

## METHODS & TECHNIQUES

### Implantation reduces the negative effects of bio-logging devices on birds

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#### SUMMARY

Animal-borne logging or telemetry devices are widely used for measurements of physiological and movement data from free-living animals. For such measurements to be relevant, however, it is essential that the devices themselves do not affect the data of interest. A recent meta-analysis reported an overall negative effect of these devices on the birds that bear them, i.e. on nesting productivity, clutch size, nest initiation date, offspring quality, body condition, flying ability, foraging behaviours, energy expenditure and survival rate. Method of attachment (harness, collar, glue, anchor, implant, breast-mounted or tailmount) had no influence on the strength of these effects but anchored and implanted transmitters had the highest reported rates of device-induced mortality. Furthermore, external devices, but not internal devices, caused an increase in ‘device-induced behaviour’ (comfort behaviours such as preening, fluffing and stretching, and unrest activities including unquantifiable ‘active’ behaviours). These findings suggest that, with the exception of device-induced behaviour, external attachment is preferable to implantation. In the present study we undertake a meta-analysis of 183 estimates of device impact from 39 studies of 36 species of bird designed to explicitly compare the effects of externally attached and surgically implanted devices on a range of traits, including condition, energy expenditure and reproduction. In contrast to a previous study, we demonstrate that externally attached devices have a consistent detrimental effect (i.e. negative influences on body condition, reproduction, metabolism and survival), whereas implanted devices have no consistent effect. We also show that the magnitude of the negative effect of externally attached devices decreases with time. We therefore conclude that device implantation is preferable to external attachment, providing that the risk of mortality associated with the anaesthesia and surgery required for implantation can be mitigated. We recommend that studies employing external devices use devices that can be borne for long periods, and, wherever possible, deploy devices in advance of the time period of interest.

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#### INTRODUCTION

In recent years, hundreds of studies on thousands of individuals have been conducted using animal-borne logging or telemetry devices. Such devices either transmit or store data that otherwise would be difficult or impossible to collect from free-ranging animals. This approach has provided information on location, movement, activity patterns, diving behaviour, body temperature and heart rate (for reviews, see Cooke, 2008; Hart and Hyrenbach, 2009; Ropert-Coudert et al., 2009; Rutz and Hays, 2009; Bograd et al., 2010). For information gathered by such techniques to be valuable, however, it is crucial that the devices used to transmit or record the data do not themselves influence the data. To understand the effect of devices on animals, Barron et al. (Barron et al., 2010) recently presented a meta-analysis of the effects of externally attached and internally implanted devices on the behaviour and ecology of birds. Barron et al. (Barron et al., 2010) demonstrated an overall negative effect of these devices on the birds that bear them, and concluded that the benefits of using these devices should be balanced against the costs to the birds and the risk of biasing the data. However, they

also reported that implanted devices caused no increase in what they classified as ‘device-induced behaviour’ (comfort behaviours such as preening, fluffing and stretching, and unrest activities including unquantifiable ‘active’ behaviours), whereas some external devices resulted in an increase in this category. Method of attachment (harness, collar, glue, anchor, implant, breast-mounted or tailmount) had no influence on the strength of effects for nesting productivity, clutch size, nest initiation date, offspring quality, body condition, flying ability, foraging behaviours, energy expenditure or survival rate, but anchored and implanted transmitters had the highest reported rates of device-induced mortality (Barron et al., 2010).

In our own work on the energetics of a range of species, we have employed both implanted (e.g. Green et al., 2009b; Portugal et al., 2009; Halsey et al., 2010; White et al., 2011) and externally attached devices (e.g. Green et al., 2009a; Halsey et al., 2009; Halsey et al., 2011). Much of this work used the heart rate technique for estimation of energy expenditure over relatively long time scales [see Green (Green, 2011) for a comprehensive review of this technique] and the loggers were internally implanted under anaesthesia. Implantation

might be considered preferable to external attachment for long-term studies because external attachment can increase mortality (e.g. Paton et al., 1991; Saraux et al., 2011), decrease reproductive output (e.g. Paton et al., 1991; Ackerman et al., 2004) and cause increases in the cost of both flight (e.g. Gessaman and Nagy, 1988; Obrecht et al., 1988) and swimming (e.g. Culik and Wilson, 1991; Culik et al., 1993; Schmid et al., 1995). The effect of device implantation on birds has been investigated in a range of studies, most of which have not reported negative effects of the devices. There was no effect of implanting a device on thermoregulation in ducklings *Anas platyrhynchos* (Bakken et al., 1996); no effect on growth or survival for wild turkey *Meleagris gallopavo* pouls (Bowman et al., 2002); no effect on laying dates, clutch sizes or hatching success for female common eiders *Somateria mollissima* (Guillemette et al., 2002); no effect on over-wintering survival rates, arrival date or mass at the beginning of the breeding season for macaroni penguins *Eudyptes chrysophrys* (Green et al., 2004); higher resighting rates 2 years after implantation (80% resighted) for 10 implanted great cormorants *Phalacrocorax carbo* compared with 15 non-implanted control birds marked with metal rings (60% resighted) (Grémillet et al., 2005); no effect on maintenance behaviours, agonistic behaviours, reproductive behaviours, blood values designed to test for infection or implant rejection, or circulating corticosterone levels in chukars *Alectoris chukar* (O'Hearn et al., 2005); no effect on nest initiation dates, clutch size or mean egg volume in Canada geese *Branta canadensis* (Hupp et al., 2006); and no effect on percentage of time spent at sea or the number and duration of overnight trips of 2–5 or 6–26 days in little penguins *Eudyptula minor* (Ritchie et al., 2010). However, implantation can cause birds to abandon their nests (Meyers et al., 1998), and implanted birds have been shown to swim more slowly than non-implanted controls and have significantly reduced energy expenditure during swimming (Culik and Wilson, 1991). Further, there was a significant migration delay for implanted Canada geese during years with unfavourable wind conditions, although there was no difference between implanted and non-implanted birds in years with favourable conditions (Hupp et al., 2006) and implanted little penguins undertook fewer trips of less than 1 day duration than non-implanted birds (Ritchie et al., 2010). These findings, that implantation has little effect on a range of traits, contrast with the conclusion of Barron et al. (Barron et al., 2010) that method of attachment had no influence on the strength of effects for a range of traits (nesting productivity, clutch size, nest initiation date, offspring quality, body condition, flying ability, foraging behaviours, energy expenditure or survival rate), perhaps because implantation was only one of multiple attachment methods considered, and subdivision into multiple

attachment categories reduced power to detect differences in mean effect size among categories.

In the present study, we present a meta-analysis designed to examine the effect of externally attached and implanted devices on a range of traits, including condition, energy expenditure and reproduction, and test for an association between the duration of a deployment and the effect of devices. In contrast to Barron et al. (Barron et al., 2010), we focus explicitly on determining if there is a benefit to using externally attached devices compared with implanted ones, or *vice versa*, and therefore compare only two broad categories of device attachment: implanted or externally attached.

## MATERIALS AND METHODS

Data were compiled from peer-reviewed literature sources identified using searches conducted on Google Scholar (<http://scholar.google.com>) and the ISI Web of Knowledge (<http://apps.isiknowledge.com>). We identified potential studies using combinations of search terms including logger, bilogger, transmitter, radiotransmitter, effect and impact. Having identified a number of studies, we then expanded the search by examining the reference lists of impact studies for additional studies, as well as by examining the studies that cited those that we identified. Studies were included in the data set only if they provided data for groups with and without devices, as well as sample size and an estimate of variance (s.d., s.e.m. or 95% CI). A total of 440 estimates from 55 studies of 49 species were available for birds, so the analysis was restricted to this subset. We then established the direction of detrimental effects by scoring each effect; this was done independently by five of the authors of the present study, and is necessary because for some effects an increase is detrimental (e.g. metabolic rate during flight or swimming), whereas for others a decrease is detrimental (e.g. survival); effects were retained in the data set only if four of the five authors that scored them agreed on the direction of a detrimental effect. This yielded a total of 183 estimates of device impact from 39 studies of 36 species (see supplementary material Table S1). For each measure of effect, Cohen's *d* was calculated as a standardised estimate of effect size (Hedges and Olkin, 1985). Cohen's *d* represents the difference in means between the groups with and without devices, standardised by the pooled standard deviation, and therefore represents the difference between the groups in units of standard deviations. Because plots of the relationship between effect size and sample size were 'funnel'-shaped and showed convergence with increasing sample size (Fig. 1), values of *d* used for the calculation of the mean effect size were weighted by the square root of sample size. This

Table 1. Mean and 95% confidence interval (2.5th, 97.5th percentiles) of the 200 resampled mean effect sizes and correlations between effect size and deployment duration for externally attached and internally implanted devices

	Sample size			Mean effect size	Correlation with deployment duration
	Estimates	Studies	Species		
All data	440	55	49		
Analysed data	185	40	37		
External	131	35	32	-0.36 (-0.48, -0.23)	0.23 (0.09, 0.35)
External (reproduction and survival)	74	19	19	-0.23 (-0.37, -0.10)	0.10 (-0.06, 0.26)
External (metabolic)	23	7	6	-0.65 (-0.98, -0.31)	0.34 (-0.02, 0.79)
External (condition)	34	13	13	-0.58 (-0.86, -0.10)	0.08 (-0.16, 0.26)
External (short)	30	13	13	-0.55 (-0.71, -0.36)	
External (medium)	57	17	16	-0.50 (-0.66, -0.33)	
External (long)	44	8	8	-0.03 (-0.14, 0.07)	
Internal	54	8	8	0.04 (-0.16, 0.30)	0.09 (-0.30, 0.74)
Internal (no outlier)	53	8	8	-0.03 (-0.23, 0.15)	0.19 (-0.25, 0.74)

