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Effects of geolocator attachments on breeding parameters of Lesser Kestrels

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ABSTRACT. Light level geolocators, also known as GLS loggers, are electronic devices intended for tracking the location of wide-ranging animals using ambient light to estimate latitude and longitude. Miniaturized geolocators that can be used on relatively small migratory birds have recently become available, but little is known about the potential harmful effects of geolocators on birds. We examined the possible effects of 1.5-g geolocators (dimensions: 21 × 6.5 × 9 mm) on the breeding success and survival of migratory Lesser Kestrels (*Falco naumanni*). During the 2007 breeding season, kestrels were fitted with geolocators using two attachment methods (Teflon wing harnesses and darvic bands), and geolocators were removed in 2008 after the birds returned to the breeding grounds. We found no differences in the breeding success of control and tagged pairs during the 2007 breeding season, but tagged pairs had greater fledgling mortality in the following breeding season. Furthermore, nestlings of tagged individuals had higher triglyceride and uric acid concentrations in their blood than control nestlings during the breeding season following tagging. As for return rates, 75% of tagged birds came back to the colony after the nonbreeding period, a proportion similar to that reported in previous studies. Although back-mounts are slightly heavier and require more skill to attach, we recommend their use on small migratory raptors because most leg-mounted geolocators in this study were damaged or rendered useless by dirt obscuring the light sensor.

RESUMEN. **Efectos de los geolocalizadores en las tasas reproductivas del Cernícalo Primilla *Falco naumanni***

Los geolocalizadores son aparatos electrónicos destinados a trazar las localizaciones de animales con gran área de campeo usando la luz ambiental para determinar las posiciones de latitud y longitud. Los diminutos geolocalizadores recientemente disponibles pueden ser usados en pequeñas aves migratorias. Sin embargo, la información sobre los posibles efectos dañinos de los geolocalizadores sobre sus portadores es escasa. El efecto de geolocalizadores de 1,5 g de peso y un tamaño de 21 × 6.5 × 9 mm sobre los parámetros de cría, la condición nutricional de los pollos y la supervivencia de los cernícalos primilla *Falco naumanni* fue valorado durante un ciclo anual. Los geolocalizadores fueron colocados durante la estación reproductora de 2007 usando dos métodos de fijación (arneses alares de Teflón y anillas de plástico en las patas), y fueron recogidos tan pronto como las aves fueron localizadas y capturadas después de la migración prenupcial. Los parámetros de cría de parejas marcadas y controles no difirieron durante la estación de cría de 2007, sin embargo, las parejas marcadas mostraron un incremento en mortalidad de sus pollos durante la siguiente estación de cría. Además, los pollos hijos de individuos marcados mostraron concentraciones más altas de triglicéridos y ácido úrico en sangre que los pollos control durante la estación de cría siguiente al marcaje. El 75% de los individuos marcados regresó a la colonia después del periodo no reproductor. Esta proporción no difiere de estimas previas hechas para la especie. Aunque los arneses son ligeramente más pesados y requieren de más esfuerzo para fijarlos, nosotros proponemos su uso en pequeñas rapaces migratorias dado que la mayoría de nuestros geolocalizadores montados en anillas fueron fuertemente dañados y sucios al recuperarlos, proporcionando datos inservibles.

Key words: biochemical parameters, breeding success, effects, *Falco naumanni*, geolocators, Lesser Kestrel, survival

Telemetry studies can provide valuable information about the behavior and ecology of birds, but the effect of devices used to track animals is often assumed to be negligible (Murray and Fuller 2000). Studies where tag impact has been considered have revealed variation among species, with some reporting no adverse effects (Hiraldo et al. 1994, Terhune et al. 2007, Anich et al. 2009) and others demonstrating the effects on breeding behavior, predation rates, breeding

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success, survival, and hunting skills (e.g., Whidden et al. 2007). Among raptors, tags have been found to have negative effects on the survival of Northern Goshawks (*Accipiter gentilis*) and Prairie Falcons (*Falco mexicanus*; Reynolds et al. 2004, Steenhof et al. 2006), as well as on the types of prey delivered to nests by Prairie Falcons (Vekasy et al. 1996).

