 days at 20 days of age. There may have been a small bias in ageing, as a result of using a correction from Buzzards for the initial non-linearity, but this will have affected all estimates equally and therefore was unimportant when comparing birds.

Pennycuick et al. (1989) showed that any loading impaired the flight performance of trained Harris' Hawks (*Parabuteo unicinctus*). Radio-tags must therefore always have some effect, although their impact may often be too small to detect unless sample sizes are very large (White and Garrott 1990) or conditions occur which stress the birds (Vekasy et al. 1996). The 9% mortality of Saker Falcons in the post-fledging period was comparable with the 9% among 96 Buzzards with backpack radios (Walls and Kenward 1995) and the 6% recorded among 156 Goshawks with tail- and leg-mounted radio tags (Kenward et al. 1993b), which in both cases had first-year survival higher than estimated by band recoveries (Kenward et al. 1999, in press). In this study, and among the Goshawks, trapping records gave no evidence that birds with radios had reduced survival to their first autumn. Nevertheless, if poor condition had made Saker

Falcons with radio tags easier to trap than falcons marked in other ways, an adverse impact of radios might not have been detectable.

Marking nestlings and trapping migrants could be used to monitor population sizes and demographic trends of Saker Falcons, as for Peregrine Falcons (*Falco peregrinus*) nesting in North America (USFWS 1983, Cade et al. 1988). Microtransponder markers originally were used to gain information on harvest rates from trapped birds after removal of rings. However, transponders also could be used to record recruitment to the breeding population, and turnover of adults, by placing automatic recorders in occupied nests to register transponders without the need to catch the breeders. Moreover, as about half the young Saker Falcons each year were marked only with bands and transponders, not radio tags, any impact of radios on long-term survival eventually should be revealed by reduced recruitment to breed.

For a very approximate estimation of the harvest rate, the single band report among a total of 4 microtransponder records gives a band reporting rate of 25%, in which case the 9 band recoveries represent 36 of the 171 young falcons (21%). For transponders alone, the recovery rate from the 3 records at the falcon hospitals in Dubai and Abu Dhabi was 1.75%, such that the average 637 juvenile Saker Falcons examined at these hospitals annually in the early 1990s (Riddle & Remple 1994) would represent an annual production of some 36 000 young Saker Falcons in the areas subject to harvest. Of these, an estimate of 2,750 falcons trapped annually for falconry (Riddle & Remple 1994) would represent a harvest rate of only 8% of juveniles. Estimates based on such small number of recaptures do no more than indicate that the current harvest of migrant Saker Falcons is probably not excessive. To estimate population sizes and harvest levels accurately, many more falcons need to be marked and reported at capture.

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FIGURE LEGENDS

FIGURE 1. The cord and toggle used to restrain the feet while measuring raptors, with the dimension recorded as foot-pad span.

FIGURE 2. The use of Teflon ribbon to attach a backpack radio tag side tubes.
(a) Knots at the center of a single ribbon are inserted and glued in the continuous side tube.
(b) The body-loop is threaded through the breast strap and split side tube before mounting, with both loops marked for length. After sliding the body-loop over the tail and legs, the neck-loop is threaded beside the neck to the breast strap and back to the split tube.
(c) The crimp is squeezed to grip gently before the neck and body-loops are adjusted for length. The crimp is then tightened, the loops sewn, and the join cemented into the split tube.

FIGURE 3. The increase of wing length with date in nestling Saker Falcons, plotted as residuals after correction for differences in elevation between individuals of the same “sex”.

FIGURE 4. The increase with body mass of nestling Saker Falcons, classed as “male” (●) or “female” (❍), of (a) the body-loop circumference and (b) the neck-loop circumference of harnesses used to attach backpack radio tags.