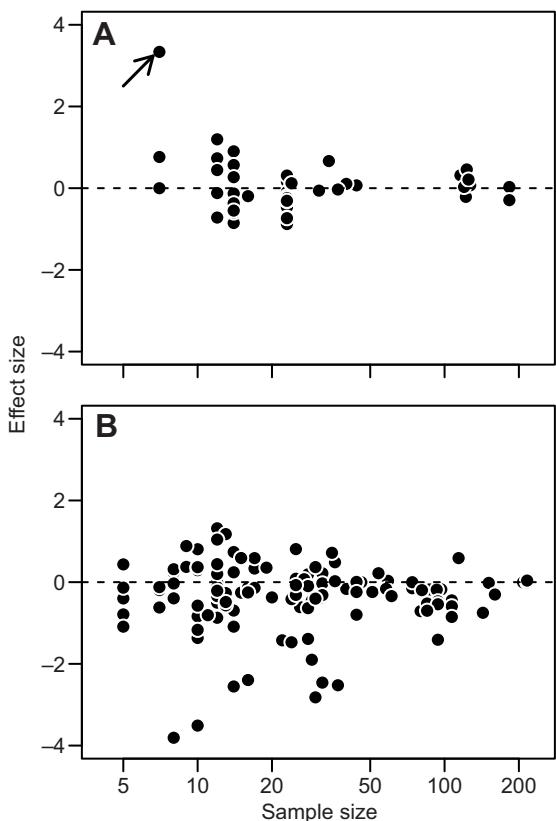


Fig. 1. Relationship between sample size and effect size for (A) internally implanted and (B) externally attached devices. Negative effects are those considered to be detrimental to the bird. Sample size is the pooled number of control and treatment (device-bearing) birds examined. The effect size indicated with an arrow was excluded from some analyses because of an unbalanced design (two implanted individuals and five non-implanted individuals).

was accomplished by multiplying each value of  $d$  by the accompanying weight, summing these values for each resample, and then dividing by the summed weights for the resample. The sign of  $d$  was set so that detrimental effects on traits were scored as negative. For example, an increase in energy expenditure during swimming or flying was coded as negative and a decrease was coded as positive; a decrease in body mass was coded as negative, as was a decrease in survival or reproductive output. Based on the information provided in the studies from which effect sizes were sourced, we also estimated the mean duration that an individual in each study bore a device; the duration of device deployment was coded as 365 days for those studies that spanned multiple years. See supplementary material Table S1 for a full list of all data, including the traits considered and the direction considered to be detrimental in the present study.

Effect sizes for externally attached devices were subdivided into broad categories according to the trait considered (body condition, reproduction, survival and metabolism; there were too few unique studies to subdivide the effect sizes for internally implanted devices) (Table 1). To minimize the bias that might arise from including multiple non-independent effect sizes from a single study, we adopted a re-sampling methodology that randomly chose (with uniform probability) only one effect size per category from each study, following Blackburn et al. (Blackburn et al., 2009). For each resample, we then calculated the mean effect size for each category,

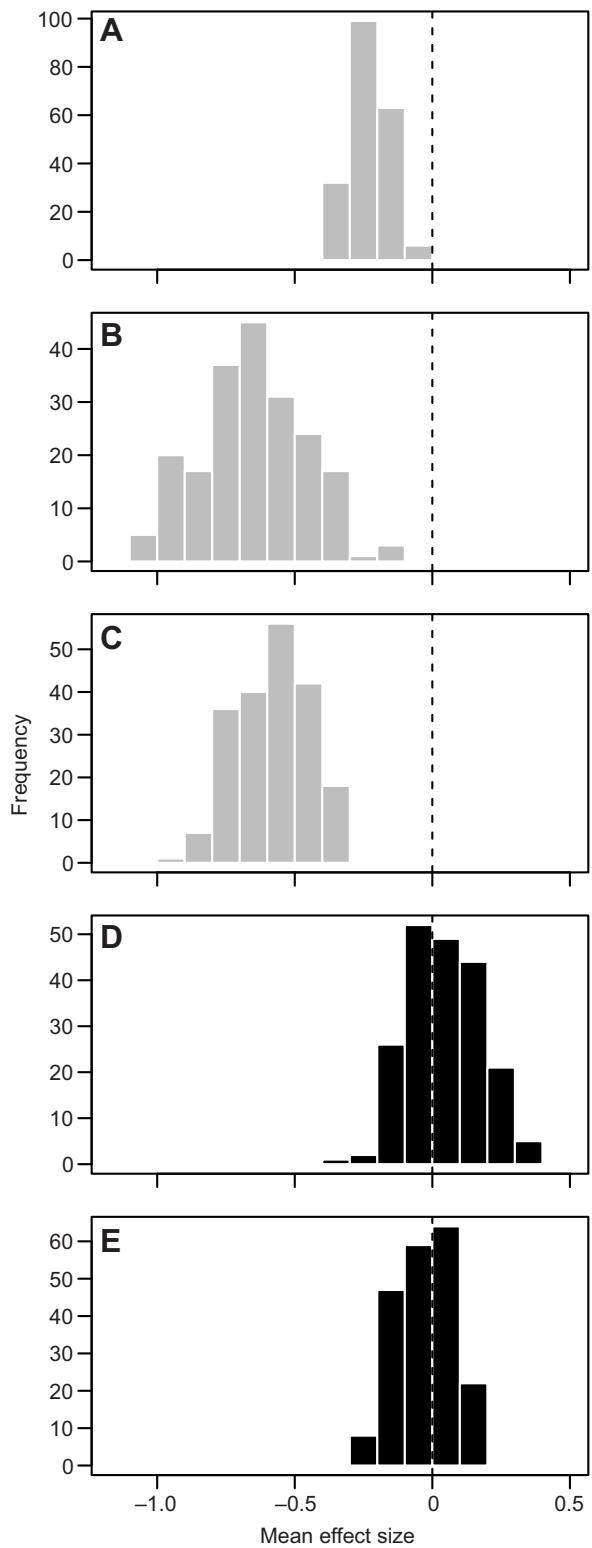


Fig. 2. Frequency distributions of 200 resampled mean effect sizes for (A–C) externally attached and (D,E) internally implanted devices. Mean effect sizes for internal loggers are shown with and without a study that included an  $N$  of 2 for implanted individuals (D and E, respectively; the excluded value is indicated with an arrow in Fig. 1A). Effects for externally attached devices are sub-divided into traits related to reproduction and survival (A), metabolism (B) and condition (C). Sufficient data were not available to subdivide traits for internally implanted devices. Vertical dashed lines in all panels correspond to a mean effect size of zero.

weighted by the square root of sample size. This resampling procedure was repeated a total of 200 times, and the distribution of mean effect sizes was examined for overlap with the null expectation of a mean effect size of zero. To determine whether effect sizes changed with the duration of deployment, we calculated for each resample the correlation coefficient (weighted by the square root of sample size) for the association between effect size and the duration of deployment, which was square root transformed to reduce skew in the distribution of deployment durations. We then arbitrarily subdivided the data for external devices into short-term ( $\leq 21$  days), medium-term (21–100 days) and long-term ( $> 100$  days) deployments, and calculated mean effect size for each category.

A mean effect or weighted correlation was considered significantly different from zero if the 2.5th and 97.5th percentiles of the distribution of resampled effect sizes or correlation coefficients excluded zero. All calculations and analyses were conducted using R v2.15.0 (R Development Core Team, 2012).

## RESULTS AND DISCUSSION

Mean effect sizes for externally attached devices and traits related to body condition, metabolism, reproduction and survival were always negative (Fig. 2A–C) and significantly lower than zero (Table 1), indicating that external attachment of devices was, on average, detrimental.

The distribution of mean effect sizes for internally implanted devices across all traits was not significantly different from zero (Fig. 2D), and continued to be not significantly different from zero following exclusion of a large positive effect of implantation from a study that included only two implanted individuals but a larger number of non-implanted individuals (Culik and Wilson, 1991), and was therefore not adequately standardised by our weighting procedure (i.e. an outlier) (Fig. 2E, Table 1). These findings do not indicate that internal deployment never has a negative effect, or that external attachment always has a negative effect, but instead indicate that the effect of device implantation is consistently neither positive nor negative and on average it is less likely to have a negative effect than external deployment.

This finding that externally attached devices show consistently negative effects whereas internally implanted devices do not contrasts that of Barron et al. (Barron et al., 2010), who found that method of attachment (harness, collar, glue, anchor, implant, breast-mounted and tailmount) had no influence on the strength of effects for a suite of traits (nesting productivity, clutch size, nest initiation date, offspring quality, body condition, flying ability, foraging behaviours, energy expenditure and survival rate). The difference between the conclusions of these studies presumably arises because Barron et al. (Barron et al., 2010) sought to partition variance in effect size among a range of attachment methods, whereas our study sought only to compare internal implantation and external attachment. Based on the clear difference in the distribution of mean effect sizes for implanted and external devices demonstrated in the present study (Fig. 2), we conclude that, on average, implanted devices can be used to obtain reliable data for birds whereas external devices have a consistently detrimental effect. This is an important distinction from the meta-analysis of the effect of transmitters on birds by Barron et al. (Barron et al., 2010). They reported an overall effect of transmitters and other devices, with relatively few differences due to method of attachment.

A surprising outcome of the present study is the finding that although the overall effect of externally attached devices is negative (Table 1), there is a significant positive association between effect size and deployment duration, such that the magnitude of the

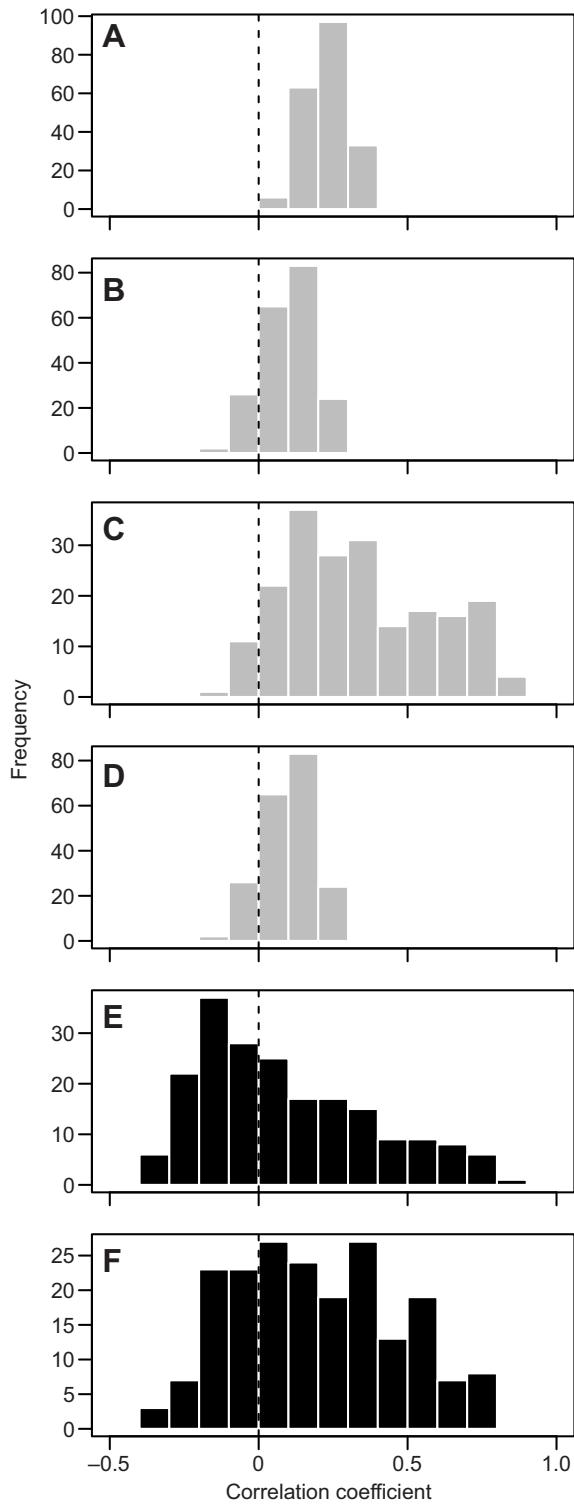


Fig. 3. Frequency distributions of 200 resampled correlation coefficients for the relationship between effect size and the square root of deployment duration for the effect of (A–D) externally attached and (E,F) internally implanted devices. Associations for internal loggers are shown with and without a study that included an  $N$  of 2 for implanted individuals (E and F, respectively; the excluded value is indicated with an arrow in Fig. 1A). Associations for externally attached devices are for all data (A) or data subdivided into traits related to reproduction and survival (B), metabolism (C) or condition (D). Sufficient data were not available to subdivide traits for internally implanted devices. Vertical dashed lines in all panels correspond to a correlation coefficient of zero.