Light-level geolocation technology has recently been used on terrestrial birds to investigate long-distance movements (Eichhorn et al. 2006, Stutchbury et al. 2009, Rodríguez et al. 2009). To determine if data derived from the use of geolocators are unbiased due to possible handicaps on the carriers and to ensure the well-being of the birds being studied, the possible effects of geolocator tags on birds need to be examined.

We examined the possible effects of geolocators on various breeding parameters (clutch size, number of fledged young, and clutch initiation date) of Lesser Kestrels (*Falco naumanni*) during two consecutive nesting seasons. Because the geolocators used represented less than 3% of Lesser Kestrels' body mass (less than the generally accepted 5% threshold; Kenward 2001), we predicted that breeding parameters would not be affected. We also evaluated selected blood biochemistry parameters (triglycerides, cholesterol, urea, and uric acid) of nestlings of tagged and control pairs because differences in these parameters may indirectly indicate subtle effects of geolocators on adult breeding behavior. Finally, because the effect of devices can be influenced by where or how they are attached (Murray and Fuller 2000), we compared two attachment methods (Teflon wing harnesses and darvic plastic leg bands).

METHODS

Geolocation and model species. Light-level geolocation uses ambient light to estimate latitude and longitude, determined by day and night lengths and time of local midday or midnight, respectively (Hill 1994). Light-level geolocators are equipped with an accurate internal clock that is used to time-stamp measurements from a photoreceptor.

Lesser Kestrels are small, partially migratory falcons that breed colonially in holes and crevices of buildings in Western Europe. During February and March, birds arrive at breeding colonies from their wintering grounds. Egg laying typically occurs during late April and early May. After 28–32 d of incubation, eggs hatch in June and young fledge during the first half of July. Both males and females share incubation and brooding duties. These kestrels are sexual dimorphic and dichromatic, with males more brightly colored and lighter than females (ranges = 90–172 g for males and 138–208 g for females). Populations have decreased by about 95% in the western Palearctic since the 1950s, and a reduction of more than 30% of the world population has been estimated, explaining its current Vulnerable status (Negro 1997).

Experimental procedures. We studied a colony (about 25–30 pairs) located on a cereal silo within the urban area of La Palma del Condado (37°23'N, 6°33'W), Huelva province, in southern Spain. Nests were located on the window ledges of the building, allowing us to capture kestrels by hand at their nests and to accurately assess breeding parameters.

During June 2007, 20 adult Lesser Kestrels representing 10 randomly chosen breeding pairs were fitted with geolocators designed and created by engineers from the British Antarctic Survey (www.birdtracker.co.uk). Weight and dimensions of the geolocators were 1.5 g and 21 × 6.5 × 9 mm, respectively, excluding the sensor stalk. Five randomly selected pairs were fitted with Mk14S (light sensor on stalk) devices on harness attachments, and five pairs were fitted with Mk14 (no stalk) devices on darvic plastic bands on the legs (see below). The remaining 14 pairs breeding in the silo colony in 2007 were used as controls. Most adult kestrels were captured while brooding 1–7-d-old chicks at their respective nest sites.

We used two different methods to attach loggers to kestrels: Teflon wing harnesses and darvic plastic leg bands. The harnesses (Figs. 1A, B) were constructed with cotton thread, cyanoacrylate glue, and approximately 30 cm of 4.75-mm-wide tubular Teflon ribbon (Biotrack Ltd., Dorset, UK; M. de la Riva, Estación Biológica de Doñana CSIC, pers. comm., Kenward 2001). The mean weight of the harness plus geolocator was 3.09 ± 0.03 (SD) g. For the leg-band method, geolocators were attached with a weatherproof cable tie (TY523MXR; Thomas and Betts, Memphis, TN) to a darvic band on the bird's leg (Fig. 1C).