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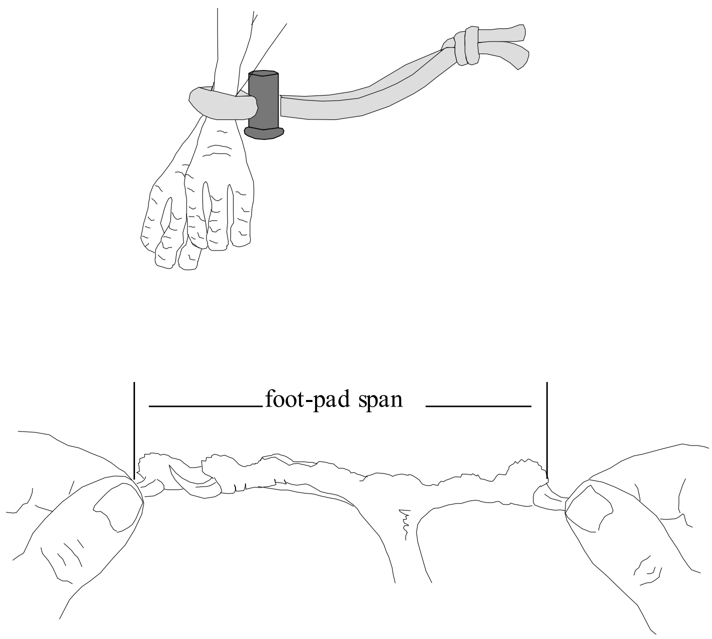
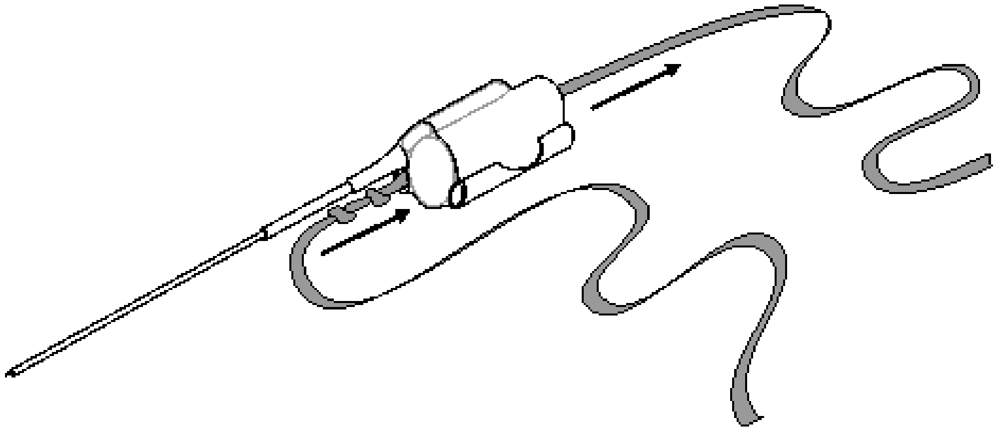
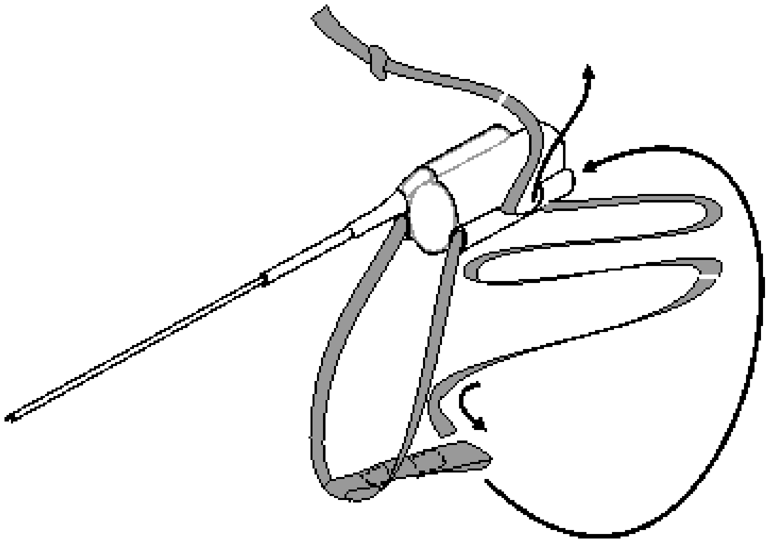


FIGURE 2. The use of Teflon ribbon to attach a backpack radio tag side tubes.