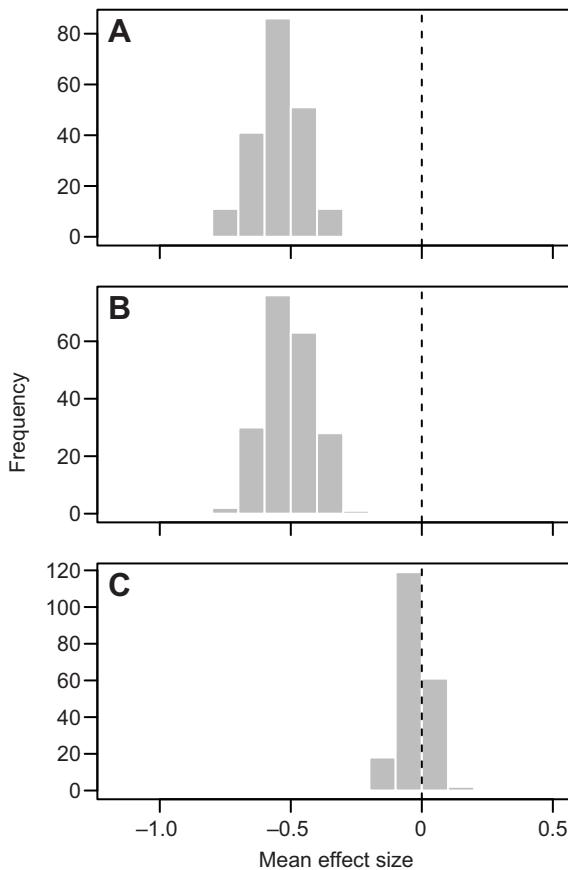


Fig. 4. Frequency distributions of 200 resampled mean effect sizes for externally attached devices. Mean effect sizes are shown for deployments of (A)  $\leq 21$  days, (B) 21–100 days and (C)  $> 100$  days. Vertical dashed lines in all panels correspond to a mean effect size of zero.

negative effect of externally attached devices decreases with the duration of device deployment (Fig. 3A). The association is also positive, but non-significant, if the data for external devices are subdivided into traits related to reproduction and survival, metabolism and condition (Fig. 3B–D, Table 1), though power to detect correlations is limited in these subdivisions. The association between effect size and deployment duration is less positive and also non-significant for internal devices (Fig. 3E,F), though again power is low. When the data for externally attached devices are pooled for all traits, and arbitrarily subdivided into short-term ( $\leq 21$  days), medium-term (21–100 days) and long-term ( $> 100$  days) deployments, the mean effect sizes are negative and significantly different from zero for short- and medium-term deployments, but not for long-term deployments (Fig. 4, Table 1). Given that the magnitude of the negative effect of externally attached devices decreases over time, we therefore suggest that future studies employ devices that can be borne for long periods, and, wherever possible, deploy devices in advance of the time period of interest.

While our findings tend to support the use of device implantation where possible, this is clearly not possible in every application. For example it would not be possible to record light levels or swim speed using a turbine from the inside of a bird's body cavity. Furthermore, reported rates of device-induced mortality are higher for implanted than externally attached devices (Barron et al., 2010). However, our conclusion is that external devices do not represent

a clear solution to the problem of mortality associated with surgical implantation of devices, because they have a consistent negative effect on survival (Fig. 2D). The benefits accruing from data obtained using implanted devices must thus be balanced against the risk of mortality associated with the anaesthesia and surgery required for implantation. In the same way, the ease of external deployment and reduction of this risk must be balanced against the knowledge that data from external deployments are highly likely to be influenced in some way by the presence of the data logger.