Fig. 1. (A) Adult female Lesser Kestrel with an Mk14S geolocator attached with a Teflon harness (2007). (B) Adult male kestrel with a geolocator attached with a Teflon harness (2008, after recovery). (C) Adult female kestrel with an Mk14 geolocator attached with a leg band (2007). Geolocator dimensions are 21 × 6.5 × 9 mm, excluding the sensor stalk. (D) Small wound on the breast of a female kestrel.

Darvic bands were provided by the Ringing Office of Doñana Biological Station, and their size and weight were 17.5 × 10 mm and 0.9 g, respectively. The mean weight of these attachments was 2.44 ± 0.08 (SD) g.

During the 2007 and 2008 breeding seasons, we monitored the colony to record clutch initiation dates, clutch sizes, and the number of fledged young per pair. From February-April 2008 (before egg laying), we used a spotting scope (×30) and binoculars (×10) to search for tagged birds and locate nest-sites (i.e., window ledges). Birds were captured at night and most tags were removed between 1 March and 15 April period (before egg-laying). At the time of capture, selected body measurements and mass were recorded.

During the 2007 and 2008 nesting seasons, a blood sample (0.5 mL) was taken from each nestling and immediately refrigerated. To minimize the possible effects of circadian rhythms on parameter levels, all blood samples were collected between 08:00 and 14:00. Within 6 hrs of sampling, blood samples were centrifuged for 10 min at 4500 g, and the plasma was separated and stored at –20°C. Plasma was analyzed for triglycerides, cholesterol, urea, and uric acid using a Screen Point autoanaliser (Hospitex Diagnostics, Sesto Fiorentino, Italy), and commercial kits (Biolabo Labs, Maizy, France). Plasma biochemical analyses were performed by Wildvets S.L.P. (Seville, Spain).

Statistical analyses. We used two-way ANOVA to test for differences in the geolocator/body mass ratio (i.e., harness/darvic included) at the time of tagging (with sex and geolocator type as factors), and in the body mass of tagged versus untagged individuals (with sex as a factor). Because variables were not normally distributed, possible differences in clutch date, clutch size, and productivity (number of fledged young) among groups were examined separately using Mann–Whitney U-tests. To avoid possible differences in productivity due to clutch size, we also assessed the productivity/clutch size ratio using Mann–Whitney U-tests. Given our small sample sizes, we calculated the statistical power (w, probability of obtaining a significant result when the hypothesis is false) following the methods of Jennions and Møller (2003), as well as the difference between the effect size of our data (ES) and the effect size required to be detected with high power (0.80) given our sample sizes (ES_{min}). Tests for possible differences in the breeding parameters (clutch date, clutch size, fledged young, and productivity/clutch size ratio) of tagged and untagged birds were one-tailed because the effect of the geolocators was expected to be negative. For comparison of the possible effects of attachment method (harnesses and leg bands) on breeding parameters, tests were two-tailed because no directional change was expected. We used Linear Mixed Models to test the possible effects of parental status (geolocators vs. controls) on the body condition (weight and plasma biochemical parameters) of nestlings. Age and the number of siblings were included as covariates, and nest identity as a random factor to avoid pseudoreplication. Age (in days) was estimated using the eighth primary (mm) according to the function AGE = 10.44 + 0.14*EIGHTH PRIMARY (Negro 1997). Biochemical variables were log transformed when assumptions of parametric statistics (normality and homocedasticity) were not met. Adult recapture asynchrony during 2008 precluded a comparison of plasma biochemical parameters of tagged versus untagged adults. In 2008, pairs that included at least one kestrel that was tagged in 2007 were compared to the remaining pairs in the colony.

RESULTS

Because of the sexual size dimorphism, the attachments represented a greater burden for male Lesser Kestrels than females ($F_{1,16} = 61.8$, $P < 0.001$), and harness attachments were heavier than those on darvic bands ($F_{1,16} = 154.1$, $P < 0.001$). No interaction between factors was detected ($F_{1,16} = 2.0$, $P = 0.18$; Fig. 2). The small number of returning birds precluded assessment of these differences in 2008, but the pattern was similar to that in 2007 (Fig. 2).