(a) Knots at the center of a single ribbon are inserted and glued in the continuous side tube.



(b) The body-loop is threaded through the breast strap and split side tube before mounting, with both loops marked for length. After sliding the body-loop over the tail and legs, the neck-loop is threaded beside the neck to the breast strap and back to the split tube.



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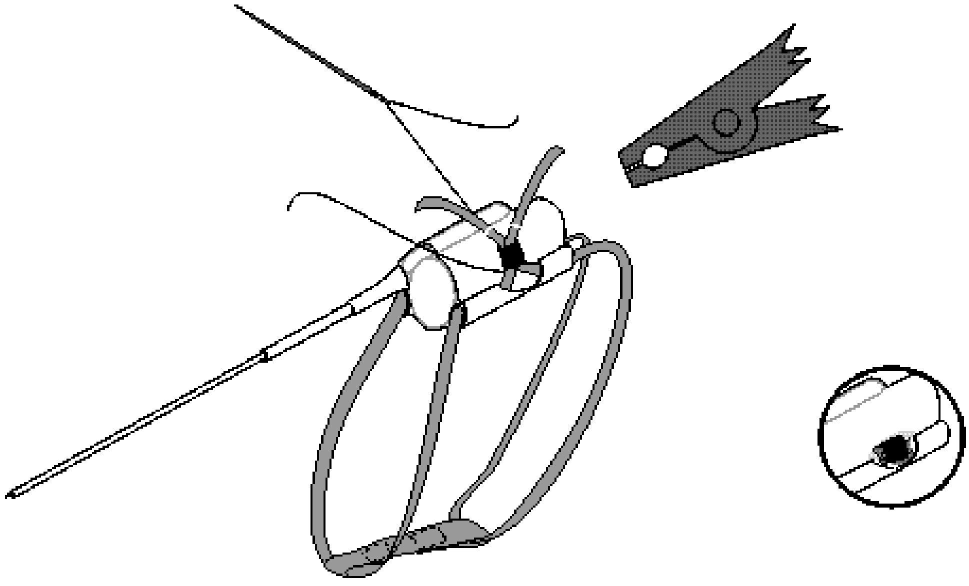

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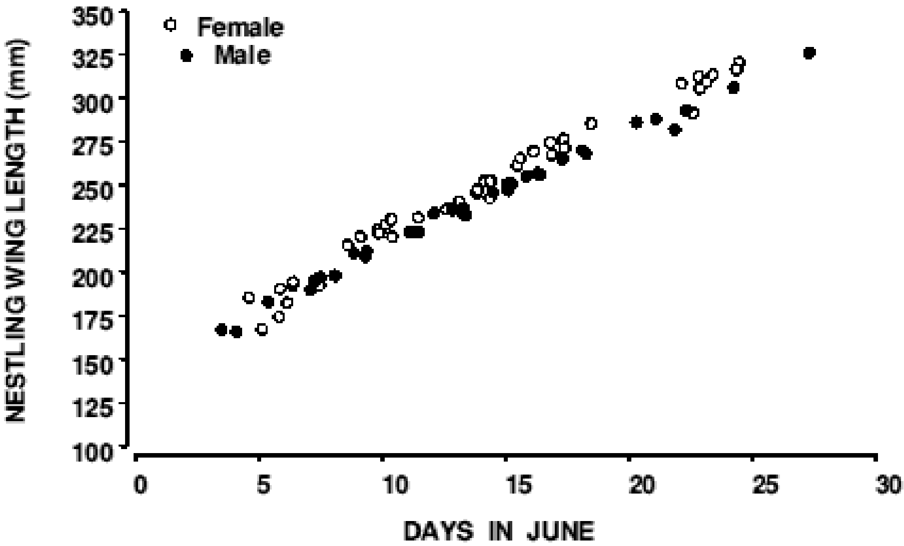

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