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Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Ptychoramphus aleuticus</i>	chick growth rate	External	Reproductive	1.95	1.56	27	3.37	2.19	17	g/day	25	-	-0.80	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	chick wing growth rate	External	Reproductive	2.46	0.69	47	2.85	0.29	33	mm/d	25	-	-0.71	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	Fledging success	External	Reproductive	61.12	45.22	75	89.99	30.14	68	%	30	-	-0.75	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	Pairs fledging second chick	External	Reproductive	4.43	20.75	46	18.16	37.12	61	%	114	-	-0.44	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	Pairs hatching second egg	External	Reproductive	4.47	19.16	46	24.70	42.71	61	%	84	-	-0.59	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	Pairs initiating second nest	External	Reproductive	6.29	23.64	46	39.31	47.62	61	%	45	-	-0.85	(Ackerman et al., 2004)
<i>Ptychoramphus aleuticus</i>	Peak fledging mass	External	Reproductive	118.90	24.75	50	148.30	15.92	44	g	37	-	-1.41	(Ackerman et al., 2004)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 10°C	Internal	Metabolic	1.38	0.18	6	1.35	0.20	6	W	1	+	-0.12	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 10°C	External	Metabolic	1.43	0.12	6	1.35	0.20	6	W	1	+	-0.50	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 15°C	Internal	Metabolic	1.29	0.13	6	1.21	0.11	6	W	1	+	-0.68	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 15°C	External	Metabolic	1.31	0.14	6	1.21	0.11	6	W	1	+	-0.87	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 20°C	Internal	Metabolic	1.14	0.09	6	1.20	0.09	6	W	1	+	0.73	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 20°C	External	Metabolic	1.10	0.07	6	1.20	0.09	6	W	1	+	1.32	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 25°C	Internal	Metabolic	0.90	0.10	6	0.99	0.06	6	W	1	+	1.20	(Bakken et al., 1996)
<i>Anas platyrhynchos</i>	Active phase RMR @ 1m/s wind, 25°C	External	Metabolic	0.97	0.14	6	0.99	0.06	6	W	1	+	0.20	(Bakken et al., 1996)
<i>Zenaida macroura</i>	% weight change	Internal	Condition	-2.98	7.86	13	3.36	7.15	10	%	21	-	-0.88	(Berdeen and Otis, 2006)
<i>Lagopus l. scoticus</i>	Daily activity	External	Behaviour	93.00	47.43	10	114.00	47.43	10	counts	18			(Boag, 1972)
<i>Lagopus l. scoticus</i>	Food intake	External	Behaviour	68.30	20.87	10	66.80	3.79	10	g	18			(Boag, 1972)
<i>Meleagris gallopavo</i>	Mass at end of deployment	External	Condition	922.00	147.59	11	904.00	9.56	21	g	37	-	0.22	(Bowman et al., 2002)
<i>Meleagris gallopavo</i>	Mass at end of deployment	Internal	Condition	889.00	466.44	10	904.00	9.56	21	g	37	-	-0.06	(Bowman et al., 2002)
<i>Lagopus mutus</i>	Survival	External	Reproductive	0.50	8.53	16	0.75	8.53	16	?	30	-	-0.03	(Cotter and Gratto, 1995)
<i>Pygoscelis antarcticus</i>	Foraging trip duration	External	Foraging	14.40	9.20	14	9.30	6.00	31	h	2			(Croll et al., 1991)
<i>Pygoscelis antarcticus</i>	Foraging trip duration	External	Foraging	11.20	7.20	8	9.30	6.00	31	h	2			(Croll et al., 1991)
<i>Pygoscelis antarctica</i>	Early Brooding Foraging Trip Duration	External	Behaviour	14.70	4.70	16	14.60	6.00	16	h	31			(Croll et al., 1996)
<i>Pygoscelis antarctica</i>	Early Brooding Nest Visit Duration	External	Behaviour	20.80	6.30	16	22.00	6.60	16	h	31			(Croll et al., 1996)
<i>Pygoscelis antarctica</i>	Late Brooding Foaging Trip Duration	External	Behaviour	7.90	1.70	6	7.60	1.10	5	h	31			(Croll et al., 1996)
<i>Pygoscelis antarctica</i>	Late Brooding Nest Visit Duration	External	Behaviour	1.30	1.90	5	14.30	5.70	5	h	31			(Croll et al., 1996)
<i>Pygoscelis antarctica</i>	Mid Brooding Foraging Trip Duration	External	Behaviour	11.50	7.00	10	9.10	2.70	14	h	31			(Croll et al., 1996)
<i>Pygoscelis antarctica</i>	Mid Brooding Nest Visit Duration	External	Behaviour	12.30	4.50	11	17.00	5.50	13	h	31			(Croll et al., 1996)
<i>Pygoscelis adeliae</i>	Jumping	Internal	Behaviour	5.60	19.85	2	18.50	28.00	5	s	41			(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Jumping	External	Behaviour	15.80	21.26	5	18.50	28.00	5	s	41			(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Unrest	Internal	Behaviour	14.10	23.69	2	9.10	22.40	5	s	41			(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Unrest	External	Behaviour	32.80	70.08	5	9.10	22.40	5	s	41			(Culik and Wilson, 1991)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		(d)	deleterious		
<i>Pygoscelis adeliae</i>	Swimming Speed	Internal	Metabolic	1.80	0.43	2	1.80	0.33	5	m/s	41	-	0.00	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Swimming Speed	External	Metabolic	2.05	0.36	5	1.80	0.33	5	m/s	41	-	0.81	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Cost of Transport	Internal	Metabolic	7.00	2.43	2	9.00	3.24	5	J/kg/m	41	+	0.76	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Cost of Transport	External	Metabolic	11.30	2.91	5	9.00	3.24	5	J/kg/m	41	+	-0.83	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Resting Energy Expenditure	Internal	Metabolic	5.05	0.12	2	8.40	1.33	5	W/kg	41	+	3.34	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Resting Energy Expenditure	External	Metabolic	10.40	1.90	5	8.40	1.33	5	W/kg	41	+	-1.36	(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Power input	Internal	Metabolic	12.70	5.47	2	15.80	5.18	5	W/kg	41			(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Power input	External	Metabolic	22.50	5.82	5	15.80	5.18	5	W/kg	41			(Culik and Wilson, 1991)
<i>Pygoscelis adeliae</i>	Time away from Nest	External	Reproductive	76.00	6.80	4	53.90	6.60	4	h	41	+	-3.81	(Culik and Wilson, 1992)
<i>Pygoscelis adeliae</i>	Field metabolic rate	External	Metabolic	14.80	6.20	4	16.10	3.00	4	kJ/day	41			(Culik and Wilson, 1992)
<i>Pygoscelis adeliae</i>	Swim speed	External	Metabolic	1.57	0.54	6	1.70	0.43	6	m/s	2	-	-0.29	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 1.2 m/s	External	Metabolic	10.80	5.72	6	9.40	2.62	6	J/kg/m	2	+	-0.34	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 1.4 m/s	External	Metabolic	9.79	5.63	6	8.99	3.79	6	J/kg/m	2	+	-0.18	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 1.6 m/s	External	Metabolic	9.37	4.19	6	8.58	2.86	6	J/kg/m	2	+	-0.24	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 1.8 m/s	External	Metabolic	9.29	4.09	6	9.26	4.37	6	J/kg/m	2	+	-0.01	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 2.0 m/s	External	Metabolic	11.15	4.82	6	9.85	3.56	6	J/kg/m	2	+	-0.34	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 2.2 m/s	External	Metabolic	10.54	4.31	6	9.82	2.86	6	J/kg/m	2	+	-0.22	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Cost of transport, 2.4 m/s	External	Metabolic	10.88	2.27	6	10.09	2.81	6	J/kg/m	2	+	-0.34	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Simming MR	External	Metabolic	17.00	8.77	6	16.10	7.31	6	W/kg	2	+	-0.12	(Culik et al., 1994)
<i>Pygoscelis adeliae</i>	Foraging trip duration, F, 2000	External	Foraging	25.90	9.07	17	19.60	4.33	13	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, F, 2001	External	Foraging	36.20	9.52	7	41.00	14.70	9	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, F, 2002	External	Foraging	55.10	15.26	11	40.40	11.22	14	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, F, 2003	External	Foraging	60.30	10.40	4	51.50	13.34	13	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, M, 2000	External	Foraging	20.30	4.12	21	18.20	3.61	13	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, M, 2001	External	Foraging	27.00	1.59	7	32.40	15.68	6	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, M, 2002	External	Foraging	41.70	14.40	16	35.50	10.46	13	h	365			(Dugger et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration, M, 2003	External	Foraging	36.70	11.40	5	36.60	10.61	18	h	365			(Dugger et al., 2006)
<i>Histrionicus histrionicus</i>	Recapture rate	External	Reproductive	21.60	40.80	185	21.70	41.24	23	%	182	-	0.00	(Esler et al., 2000)
<i>Eudyptula minor</i>	Mass loss December	External	Condition	3.60	4.90	7	0.96	3.12	7	%/day	6	+	-0.69	(Gales et al., 1990)
<i>Eudyptula minor</i>	Mass loss September	External	Condition	1.70	6.80	7	0.30	4.00	6	%/day	6	+	-0.27	(Gales et al., 1990)
<i>Eudyptula minor</i>	CO2 production rate	External	Metabolic	2.21	0.18	7	2.74	0.21	4	mL/g/day	6			(Gales et al., 1990)
<i>Eudyptula minor</i>	Field metabolic rate	External	Metabolic	1348.80	111.60	6	1670.50	130.10	4	kJ/kg/day	6			(Gales et al., 1990)
<i>Eudyptula minor</i>	Water Influx rate December	External	Metabolic	295.00	86.80	7	473.60	79.30	7	ml/kg/day	6			(Gales et al., 1990)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d	
<i>Eudyptula minor</i>	Water Influx rate September	External	Metabolic	159.90	36.80	7	306.60	47.00	6	ml/kg/day	6		(Gales et al., 1990)
<i>Columba livia</i>	Flight metabolic rate	External	Metabolic	222.13	34.48	8	157.60	21.70	8	kJ/h	1	+	-2.39 (Gessaman and Nagy, 1988)
<i>Columba spp</i>	Flight metabolic rate	External	Metabolic	14.60	4.30	4	14.00	2.50	3	mlCo2/g/h	1	+	-0.19 (Gessaman et al., 1991)
<i>Columba spp</i>	Flight metabolic rate	External	Metabolic	18.40	3.90	3	15.50	6.40	4	mlCo2/g/h	1	+	-0.62 (Gessaman et al., 1991)
<i>Porphyrio mantelli</i>	Behaviour: feed	External	Behaviour	75.57	9.08	5	75.36	5.98	6	%	6		(Godfrey and Bryant, 2003)
<i>Porphyrio mantelli</i>	Behaviour: preen	External	Behaviour	1.72	2.01	5	0.42	0.59	6	%	6		(Godfrey and Bryant, 2003)
<i>Porphyrio mantelli</i>	Behaviour: run	External	Behaviour	0.15	0.18	5	0.06	0.15	6	%	6		(Godfrey and Bryant, 2003)
<i>Porphyrio mantelli</i>	Behaviour: stand	External	Behaviour	8.45	4.41	5	10.34	7.10	6	%	6		(Godfrey and Bryant, 2003)
<i>Porphyrio mantelli</i>	Behaviour: walk	External	Behaviour	12.12	4.67	5	13.82	4.41	6	%	6		(Godfrey and Bryant, 2003)
<i>Porphyrio mantelli</i>	Field metabolic rate	External	Metabolic	1269.00	374.77	6	1179.00	311.09	6	kJ/day	6		(Godfrey and Bryant, 2003)
<i>Eudyptes chrysolophus</i>	Mass after foraging trip (female)	Internal	Condition	5.74	1.92	23	5.63	1.24	21	kg	247	-	0.07 (Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Mass after foraging trip (male)	Internal	Condition	6.34	1.70	21	6.18	1.35	19	kg	247	-	0.11 (Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Mass after migration (Female)	Internal	Condition	5.26	0.29	17	5.06	0.33	17	kg	247	-	0.67 (Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Mass after migration (Male)	Internal	Condition	5.26	0.37	17	5.29	1.30	20	kg	247	-	-0.03 (Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Foraging trip duration	Internal	Foraging	14.61	5.42	39	14.99	4.04	39	d	247		(Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Foraging trip duration	Internal	Foraging	13.60	2.28	19	14.13	1.92	19	d	247		(Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Fledging mass of chick (01/02)	Internal	Reproductive	3.47	0.32	11	3.36	0.35	105	kg	247	-	0.32 (Green et al., 2004)
<i>Eudyptes chrysolophus</i>	Fledging mass of chick (02/03)	Internal	Reproductive	3.52	0.33	18	3.36	0.35	105	kg	247	-	0.46 (Green et al., 2004)
<i>Somateria mollissima</i>	Clutch size	Internal	Reproductive	5.09	0.65	9	5.51	1.10	14	eggs	365	-	-0.46 (Guillemette et al., 2002)
<i>Somateria mollissima</i>	Hatching success	Internal	Reproductive	3.88	3.49	9	3.59	3.99	14	chicks	365	-	0.08 (Guillemette et al., 2002)
<i>Somateria mollissima</i>	Laying date	Internal	Reproductive	6.08	6.34	9	8.04	7.25	14		365	+	0.30 (Guillemette et al., 2002)
<i>Anas acuta</i>	Clutch size	External	Reproductive	6.86	7.20	36	7.08	13.94	115		50	-	-0.02 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Egg volume	External	Reproductive	39.20	2.49	23	39.60	2.24	74		50	-	-0.18 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Hatching success	External	Reproductive	6.50	1.78	15	6.50	1.73	31	chicks	50	-	0.00 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Laying date (94)	External	Reproductive	135.00	15.86	13	132.00	17.20	74		50	+	-0.18 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Laying date (95)	External	Reproductive	137.00	14.00	25	134.00	17.32	68		50	+	-0.18 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Laying date (96)	External	Reproductive	132.00	16.63	12	142.00	17.17	102		50	+	0.59 (Guyn and Clark, 1999)
<i>Anas acuta</i>	Laying date (first clutch)	External	Reproductive	125.00	8.76	30	122.00	10.26	130		50	+	-0.30 (Guyn and Clark, 1999)
<i>Tympanuchus pallidicinctus</i>	Survival (summer)	External	Reproductive	0.67	0.60	72	0.67	0.90	144		91	-	0.00 (Hagen et al., 2006)
<i>Tympanuchus pallidicinctus</i>	Survival (winter)	External	Reproductive	0.65	0.55	72	0.62	1.02	144		91	-	0.04 (Hagen et al., 2006)
<i>Uria aalge</i>	Behaviour: preen	External	Behaviour	11.32	5.29	13	9.64	4.54	13		24		(Hamel et al., 2004)
<i>Uria aalge</i>	Behaviour: sit/sleep	External	Behaviour	65.41	11.34	13	61.22	15.87	13		24		(Hamel et al., 2004)
<i>Uria aalge</i>	Behaviour: Stand	External	Behaviour	22.22	12.09	13	27.25	15.87	13		24		(Hamel et al., 2004)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Aix sponsa</i>	Early incubation mass	External	Condition	553.70	44.15	15	576.50	44.35	13	g	60.5	-	-0.53	(Hepp et al., 2002)
<i>Aix sponsa</i>	Late incubation mass	External	Condition	544.00	31.06	14	566.80	46.42	12	g	70.5	-	-0.61	(Hepp et al., 2002)
<i>Aix sponsa</i>	Incubation constancy	External	Reproductive	81.00	5.42	15	81.60	5.41	13	%	81.5	-	-0.11	(Hepp et al., 2002)
<i>Aix sponsa</i>	incubation period	External	Reproductive	31.50	1.39	12	30.80	2.08	12	d	81.5	+	-0.41	(Hepp et al., 2002)
<i>Aix sponsa</i>	Recess frequency	External	Reproductive	2.10	0.39	15	2.10	0.36	13		81.5			(Hepp et al., 2002)
<i>Canachites canadensis</i>	Daily movement distance (early spring)	External	Foraging	113.00	77.00	25	139.00	97.00	19	m	67			(Herzog, 1979)
<i>Canachites canadensis</i>	Daily movement distance (late spring)	External	Foraging	140.00	85.00	25	135.00	76.00	11	m	67			(Herzog, 1979)
<i>Canachites canadensis</i>	Daily movement distance (summer)	External	Foraging	123.00	72.00	25	152.00	110.00	10	m	67			(Herzog, 1979)
<i>Canachites canadensis</i>	Daily movement distance (winter)	External	Foraging	49.00	45.00	25	44.00	36.00	12	m	67			(Herzog, 1979)
<i>Turdus merula</i>	Brood weight	External	Reproductive	63.50	2.87	6	63.20	5.26	19	g	122	-	0.06	(Hill et al., 1999)
<i>Turdus merula</i>	Brood wing length	External	Reproductive	65.20	2.82	6	64.80	4.82	19	mm	122	-	0.09	(Hill et al., 1999)
<i>Turdus merula</i>	Clutch size	External	Reproductive	3.69	0.60	16	3.79	0.64	24		122	-	-0.16	(Hill et al., 1999)
<i>Turdus merula</i>	Condition index	External	Reproductive	0.97	0.04	6	0.98	0.07	19		122	-	-0.06	(Hill et al., 1999)
<i>Turdus merula</i>	Daily survival for nests	External	Reproductive	0.95	0.06	20	0.96	0.04	54		122	-	-0.15	(Hill et al., 1999)
<i>Turdus merula</i>	Daily survival to fledge	External	Reproductive	0.95	0.07	14	0.97	0.06	37		122	-	-0.24	(Hill et al., 1999)
<i>Turdus merula</i>	Daily survival to hatch	External	Reproductive	0.96	0.08	20	0.96	0.07	54		122	-	0.00	(Hill et al., 1999)
<i>Turdus merula</i>	Egg volume	External	Reproductive	7.09	0.41	10	7.13	0.46	15	mlCo2/g/h	122	-	-0.09	(Hill et al., 1999)
<i>Turdus merula</i>	Parental visits to nest	External	Reproductive	6.54	1.89	3	6.70	1.32	4	per h	122	-	-0.12	(Hill et al., 1999)
<i>Turdus merula</i>	Prop. Time off nest	External	Reproductive	0.59	0.12	3	0.72	0.04	4		122			(Hill et al., 1999)
<i>Turdus merula</i>	Season adj. nest survival	External	Reproductive	0.95	0.06	20	0.95	0.06	39		122	-	0.03	(Hill et al., 1999)
<i>Turdus merula</i>	Weight difference	External	Reproductive	6.16	2.93	6	5.73	2.69	19		122			(Hill et al., 1999)
<i>Dendragapus obscurus</i>	Brood size at hatching	External	Reproductive	4.40	5.42	15	4.00	4.11	10	chicks	291	-	0.08	(Hines and Zwickerl, 1985)
<i>Dendragapus obscurus</i>	Clutch size	External	Reproductive	5.00	4.12	21	4.90	4.65	15	eggs	291	-	0.02	(Hines and Zwickerl, 1985)
<i>Falco naumanni</i>	Chick-feeds/h	External	Reproductive	0.89	0.22	3	0.95	0.13	2		49	-	-0.40	(Hiraldo et al., 1994)
<i>Falco naumanni</i>	Clutch size	External	Reproductive	4.60	0.50	7	4.20	0.90	29		49	-	0.49	(Hiraldo et al., 1994)
<i>Falco naumanni</i>	Copulation period	External	Reproductive	83.70	9.50	4	79.30	5.20	6	d	49			(Hiraldo et al., 1994)
<i>Falco naumanni</i>	Copulations per season	External	Reproductive	235.20	32.70	4	361.50	47.40	6		49			(Hiraldo et al., 1994)
<i>Falco naumanni</i>	Fledged young	External	Reproductive	1.50	1.30	10	1.70	1.00	71		49	-	-0.19	(Hiraldo et al., 1994)
<i>Falco naumanni</i>	Mate-feeds/h	External	Reproductive	0.44	0.13	2	0.49	0.04	3		49	-	-0.79	(Hiraldo et al., 1994)
<i>Melanerpes formicivorus</i>	Aggression	External	Behaviour	0.02	0.01	5	0.01	0.01	5					(Hooge, 1991)
<i>Melanerpes formicivorus</i>	Aggression	External	Behaviour	0.01	0.01	5	0.01	0.01	5					(Hooge, 1991)
<i>Melanerpes formicivorus</i>	Defense	External	Behaviour	0.01	0.01	5	0.02	0.01	5					(Hooge, 1991)
<i>Melanerpes formicivorus</i>	Defense	External	Behaviour	0.01	0.01	5	0.02	0.01	5					(Hooge, 1991)