Fifteen of 20 birds (75%) tagged in 2007 were resighted during the 2008 breeding season, with 14 of those 15 recaptured and 13 geolocators recovered (see below). Despite differences in

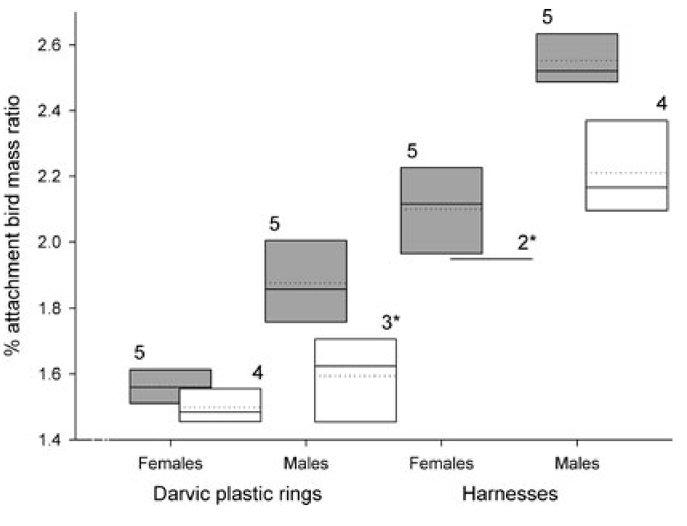

Fig. 2. Geolocator masses (including the whole attachment, that is, geolocators plus harness/band) in relation to body mass of Lesser Kestrels when they were tagged (2007 breeding season; gray boxes) and recaptured (early 2008 breeding season; white boxes). Numbers indicate sample sizes. Dotted internal line, solid line, and box boundaries indicate mean, median, and 25% and 75% percentile values, respectively. * indicates classes in which a bird was not measured (see Results).

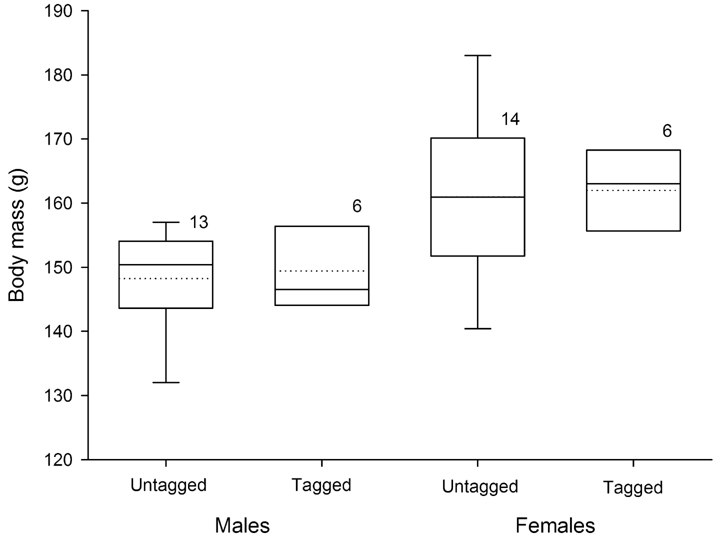

Fig. 3. Body masses of tagged and untagged Lesser Kestrels during the prelaying period (1 March–15 April 2008). Numbers indicate sample sizes. Dotted internal line, solid line, box boundaries, and whisker caps indicate mean, median, 25% and 75% percentile values, and 10% and 90% percentile values, respectively.

geolocator/body mass ratios, return rates of the birds did not differ with either attachment type (seven harnesses and eight darvic bands) or sex (eight males and seven females). We found no difference in the body mass of tagged and untagged individuals during the 2008 prelaying period ($F_{1,35} = 0.1$, $P = 0.79$; Fig. 3).