Species	Measurement	Device	Subset	Logger		Control		Duration	Direction		Reference			
				Mean	s.d.	n	Mean		n	Units	(d)			
<i>Melanerpes formicivorus</i>	Eat	External	Behaviour	0.04	0.02	5	0.04	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Eat	External	Behaviour	0.07	0.04	5	0.04	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Fly	External	Behaviour	0.08	0.03	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Fly	External	Behaviour	0.05	0.03	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Fly catch	External	Behaviour	0.03	0.02	5	0.03	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Fly catch	External	Behaviour	0.02	0.01	5	0.03	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Glean	External	Behaviour	0.08	0.05	5	0.08	0.03	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Glean	External	Behaviour	0.10	0.05	5	0.08	0.03	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Move	External	Behaviour	0.02	0.02	5	0.01	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Move	External	Behaviour	0.00	0.01	5	0.01	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Preen	External	Behaviour	0.08	0.03	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Preen	External	Behaviour	0.13	0.04	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Sit	External	Behaviour	0.09	0.03	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Sit	External	Behaviour	0.16	0.04	5	0.08	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Vigilance	External	Behaviour	0.60	0.20	5	0.62	0.24	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Vigilance	External	Behaviour	0.68	0.22	5	0.62	0.24	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	waka	External	Behaviour	0.01	0.02	5	0.01	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	waka	External	Behaviour	0.01	0.01	5	0.01	0.01	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Work stores	External	Behaviour	0.06	0.04	5	0.05	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Work stores	External	Behaviour	0.02	0.01	5	0.05	0.02	5			(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Daily movement distance	External	Foraging	47.30	19.74	5	41.98	16.15	5	m		(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Daily movement distance	External	Foraging	27.84	13.75	5	41.98	16.15	5	m		(Hooge, 1991)		
<i>Melanerpes formicivorus</i>	Daily movement distance	External	Foraging	21.22	17.54	5	41.98	16.15	5	m		(Hooge, 1991)		
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	10.70	1.22	6	10.40	1.41	8		106	-	0.24	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	10.10	1.06	7	10.40	1.41	8		106	-	-0.26	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	10.20	1.70	8	10.40	1.41	8		106	-	-0.14	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	10.70	1.21	3	10.40	0.79	7		106	-	0.37	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	10.00	0.73	6	10.40	0.79	7		106	-	-0.57	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	9.60	0.79	7	10.40	0.79	7		106	-	-1.09	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	9.50	2.12	2	9.30	0.49	6		106	-	0.24	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	9.50	1.47	6	9.30	0.49	6		106	-	0.20	(Houston and Greenwood, 1993)
<i>Anas platyrhynchos</i>	Clutch size	External	Reproductive	9.00	0.79	7	9.30	0.49	6		106	-	-0.48	(Houston and Greenwood, 1993)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		Units	(d)		
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	17.00	8.57	6	19.00	5.94	8	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	19.60	7.67	7	19.00	5.94	8	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	17.90	5.66	8	19.00	5.94	8	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	6.30	1.04	3	7.10	1.06	7	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	7.30	1.71	6	7.10	1.06	7	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	7.30	0.53	7	7.10	1.06	7	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	7.00	1.41	2	9.70	4.65	6	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	8.00	1.96	6	9.70	4.65	6	d	106		(Houston and Greenwood, 1993)	
<i>Anas platyrhynchos</i>	Inter-clutch interval	External	Reproductive	8.40	3.44	7	9.70	4.65	6	d	106		(Houston and Greenwood, 1993)	
<i>Eudyptes schlegeli</i>	Body composition	External	Condition	2.90	2.30	5	4.50	2.10	6	%	25	-	-0.81	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Body composition	External	Condition	5.70	3.60	5	4.20	3.80	7	% difference	25	-	0.44	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Body composition	External	Condition	-4.90	3.90	7	4.20	3.80	7	% difference	25	-	-2.55	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Foraging trip duration	External	Behaviour	24.90	2.50	7	22.90	1.70	16	d	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Foraging trip duration	External	Behaviour	15.50	2.80	8	15.90	2.60	9	d	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Foraging trip duration	External	Behaviour	20.10	4.30	8	15.90	2.60	9	d	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Foraging trip duration	External	Behaviour	3.30	1.80	10	3.90	2.40	10	d	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Foraging trip duration	External	Behaviour	5.00	2.00	3	3.90	2.40	10	d	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Mass gained	External	Condition	32.40	11.90	7	46.00	9.10	15	%	25	-	-1.42	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Mass gained	External	Condition	36.20	8.00	8	33.30	10.20	9	% difference	25	-	0.33	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Mass gained	External	Condition	31.90	11.20	8	33.30	10.20	9	% difference	25	-	-0.14	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Mass gained	External	Condition	8.00	9.00	10	10.60	5.20	10	% difference	25	-	-0.37	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Mass gained	External	Condition	15.90	3.20	3	10.60	5.20	10	% difference	25	-	1.18	(Hull, 1997)
<i>Eudyptes schlegeli</i>	Water influx	External	Metabolic	148.00	19.80	5	77.40	7.00	6	ml/kg/day	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Water influx	External	Metabolic	194.40	16.70	5	191.40	45.40	7	ml/kg/day	25			(Hull, 1997)
<i>Eudyptes schlegeli</i>	Water influx	External	Metabolic	201.10	28.10	7	191.40	45.40	7	ml/kg/day	25			(Hull, 1997)
<i>Branta canadensis</i>	Clutch size	Internal	Reproductive	4.50	1.44	19	4.80	1.42	103	# eggs	365	-	-0.21	(Hupp et al., 2006)
<i>Branta canadensis</i>	Clutch size	Internal	Reproductive	4.90	1.42	24	4.80	1.42	103	# eggs	365	-	0.07	(Hupp et al., 2006)
<i>Branta canadensis</i>	Julian Date of nest initiation	Internal	Reproductive	124.30	6.68	31	124.50	6.90	152	LSQM	365	+	0.03	(Hupp et al., 2006)
<i>Branta canadensis</i>	Julian Date of nsxt initiation	Internal	Reproductive	126.50	6.68	31	124.50	6.90	152	LSQM	365	+	-0.29	(Hupp et al., 2006)
<i>Branta canadensis</i>	Mean Egg volume	Internal	Reproductive	107.90	6.10	19	107.70	6.73	101	cm^3	365	-	0.03	(Hupp et al., 2006)
<i>Branta canadensis</i>	Mean Egg volume	Internal	Reproductive	109.10	6.37	24	107.70	6.73	101	cm^3	365	-	0.21	(Hupp et al., 2006)

Species	Measurement	Device	Subset	Logger		Control		Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n	Units	(d)	
<i>Calonectris diomedea</i>	$\delta^{13}\text{C}$ blood	External	Foraging	-18.10	0.14	6	-18.01	0.36	16		365	(Igual et al., 2005)
<i>Calonectris diomedea</i>	$\delta^{13}\text{C}$ feather P1	External	Foraging	-17.43	0.53	9	-17.09	0.90	22		365	(Igual et al., 2005)
<i>Calonectris diomedea</i>	$\delta^{13}\text{C}$ feather S8	External	Foraging	-15.62	1.45	9	-15.32	0.99	22		365	(Igual et al., 2005)
<i>Calonectris diomedea</i>	$\delta^{15}\text{N}$ blood	External	Foraging	11.17	0.22	6	11.32	0.27	16		365	(Igual et al., 2005)
<i>Calonectris diomedea</i>	$\delta^{15}\text{N}$ feather P1	External	Foraging	11.64	0.72	9	11.98	0.92	22		365	(Igual et al., 2005)
<i>Calonectris diomedea</i>	$\delta^{15}\text{N}$ feather S8	External	Foraging	13.91	1.40	9	13.69	1.28	22		365	(Igual et al., 2005)
<i>Rissa tridacyla</i>	Chick-growth rate	External	Reproductive	16.24	2.31	13	16.64	2.55	45	g/d	13	- -0.16 (Irons, 1998)
<i>Phasianus colchicus</i>	Dispersal Distance	External	Behaviour	1.20	2.47	38	1.20	3.00	36	km	49	(Johnson and Berner, 1980)
<i>Gallinago media</i>	Clutch Volume Index	External	Reproductive	186.90	5.69	19	189.60	7.07	10		6	- -0.45 (Kålås et al., 1989)
<i>Gallinago media</i>	Weight of incubating females	External	Reproductive	183.60	5.72	23	179.10	7.70	12	g	15	- 0.72 (Kålås et al., 1989)
<i>Accipiter gentilis</i>	all bird weight change (adults inc)	External	Condition	25.40	23.80	14	21.40	19.10	14	g	13.1	- 0.19 (Kenward, 1978)
<i>Accipiter gentilis</i>	juvenile weight change	External	Condition	22.50	25.40	10	7.10	31.10	7	g	15.3	- 0.59 (Kenward, 1978)
<i>Sterna hirundo</i>	Energy Expenditure	External	Condition	368.00	58.00	5	343.00	37.00	5	kJ/day	2.26	+ -0.57 (Klaassen et al., 1992)
<i>Alectoris chukar</i>	Agonistic	Internal	Behaviour	12.00	3.46	12	9.00	6.93	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Maintenance (excl. preeeing)	Internal	Behaviour	643.00	58.89	12	640.00	62.35	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Maintenance (incl. preening)	Internal	Behaviour	697.00	62.35	12	692.00	65.82	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Pacing	Internal	Behaviour	789.00	58.89	12	796.00	58.89	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Preening	Internal	Behaviour	54.00	3.46	12	52.00	6.93	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Total non-pacing	Internal	Behaviour	711.00	58.89	12	704.00	58.89	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Unobserved	Internal	Behaviour	9.00	6.93	12	5.00	3.46	12	s /25 min	77	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute basophils	Internal	Condition	500.00	200.86	6	339.00	206.48	8		77	+ -0.85 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute basophils	Internal	Condition	165.00	172.03	10	155.00	151.79	13		77	+ -0.07 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute eosinophils	Internal	Condition	0.00	0.00	6	30.00	75.80	8		77	+ 0.56 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute eosinophils	Internal	Condition	16.00	34.79	10	8.50	30.65	13		77	+ -0.24 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute lymphocytes	Internal	Condition	2700.00	1067.98	6	3056.00	537.40	8		77	+ 0.48 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute lymphocytes	Internal	Condition	5483.00	1745.58	10	4222.00	1885.70	13		77	+ -0.72 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute monophils	Internal	Condition	191.67	191.55	6	113.75	90.51	8		77	+ -0.59 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	absolute monophils	Internal	Condition	141.00	141.07	10	93.85	167.66	13		77	+ -0.31 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Absolute neutrophils	Internal	Condition	5570.00	1832.22	6	5382.00	1351.99	8		77	+ -0.13 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Absolute neutrophils	Internal	Condition	4395.00	2188.30	10	3982.00	2015.50	13		77	+ -0.21 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Body fat score	Internal	Condition	1.80	0.55	12	1.80	0.53	11		77	- 0.00 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Body fat score	Internal	Condition	2.20	0.63	10	2.10	0.64	14		77	- 0.16 (O'Hearn et al., 2005)
<i>Alectoris chukar</i>	estimated basophils	Internal	Condition	3.00	2.28	6	4.75	1.95	8		77	+ 0.90 (O'Hearn et al., 2005)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Alectoris chukar</i>	estimated basophils	Internal	Condition	1.70	1.77	10	2.00	2.09	13	77	+	0.16	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated eosinophils	Internal	Condition	0.00	0.00	6	0.25	0.62	8	77	+	0.57	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated eosinophils	Internal	Condition	0.20	0.41	10	0.17	0.25	13	77	+	-0.10	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated lymphocytes	Internal	Condition	37.80	10.39	6	34.75	7.72	8	77	+	-0.37	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated lymphocytes	Internal	Condition	54.40	15.81	10	50.08	17.20	13	77	+	-0.27	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated monophils	Internal	Condition	2.00	2.01	6	1.25	0.93	8	77	+	-0.55	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	estimated monophils	Internal	Condition	1.40	1.26	10	1.10	1.77	13	77	+	-0.20	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	Estimated WBC	Internal	Condition	9.67	2.42	6	9.30	1.77	10	77	+	-0.19	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	Estimated WBC	Internal	Condition	10.00	1.93	10	8.46	2.38	13	77	+	-0.73	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	haematocrit	Internal	Condition	42.70	6.58	10	44.50	4.90	10	77			(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	haematocrit	Internal	Condition	40.80	6.04	10	45.31	7.36	13	77			(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	heterophils/polymphils	Internal	Condition	57.17	7.15	6	59.00	7.44	8	77	+	0.27	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	heterophils/polymphils	Internal	Condition	42.30	14.67	10	46.84	15.86	13	77	+	0.31	(O'Hearn et al., 2005)	
<i>Alectoris chukar</i>	Mass	Internal	Condition	443.96	26.99	12	450.89	32.70	11	g	77	-	-0.24	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Mass	Internal	Condition	549.67	23.53	10	546.80	31.54	14	g	77	-	0.11	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Mass/tarsus	Internal	Condition	8.34	0.45	12	8.50	0.63	11	g/mm	77	-	-0.31	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Mass/tarsus	Internal	Condition	9.55	0.35	10	9.49	0.60	14	g/mm	77	-	0.12	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Egg volume	Internal	Reproductive	21.17	0.54	6	21.78	1.20	6	cm^3	77	-	-0.72	(O'Hearn et al., 2005)
<i>Alectoris chukar</i>	Eggs per female	Internal	Reproductive	35.20	4.16	6	30.00	17.64	6		77	-	0.44	(O'Hearn et al., 2005)
<i>Colinus virginianus</i>	Dried lean	External	Condition	63.10	5.48	47	65.40	4.11	47	g	84			(Osborne et al., 1997)
<i>Colinus virginianus</i>	Dried lean	External	Condition	63.80	4.93	38	65.40	4.11	47	g	84			(Osborne et al., 1997)
<i>Colinus virginianus</i>	Fresh carcass	External	Condition	215.50	20.57	47	224.00	15.77	47	g	84	-	-0.47	(Osborne et al., 1997)
<i>Colinus virginianus</i>	Fresh carcass	External	Condition	215.50	17.26	38	224.00	15.77	47	g	84	-	-0.52	(Osborne et al., 1997)
<i>Colinus virginianus</i>	Lipid	External	Condition	15.30	6.17	47	18.60	6.17	47	g	84	-	-0.54	(Osborne et al., 1997)
<i>Colinus virginianus</i>	Lipid	External	Condition	14.70	4.93	38	18.60	6.17	47	g	84	-	-0.70	(Osborne et al., 1997)
<i>Colinus virginianus</i>	Water	External	Condition	137.20	10.97	47	140.30	8.91	47	g	84			(Osborne et al., 1997)
<i>Colinus virginianus</i>	Water	External	Condition	137.00	9.86	38	140.30	8.91	47	g	84			(Osborne et al., 1997)
<i>Uria lomvia</i>	mass change females	External	Condition	-18.50	11.64	21	3.94	3.80	16	g/day	91	-	-2.52	(Paredes et al., 2005)
<i>Uria lomvia</i>	mass change males	External	Condition	-27.01	11.70	15	-3.98	2.48	15	g/day	91	-	-2.82	(Paredes et al., 2005)
<i>Uria lomvia</i>	chick attendance females	External	Reproductive	8.90	1.57	19	9.90	1.01	13	h	91			(Paredes et al., 2005)
<i>Uria lomvia</i>	chick attendance males	External	Reproductive	12.30	3.44	16	14.50	1.08	13	h	91			(Paredes et al., 2005)
<i>Uria lomvia</i>	duration of chick rearing	External	Reproductive	20.69	2.85	40	21.15	2.53	22	days	91			(Paredes et al., 2005)
<i>Uria lomvia</i>	feeding/day females	External	Reproductive	0.90	0.57	19	2.70	0.97	13		91	-	-2.46	(Paredes et al., 2005)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Uria lomvia</i>	feeding/day males	External	Reproductive	0.90	0.88	16	2.50	0.87	13		-	-1.90	(Paredes et al., 2005)	
<i>Uria lomvia</i>	food provisioning rates	External	Reproductive	2.20	0.65	35	2.46	0.92	26	meals/d	-	-0.34	(Paredes et al., 2005)	
<i>Uria lomvia</i>	foraging trips/day females	External	Reproductive	1.90	0.74	19	4.00	0.97	13				(Paredes et al., 2005)	
<i>Uria lomvia</i>	foraging trips/day males	External	Reproductive	2.00	0.88	16	3.70	1.05	13				(Paredes et al., 2005)	
<i>Uria lomvia</i>	trip duration females	External	Reproductive	1.80	2.09	19	1.40	1.33	13	h			(Paredes et al., 2005)	
<i>Uria lomvia</i>	trip duration males	External	Reproductive	4.60	1.96	16	2.20	1.41	13	h			(Paredes et al., 2005)	
<i>Perdix perdix</i>	Climbing power	External	Metabolic	6.65	2.28	14	9.26	1.42	14	W	1		(Putaala et al., 1997)	
<i>Perdix perdix</i>	Climbing speed	External	Metabolic	1.79	0.71	14	2.52	0.30	14	m/s	1	-	-1.39	(Putaala et al., 1997)
<i>Perdix perdix</i>	Flight speed	External	Metabolic	3.43	0.67	14	3.79	0.49	14	m/s	1	-	-0.64	(Putaala et al., 1997)
<i>Perdix perdix</i>	Takeoff angle	External	Metabolic	31.60	11.22	14	42.30	5.61	14	degrees	1			(Putaala et al., 1997)
<i>Bucephala islandica</i>	Alert	External	Behaviour	15.00	7.60	5	14.50	3.67	6	%	35			(Robert et al., 2006)
<i>Bucephala islandica</i>	Feeding	External	Behaviour	24.60	10.96	5	43.20	7.35	6	%	35			(Robert et al., 2006)
<i>Bucephala islandica</i>	Locomotion	External	Behaviour	10.00	5.14	5	11.30	7.59	6	%	35			(Robert et al., 2006)
<i>Bucephala islandica</i>	Maintenance	External	Behaviour	50.50	13.42	5	31.00	9.55	6	%	35			(Robert et al., 2006)
<i>Bucephala islandica</i>	Preening	External	Behaviour	17.30	11.63	5	10.80	3.92	6	%	35			(Robert et al., 2006)
<i>Bucephala islandica</i>	Resting	External	Behaviour	33.20	17.44	5	20.10	10.53	6	%	35			(Robert et al., 2006)
<i>Pygoscelis adeliae</i>	Foraging trip duration	External	Foraging	35.60	4.80	7	32.90	4.30	7	h	2			(Ropert-Coudert et al., 2007)
<i>Pygoscelis adeliae</i>	Foraging trip duration	External	Foraging	37.50	19.10	7	32.90	4.30	7	h	2			(Ropert-Coudert et al., 2007)
<i>Phalacrocorax carbo</i>	energy required to swim at 1.4-1.8m/s	External	Condition	35.10	10.78	4	31.40	10.82	4	W/kg	1	+	-0.40	(Schmid et al., 1995)
<i>Branta bernicla nigricans</i>	Mass Loss (Females)	External	Condition	4.80	4.70	5	6.30	6.75	3	%	28.5	+	0.32	(Sedinger et al., 1990)
<i>Branta bernicla nigricans</i>	Mass Loss (Males)	External	Condition	3.20	2.60	4	4.60	5.14	5	%	28.5	+	0.37	(Sedinger et al., 1990)
<i>Branta bernicla nigricans</i>	Daily E Expenditure (Females)	External	Metabolic	741.00	111.80	5	738.00	100.46	3	kJ/Kg	28.5	+	-0.03	(Sedinger et al., 1990)
<i>Branta bernicla nigricans</i>	Daily E Expenditure (Males)	External	Metabolic	474.00	74.00	4	540.00	91.68	5	kJ/Kg	28.5	+	0.89	(Sedinger et al., 1990)
<i>Zenaida asiatica</i>	Agonistic Females	External	Behaviour	0.55	1.23	11	0.71	1.01	14	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic Females	Internal	Behaviour	0.70	1.33	10	0.69	1.05	13	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic Females	Internal	Behaviour	0.50	0.54	10	0.50	0.80	12	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic HY	External	Behaviour	2.55	2.42	11	2.50	3.14	14	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic HY	Internal	Behaviour	1.10	1.55	10	1.31	1.48	13	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic HY	Internal	Behaviour	3.30	3.10	10	0.83	1.42	12	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic Males	External	Behaviour	3.09	4.74	11	2.79	7.45	14	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic Males	Internal	Behaviour	1.50	2.91	10	1.31	2.34	13	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Agonistic Males	Internal	Behaviour	1.60	3.13	10	2.67	4.78	12	frequency	21			(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert Females	External	Behaviour	18.18	16.95	11	21.86	13.58	14	frequency	21			(Small et al., 2004)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference
				Mean	s.d.	n	Mean	s.d.	n		Units	(d)	
<i>Zenaida asiatica</i>	Alert Females	Internal	Behaviour	23.50	30.93	10	17.08	8.08	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert Females	Internal	Behaviour	18.70	12.65	10	18.08	9.91	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert HY	External	Behaviour	17.46	8.95	11	21.00	18.11	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert HY	Internal	Behaviour	16.30	16.67	10	14.58	17.49	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert HY	Internal	Behaviour	15.80	10.53	10	10.00	7.48	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert Males	External	Behaviour	18.27	21.49	11	22.86	39.03	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert Males	Internal	Behaviour	12.10	13.63	10	15.92	24.12	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Alert Males	Internal	Behaviour	17.10	21.22	10	18.50	19.81	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Females	External	Behaviour	9.82	8.46	11	11.29	7.07	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Females	Internal	Behaviour	8.10	6.20	10	10.62	5.91	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Females	Internal	Behaviour	8.80	5.15	10	8.17	4.54	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort HY	External	Behaviour	8.27	4.34	11	7.43	5.31	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort HY	Internal	Behaviour	7.60	4.24	10	5.39	4.72	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort HY	Internal	Behaviour	6.00	2.47	10	4.33	3.33	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Males	External	Behaviour	4.64	3.45	11	4.50	5.13	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Males	Internal	Behaviour	2.10	3.19	10	5.85	7.79	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Comfort Males	Internal	Behaviour	6.60	6.17	10	5.92	6.30	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Females	External	Behaviour	3.09	5.14	11	5.64	6.44	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Females	Internal	Behaviour	9.30	24.16	10	4.60	5.77	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Females	Internal	Behaviour	5.06	5.06	10	6.33	6.10	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying HY	External	Behaviour	3.55	5.17	11	5.79	9.77	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying HY	Internal	Behaviour	4.70	10.75	10	6.08	16.04	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying HY	Internal	Behaviour	6.79	6.80	10	1.67	1.97	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Males	External	Behaviour	3.00	4.97	11	11.36	31.43	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Males	Internal	Behaviour	5.50	10.06	10	6.31	15.18	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Flying Males	Internal	Behaviour	5.80	12.97	10	4.17	10.46	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging Females	External	Behaviour	1.64	2.29	11	0.64	1.09	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging Females	Internal	Behaviour	1.40	2.21	10	0.69	1.69	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging Females	Internal	Behaviour	1.10	2.50	10	2.00	2.39	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging HY	External	Behaviour	0.64	1.13	11	1.07	1.87	14	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging HY	Internal	Behaviour	0.90	1.52	10	0.39	0.87	13	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging HY	Internal	Behaviour	2.85	2.85	10	1.42	3.15	12	frequency	21		(Small et al., 2004)
<i>Zenaida asiatica</i>	Foraging Males	External	Behaviour	0.27	0.90	11	0.21	0.60	14	frequency	21		(Small et al., 2004)