Only one kestrel had an injury at the time of recovery. This bird, a female, had a small wound on the breast, probably due to a bad harness fit. When we removed her harness, the frontal knot was partly embedded in the underlying tissue (Fig. 1D). In addition, one male fitted with a leg-mounted geolocator was found apparently exhausted in late summer, 2 mo after being banded, and well after his brood of five nestlings had fledged. This male was found 140 km north of the colony by a private citizen, and admitted to a wildlife rehabilitation center. After about 6 mo, the male was released on 2 February 2008 with the geolocator removed. This individual returned to the silo colony and successfully fledged three young in 2008.

At least 10 of the returned and tagged kestrels (without geolocators because they were all removed) bred successfully in 2008, fledging at least one young. The remaining five individuals were captured or sighted in the colony before egg-laying (February–April), but we were not able to determine if they bred. In 2008, most previously tagged birds ($N = 8$) paired with a different mate. However, one pair of kestrels remained together and nested in the same cavity as in 2007.

We found no significant differences between pairs with attachments and controls in clutch sizes and number of fledged young (Table 1). In 2008, the productivity/clutch size ratio varied (Table 1), but clutch initiation date did not differ between experimental groups ($U = 33.0$, $P = 0.29$, $w = 18.7\%$, ES-ES$_{min} = -0.87$). As expected (because birds to be tagged were captured after hatching and pairs were randomly selected), we detected no differences in clutch sizes between pairs with tags and control pairs in 2007. However, differences approaching significance were detected in clutch size and the number of young fledged for pairs with different attachment methods (Table 2). Pairs with harness attachments had a lower breeding success, but the productivity/clutch size ratio was similar (Table 2). During the 2008 nesting season, nestlings of tagged pairs had higher concentrations of triglycerides and uric acid than nestlings of untagged birds, but the body mass of nestlings in the two experimental groups was similar (Table 3).

Table 1. Breeding parameters of geolocator-tagged and control Lesser Kestrels at the Silo colony (Huelva province, southern Spain). Geolocators were deployed during the nestling period in 2007 and before egg laying in 2008. In 2007, clutches were recorded before tagging kestrels whereas breeding parameters were recorded after deployment in 2008 (see "Methods"). Statistical and *P*-values are shown.

	Controls			Geolocator						
	Mean	SD	*N*	Mean	SD	*N*	*U*-test	*P*-Value	Power%	$Es\text{-}Es_{min}$
2007										
Clutch size	4.36	0.76	14	4.20	1.03	10	67.5	0.34	10.9	−0.886
Fledged young	2.93	1.39	14	3.60	0.97	10	58.5	0.18	36.8	−0.504
Productivity/clutch size ratio	0.69	0.32	14	0.86	0.15	10	54.0	0.13	47.9	−0.383
2008										
Clutch size	4.00	0.82	10	4.50	0.76	8	26.0	0.12	35.6	−0.601
Fledged young	3.70	1.06	10	3.25	1.04	8	33.0	0.29	21.8	−0.804
Productivity/clutch size ratio	0.92	0.14	10	0.70	0.16	8	16.0	0.017	90.4	0.23

Table 2. Breeding parameters of Lesser Kestrel pairs tagged with either harnesses or leg bands at the Silo colony (Huelva province, southern Spain) in 2007. Clutch sizes were recorded before tagging kestrels (see "Methods").

	Harnesses			Leg bands						
	Mean	SD	*N*	Mean	SD	*N*	*U*-test	*P*-values	Power%	$ES\text{-}Es_{min}$
Clutch size	3.60	0.89	5	4.80	0.84	5	4.0	0.095	48.7	–0.637
Fledged young	3.00	0.71	5	4.20	0.84	5	3.5	0.055	57.3	–0.481
Productivity/clutch size ratio	0.84	0.15	5	0.88	0.16	5	11.0	0.84	6.5	–1.766

Table 3. Comparison (linear mixed model, with age and number of siblings as fixed factors and nest identity as a random factor) of the plasma biochemical parameters and mass of nestling Lesser Kestrels in the nests of control pairs versus pairs with geolocators attached.

	Control			Geolocator					
Parameter	Mean	SD	*N*	Mean	SD	*N*	*F*	*P*	Confidence intervals
2007									
Mass (g)	151.3	19.0	42	149.9	13.4	36	2.0	0.18	[−4.02, 20.25]
Triglycerides[a] ($mg\ dL^{-1}$)	341.4	210.2	39	335.1	229.5	36	0.2	0.63	[−0.13, 0.21]
Cholesterol[a] ($mg\ dL^{-1}$)	190.6	67.4	37	191.5	48.4	36	0.02	0.90	[−0.10, 0.11]
Urea ($mg\ dL^{-1}$)	14.3	3.5	36	12.6	4.2	36	3.0	0.10	[−0.43, 4.16]
Uric acid ($mg\ dL^{-1}$)	16.4	5.6	35	15.4	6.0	35	0.5	0.51	[−2.85, 5.58]
2008									
Mass (g)	145.2	20.3	34	144.3	15.2	27	0.02	0.90	[−15.3, 13.6]
Triglycerides[a] ($mg\ dL^{-1}$)	226.5	168.7	29	292.7	120.1	26	11.3	0.005	[−0.39, −0.08]
Cholesterol[a] ($mg\ dL^{-1}$)	200.2	44.9	29	226.5	47.2	26	2.9	0.12	[−0.12, 0.01]
Urea ($mg\ dL^{-1}$)	15.8	7.0	29	21.7	9.7	26	4.3	0.06	[−12.1, 0.31]
Uric acid ($mg\ dL^{-1}$)	16.7	5.2	29	19.8	5.5	25	7.8	0.018	[−8.28, −0.96]

[a]Variable was log transformed.

When recovered, some geolocators were damaged. All leg-mounted geolocators ($N = 7$) had scratches, peck marks, and dirt, and three had been destroyed. However, geolocators mounted on harnesses had no scratches or dirt ($N = 6$), and only one had been damaged (missing light sensor).

DISCUSSION

Light-level geolocator tags representing 1.4–2.7% of body mass did not affect the breeding success of adult Lesser Kestrels in our study during the year they were tagged. Similarly, previous studies have revealed no effects of either 3–5 g tail-mounted radio-tags on breeding Lesser Kestrels (Hiraldo et al. 1994), or back-mounted radio-tags on other falcons (Vekasy et al. 1996). However, pairs of Lesser Kestrels with at least one-tagged member fledged fewer young in the following breeding season. Such results are difficult to explain because we found no differences between tagged and untagged birds in body mass during the 2008 prelaying period. One possible explanation is that the difference in fledging rates may be related to differences in environmental conditions in 2007 and 2008. Mean breeding success for the entire colony (fledged young per breeding attempt) was higher in 2007 (3.21 ± 1.25, $N = 25$) than in 2008 (2.84 ± 1.66, $N = 31$) as was the mean body mass of fledglings, suggesting that conditions may have been more favorable for kestrels in 2007. Thus, when conditions were more favorable, no effects of geolocators were detected (2007), but, with less favorable conditions, effects may have been more apparent (Murray and Fuller 2000).

The productivity/clutch size ratio did not vary for pairs of kestrels with different attachment methods (harnesses and leg bands), suggesting that the marginal differences in clutch size and productivity may have been due to our small sample size (note that clutch size was recorded before tagging kestrels; see Table 2). In addition, high return rates in 2008 suggest that geolocator attachment had little or no effect on kestrel flight capacity. In fact, return rates in our study were similar to those reported in a previous and larger study of the same population (Hiraldo et al. 1996; see also Negro 1997). Given that breeding success and return rates were not affected by attachment type, we recommend the use of back-mounts (at least for raptors or other species with strong bills) even though they are slightly heavier and attaching them requires more skill than leg-mounted geolocators. In contrast, most leg-mounted geolocators in our study were heavily damaged and dirty when recovered and did not provide usable data (Rodríguez et al. 2009).