Species	Measurement	Device	Subset	Logger		Control		Duration	Direction		Reference			
				Mean	s.d.	n	Mean	s.d.	n	Units	(d)			
<i>Zenaida asiatica</i>	Foraging Males	Internal	Behaviour	1.20	3.13	10	0.62	1.19	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Foraging Males	Internal	Behaviour	0.40	1.26	10	0.58	1.39	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Females	External	Behaviour	0.00	0.00	11	0.00	0.00	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Females	Internal	Behaviour	0.00	0.00	10	0.00	0.00	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Females	Internal	Behaviour	0.00	0.00	10	0.00	0.00	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction HY	External	Behaviour	0.00	0.00	11	0.07	0.26	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction HY	Internal	Behaviour	0.00	0.00	10	0.00	0.00	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction HY	Internal	Behaviour	0.00	0.00	10	0.25	0.87	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Males	External	Behaviour	0.00	0.00	11	0.00	0.00	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Males	Internal	Behaviour	0.10	0.32	10	0.08	0.29	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Interaction Males	Internal	Behaviour	0.10	0.32	10	0.00	0.00	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Females	External	Behaviour	0.36	0.66	11	0.93	1.38	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Females	Internal	Behaviour	0.20	0.63	10	0.23	0.61	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Females	Internal	Behaviour	0.20	0.41	10	0.83	1.59	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting HY	External	Behaviour	0.18	0.40	11	0.71	1.38	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting HY	Internal	Behaviour	0.40	0.51	10	0.54	0.65	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting HY	Internal	Behaviour	0.50	0.70	10	0.92	1.18	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Males	External	Behaviour	0.55	0.53	11	0.79	1.05	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Males	Internal	Behaviour	1.10	1.58	10	1.15	1.33	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Resting Males	Internal	Behaviour	0.80	0.92	10	0.67	0.97	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Females	External	Behaviour	4.36	6.10	11	4.71	6.55	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Females	Internal	Behaviour	5.40	10.06	10	2.23	1.98	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Females	Internal	Behaviour	5.40	6.51	10	4.00	3.15	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking HY	External	Behaviour	2.73	3.02	11	5.71	6.02	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking HY	Internal	Behaviour	2.70	3.92	10	1.39	1.80	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking HY	Internal	Behaviour	2.50	2.47	10	2.33	3.33	12	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Males	External	Behaviour	7.09	10.85	11	4.21	7.11	14	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Males	Internal	Behaviour	3.80	5.57	10	3.46	4.83	13	frequency	21	(Small et al., 2004)		
<i>Zenaida asiatica</i>	Walking Males	Internal	Behaviour	3.70	5.91	10	5.50	9.39	12	frequency	21	(Small et al., 2004)		
<i>Falco columbarius</i>	reproductive success 1988	External	Reproductive	3.70	1.56	3	4.00	0.94	22		52.5	-	-0.31	(Sodhi et al., 1991)
<i>Falco columbarius</i>	reproductive success 1989	External	Reproductive	3.20	1.79	5	3.80	1.53	26		52.5	-	-0.40	(Sodhi et al., 1991)
<i>Falco columbarius</i>	reproductive success 1990	External	Reproductive	4.00	1.40	4	3.90	1.44	23		52.5	-	0.07	(Sodhi et al., 1991)
<i>Puffinus griseus</i>	mass at second capture	External	Condition	784.40	48.52	9	852.70	48.50	15	g	45	-	-1.47	(Söhle, 2003)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Puffinus griseus</i>	mass at second Recapture	External	Condition	797.00	62.60	16	750.60	54.00	9	g	175	-	0.81	(Söhle, 2003)
<i>Spiza americana</i>	Change in fecal glucocorticoid levels	External	Condition	102.30	30.63	5	6.10	30.63	5	ng/g	1	+	-3.51	(Wells et al., 2003)
<i>Spiza americana</i>	Mass change	External	Condition	6.40	4.25	5	9.80	1.79	5	g	27	-	-1.17	(Wells et al., 2003)
<i>Strix aluco</i>	Incubating female	External	Condition	610.00	46.25	3	594.00	44.69	27	g	365	-	0.37	(Sunde, 2006)
<i>Strix aluco</i>	Late nestling female	External	Condition	540.00	1428.71	7	546.00	45.62	37	g	365	-	-0.01	(Sunde, 2006)
<i>Strix aluco</i>	Late nestling male	External	Condition	403.00	21.80	6	405.00	21.58	22	g	365	-	-0.10	(Sunde, 2006)
<i>Strix aluco</i>	Non-breeding female	External	Condition	564.00	49.20	9	579.00	48.92	23	g	365	-	-0.32	(Sunde, 2006)
<i>Strix aluco</i>	Non-breeding male	External	Condition	480.00	29.41	10	482.00	29.05	15	g	365	-	-0.07	(Sunde, 2006)
<i>Strix aluco</i>	Mean clutch size female	External	Reproductive	3.19	1.35	14	3.18	1.59	30		365	-	0.01	(Sunde, 2006)
<i>Strix aluco</i>	Mean clutch size m & f	External	Reproductive	3.05	1.10	6	3.44	0.98	24		365	-	-0.40	(Sunde, 2006)
<i>Strix aluco</i>	Mean clutch size male	External	Reproductive	2.92	1.39	12	3.26	1.47	32		365	-	-0.24	(Sunde, 2006)
<i>Tyto alba</i>	# young	External	Reproductive	4.30	2.20	6	4.70	1.96	6		90	-	-0.21	(Taylor, 1991)
<i>Tyto alba</i>	mass of young	External	Reproductive	382.50	36.71	26	375.30	30.16	28	g	90	-	0.22	(Taylor, 1991)
<i>Spheniscus humboldti</i>	foraging trip duration	External	Foraging	9.40	1.80	22	7.20	1.50	30	h	68.5			(Taylor et al., 2001)
<i>Spheniscus humboldti</i>	overnight trip duration	External	Foraging	25.50	2.80	22	22.90	2.10	30	h	68.5			(Taylor et al., 2001)
<i>Falco mexicanus</i>	1991 Female Nest attendance	External	Reproductive	33.10	13.86	3	39.40	14.10	9	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Female Nest attendance	External	Reproductive	12.60	5.54	3	18.20	5.70	9	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Female Territory attendance	External	Reproductive	45.10	9.76	2	47.50	9.90	9	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Female Territory attendance	External	Reproductive	34.80	11.74	2	41.90	11.70	9	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Male Nest attendance	External	Reproductive	16.70	8.40	9	19.50	8.31	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Male Nest attendance	External	Reproductive	11.70	5.10	9	6.90	5.02	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Male Territory attendance	External	Reproductive	29.00	8.40	9	33.20	8.49	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1991 Male Territory attendance	External	Reproductive	32.70	9.00	9	30.30	8.91	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Nest attendance	External	Reproductive	35.90	15.19	6	41.00	11.76	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Nest attendance	External	Reproductive	10.00	6.12	6	9.60	5.37	8	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Prey caching	External	Reproductive	0.10	0.07	6	0.05	0.07	6	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Prey caching	External	Reproductive	0.03	0.05	6	0.02	0.06	8	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Prey delivery	External	Reproductive	0.11	0.07	6	0.04	0.07	6	items/h	365	-	1.04	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Prey delivery	External	Reproductive	0.17	0.12	6	0.09	0.11	8	items/h	365	-	0.74	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Territory attendance	External	Reproductive	54.70	10.53	6	61.20	8.33	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Female Territory attendance	External	Reproductive	50.20	12.74	6	46.20	11.31	8	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Male Nest attendance	External	Reproductive	17.10	8.20	8	17.40	10.47	8	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Male Nest attendance	External	Reproductive	8.00	4.81	8	2.90	5.63	6	% time	365			(Vekasy et al., 1996)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		deleterious	d		
<i>Falco mexicanus</i>	1992 Male Prey delivery	External	Reproductive	0.23	0.11	8	0.26	0.14	8	items/h	365	-	-0.25	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Male Prey delivery	External	Reproductive	0.31	0.11	8	0.23	0.12	6	items/h	365	-	0.74	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Male Territory attendance	External	Reproductive	43.10	8.20	8	44.30	10.75	8	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1992 Male Territory attendance	External	Reproductive	39.30	8.77	8	30.20	9.80	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Nest attendance	External	Reproductive	51.00	13.68	3	51.30	13.44	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Nest attendance	External	Reproductive	12.30	5.37	3	11.80	5.37	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Prey caching	External	Reproductive	0.16	0.07	3	0.07	0.07	2	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Prey caching	External	Reproductive	0.05	0.05	3	0.03	0.04	2	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Prey delivery	External	Reproductive	0.08	0.07	3	0.14	0.07	2	items/h	365	-	-1.11	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Prey delivery	External	Reproductive	0.15	0.12	3	0.25	0.11	2	items/h	365	-	-1.09	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Territory attendance	External	Reproductive	65.00	9.53	3	55.80	9.48	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Female Territory attendance	External	Reproductive	37.30	11.43	3	37.30	11.31	2	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Nest attendance	External	Reproductive	18.10	8.06	2	12.30	8.14	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Nest attendance	External	Reproductive	9.60	4.95	2	12.50	4.85	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Prey delivery	External	Reproductive	0.26	0.11	2	0.27	0.09	3	items/h	365	-	-0.13	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Prey delivery	External	Reproductive	0.19	0.11	2	0.15	0.12	3	items/h	365	-	0.44	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Territory attendance	External	Reproductive	32.00	8.20	2	28.10	8.31	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1993 Male Territory attendance	External	Reproductive	33.50	4.95	2	33.90	8.66	3	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Nest attendance	External	Reproductive	37.40	1.40	4	36.60	13.47	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Nest attendance	External	Reproductive	16.70	5.60	4	14.70	5.39	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Prey caching	External	Reproductive	0.09	0.08	4	0.09	0.07	6	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Prey caching	External	Reproductive	0.01	0.06	4	0.03	0.05	6	items/h	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Prey delivery	External	Reproductive	0.15	0.08	4	0.13	0.07	6	items/h	365	-	0.29	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Prey delivery	External	Reproductive	0.16	0.12	4	0.12	0.12	6	items/h	365	-	0.37	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Territory attendance	External	Reproductive	62.10	9.80	4	46.60	16.90	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Female Territory attendance	External	Reproductive	45.20	11.80	4	35.80	11.27	6	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Nest attendance	External	Reproductive	13.50	8.08	6	12.30	9.40	4	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Nest attendance	External	Reproductive	9.20	4.90	6	12.50	5.80	4	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Prey delivery	External	Reproductive	0.24	0.12	6	0.20	0.12	4	items/h	365	-	0.37	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Prey delivery	External	Reproductive	0.17	0.12	6	0.13	0.12	4	items/h	365	-	0.37	(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Territory attendance	External	Reproductive	32.00	8.57	6	23.40	8.60	4	% time	365			(Vekasy et al., 1996)
<i>Falco mexicanus</i>	1994 Male Territory attendance	External	Reproductive	33.80	8.57	6	23.80	9.00	4	% time	365			(Vekasy et al., 1996)
<i>Uria aalge</i>	Time away from site	External	Reproductive	141.00	12.25	6	155.00	34.00	4	min				(Wanless et al., 1988)

Species	Measurement	Device	Subset	Logger			Control			Duration	Direction		Reference	
				Mean	s.d.	n	Mean	s.d.	n		(d)	deleterious		
<i>Uria aalge</i>	Time away from site	External	Reproductive	428.00	97.98	6	155.00	34.00	4	min	-	-	(Wanless et al., 1988)	
<i>Rissa tridactyla</i>	Number of checks brood unattended	External	Reproductive	1.10	3.74	14	0.00	0.00	5		3	-	0.36	(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of checks brood unattended	External	Reproductive	24.00	20.24	10	12.80	20.57	5		3	-	0.59	(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of checks pair together	External	Reproductive	0.40	0.77	15	0.40	0.45	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of checks pair together	External	Reproductive	1.30	3.37	14	0.40	0.45	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of checks pair together	External	Reproductive	0.00	0.00	10	0.60	0.89	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of Trips	External	Reproductive	2.50	0.77	15	3.40	0.45	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of Trips	External	Reproductive	2.30	0.37	14	2.80	0.45	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Number of Trips	External	Reproductive	2.00	0.63	10	2.00	0.00	5		3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Total time away	External	Reproductive	8.10	1.94	15	8.50	0.89	5	h	3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Total time away	External	Reproductive	8.60	3.74	14	7.70	2.01	5	h	3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Total time away	External	Reproductive	13.80	3.48	10	9.40	4.02	5	h	3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Trip duration	External	Reproductive	5.20	1.94	15	4.40	1.57	5	h	3			(Wanless, 1992)
<i>Rissa tridactyla</i>	Trip duration	External	Reproductive	3.90	2.88	13	3.40	1.79	5	h	3			(Wanless, 1992)

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