The apparent similarity in nestling condition (nestling body mass was similar between experimental groups) suggests that the higher concentrations of triglycerides and uric acid in nestlings of tagged pairs might be due to differences in types of prey delivered to the nest, possibly a consequence of a posttagging effect of geolocators on the behavior of parents. Prey delivery rates of radio-tagged and untagged adults were similar in other studies involving this and other species (Hiraldo et al. 1994, Vekasy et al. 1996), but the types of prey brought to the nest differed between the two experimental groups (Vekasy et al. 1996). Another possible explanation, not mutually exclusive, is that tagged birds incurred a delayed handicap during the 2008 mating season and, as a result, might have been more likely to mate with poor quality individuals. In support of this hypothesis, we found that differences were not significant in 2007 when pairing occurred before attachment of the geolocators.

To date, the use of light level geolocators to investigate the migratory strategies of birds has largely been limited to relatively large species (Croxall et al. 2005, Eichhorn et al. 2006, Shaffer et al. 2006, González-Solís et al. 2007). As their weight and size decreases, geolocators can be used on smaller species. However, their possible negative effects must be tested, especially with small species with greater attachment-to-bird mass ratios. To our knowledge, Lesser Kestrels are one of the lightest species in which light-level geolocation technology and their effects have been used and evaluated, respectively (see Igual et al. 2005 and Rayner 2007 for larger species, and Stutchbury et al. 2009 for smaller ones).

Despite the possible negative effects of geolocators on Lesser Kestrels during the breeding season following attachment, we believe that the use of geolocators was justified because of the importance of learning more about the migration and winter ecology of these threatened kestrels (Rodríguez et al. 2009). We found that Lesser Kestrels were particularly well suited for using geolocation because this technique relies on the ease of recapturing of tagged birds after a protracted period of time. As with many seabirds, where use of geolocators is more common, adult Lesser Kestrels are extremely philopatric (Negro et al. 1997, Serrano et al. 2001) and tend to return to breed at the same colony where they bred the previous year. Other small raptors whose migration might be tracked using geolocation are the colonial Red-legged Falcons (*Falco vespertinus*) and Amur Falcons (*F. amurensis*), as well as small migratory owls, such as Scops Owls (*Otus scops*). However, loggers must be retrieved and downloaded and, therefore, the probability of recovery of fitted birds must be taken into account in the design of studies. In addition, investigators should evaluate the trade-off between possible harmful effects on their focal species and the potential information that might be obtained (Murray and Fuller 2000).

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LITERATURE CITED

ANICH, N. M., T. J. BENSON, AND J. C. BEDNARZ. 2009. Effect of radio transmitters on return rates of Swainson's Warblers. Journal of Field Ornithology 80: 206–211.

CROXALL, J. P., J. R. D. SILK, R. A. PHILLIPS, V. AFANASYEV, AND D. R. BRIGGS. 2005. Global circumnavigations: tracking year-round ranges of nonbreeding albatrosses. Science 307: 249–250.

EICHHORN, G., V. AFASNASYEV, R. H. DRENT, AND J. P. VAN DER JEUD. 2006. Spring stopover routines in Russian Barnacle Geese *Branta leucopsis* tracked by resightings and geolocation. Ardea 94: 667–678.

GONZÁLEZ-SOLÍS, J., J. P. CROXALL, D. ORO, AND X. RUIZ. 2007. Trans-equatorial migration and mixing in the wintering areas of a pelagic seabird. Frontiers in Ecology and Environment 6: 297–301.

HILL, R. D. 1994. Theory of geolocation by light levels. In: Elephant seals, population, ecology, behavior and physiology (B. J. Le Boeuf, and R. M. Laws, eds.), pp. 227–236. University of California Press, Berkeley, CA.

HIRALDO, F., J. A. DONÁZAR, AND J. J. NEGRO. 1994. Effects of tail-mounted radio-tags on adult Lesser Kestrels. Journal of Field Ornithology 65: 466–471.

HIRALDO, F., J. J. NEGRO, J. A. DONÁZAR, AND P. GAONA. 1996. A demographic model for a population of the endangered Lesser Kestrel in southern Spain. Journal of Applied Ecology 33: 1085–1093.

IGUAL, J. M., M. G. FORERO, G. TAVECCHIA, J. GONZÁLEZ-SOLÍS, A. MARTÍNEZ-ABRAÍN, K. A. HOBSON, X. RUIZ, AND D. ORO. 2005. Short-term effects of data-loggers on Cory's Shearwater (*Calonectris diomedea*). Marine Biology 146: 619–624.

JENNIONS, M. D., AND A. P. MØLLER. 2003. A survey of the statistical power of research in behavioral ecology and animal behavior. Behavioral Ecology 14: 438–445.

KENWARD, R. E. 2001. A manual for wildlife radiotagging. Academic Press, London, UK.

MURRAY, D. L., AND M. R. FULLER. 2000. A critical review of the effects of marking on the biology of vertebrates. In: Research techniques in animal ecology – controversies and consequences (L. Boitani and M. R. Fuller, eds.), pp. 15–64. Columbia University Press, New York.

NEGRO, J. J. 1997. Lesser Kestrel *Falco naumanni*. BWP Update 1: 49–56.

NEGRO, J. J., F. HIRALDO, AND J. A. DONÁZAR. 1997. Causes of natal dispersal in the Lesser Kestrel: inbreeding avoidance or resource competition? Journal of Animal Ecology 66: 640–648.

RAYNER, M. J. 2007. Effects of dummy global location sensors on foraging behavior of Cook's Petrel (*Pterodroma cookie*). Wilson Journal of Ornithology 119: 109–111.

REYNOLDS, R. T., G. C. WHITE, S. M. JOY, AND R. W. MANNAN. 2004. Effects of radiotransmitters on Northern Goshawks: do tailmounts lower survival of breeding males? Journal of Wildlife Management 68: 25–32.

RODRÍGUEZ, A., J. J. NEGRO, J. BUSTAMANTE, J. W. FOX, AND V. AFANASYEV. 2009. Geolocators map the wintering grounds of threatened Lesser Kestrels in Africa. Diversity and Distributions 15: 1010–1016.

SERRANO, D., J. L. TELLA, M. G. FORERO, AND J. A. DONÁZAR. 2001. Factors affecting breeding dispersal in the facultatively colonial Lesser Kestrel: individual experience vs. conspecific cues. Journal of Animal Ecology 70: 568–578.

SHAFFER, S. A., Y. TREMBLAY, H. WEIMERSKIRCH, D. SCOTT, D. R. THOMPSON, P. M. SAGAR, H. MOLLER, G. A. TAYLOR, D. G. FOLEY, B. A. BLOCK, AND D. P. COSTA. 2006. Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. Proceedings of the National Academy of Sciences USA 103: 12799–12802.

STEENHOF, K., K. K. BATES, M. R. FULLER, M. N. KOCHERT, J. O. MCKINLEY, AND P. M. LUKACS. 2006. Effects of radiomarking on Prairie Falcons: attachment failures provide insights about survival. Wildlife Society Bulletin 34: 116–126.

STUTCHBURY, B. J. M., S. A. TAROF, T. DONE, E. GOW, P. M. KRAMER, J. TAUTIN, J. W. FOX, AND V. AFANASYEV. 2009. Tracking long-distance songbird migration by using geolocators. Science 323: 896.

TERHUNE, T. M., D. C. SISSON, J. B. GRAND, AND H. L. STRIBLING. 2007. Factors influencing survival of radiotagged and banded Northern Bobwhites in Georgia. Journal of Wildlife Management 71: 1288–1297.

VEKASY, M. S., J. M. MARZLUFF, M. N. KOCHERT, R. N. LEKMAN, AND K. STEENHOF. 1996. Influence of radio transmitters on Prairie Falcons. Journal of Field Ornithology 67: 680–690.

WHIDDEN, S. R., C. T. WILLIAMS, A. R. BRETON, AND C. L. BUCK. 2007. Effects of transmitters on the reproductive success of Tufted Puffins. Journal of Field Ornithology 78: 206–212.