Online supporting information

Rory P. Wilson *et al*. Estimates for energy expenditure in free-living animals using acceleration proxies; a reassessment

SI 1

The data presented in Fig. 1 were collected on free-ranging animals at the sites shown in Table 1, with all devices (Daily Diaries (Wilson, Shepard & Liebsch 2008)) set to record at 40 Hz except for the cormorant tags that recorded at 8 Hz (Shepard *et al.* 2008). No tag exceeded 2% of any carrier animal's body mass and no tag deployment exceeded 21 days. The tag attachment mechanism varied and was based on; collars (badgers (McClune *et al.* 2015), oryx (Davimes *et al.* 2016) and sheep), harnesses (tamarins), tape (penguins and cormorants (Wilson *et al.* 2017)) and glue (turtles). Ethical permissions for the procedures were granted by Queen's University Belfast[1], Swansea University[2] or the Ministry of Agriculture and Environment and the National Directorate of Environment of Cabo Verde[3] (authorization 040/GP.INDP/14) with additional permissions granted by local authorities.

Table S1 – Details of the species, activities and associated mean DBA values (grand means derived from five individuals in each case) used for Fig. 1. The study site refers to the location where animals were tagged and the number gives the institution where ethical permission was obtained (see main text).

Species	**Activity**	**VeDBA (*g*)**	**ODBA (*g*)**	**Site**
European badger, *Meles meles*	Sleeping Trotting Walking	0.027 0.392 0.276	0.041 0.574 0.413	(54.307°N, 6.297°W) Northern Ireland[1]
Golden lion tamarin, *Leontopithecus rosalia*	Travelling	0.375	0.565	(22.602°S, 42.394°W) Brazil[2]
Arabian oryx, *Oryx leucoryx*	Grazing Walking	0.035 0.149	0.052 0.214	(28.250°N, 41.667°E) Saudi Arabia[1]
Magellanic penguin, *Spheniscus magellanicus*	Diving Walking Washing	0.222 0.360 1.006	0.317 0.550 1.440	(50.900°S, 69.133°W) Argentina[2]
Domestic sheep, *Ovis aries*	Grazing	0.149	0.220	(54.990°N, 5.992°W) Northern Ireland[1]
Imperial cormorant, *Phalacrocorax atriceps*	Flying Washing Diving Resting	0.618 0.477 0.270 0.081	0.877 0.696 0.386 0.110	(43.064°S, 64.458°W) Argentina[2]
Loggerhead turtle, *Caretta caretta*	Resting Swimming	0.069 0.040	0.100 0.059	(15.592°N, 22.800°W) Cape Verde[3]

SI 2

All participants in the study were healthy adults and gave informed consent before the study commenced. The protocol was approved by the Swansea University Ethics Committee. The procedure is detailed in Qasem et al. (Qasem *et al.* 2012). Briefly, all participants were asked to move on a treadmill (Woodway Ergo ELG55, Germany) at speeds up to 13 km/h in 1 km/h increments, starting at 3 km/h but randomly assigned in time. Participants breathed into a mask so that expired air could be analysed for oxygen using an Oxygon Pro (Jaeger Oxycon Manual 4.5, VIASYS Heathcare GmbH, Germany). During this process, participants were also equipped with two triaxial accelerometer loggers (X6-1A USB; Gulf Coast Data Concepts, USA) mounted on the upper back or at the base of the back, and held in place using elastic harnesses. Units recorded at 80 Hz throughout.

SI 3

A tippler pigeon, *Columbia livia*, was flown in the wind tunnel at the Max Planck Institute for Ornithology, Seewiesen Germany. Miniaturised Daily Diary loggers (DD) were attached to the upper and lower back using micropore tape. Each DD circuit board was 18 x 14 x 4 mm and the total mass of the tags and the batteries was 7.1 g, which represented 2.5% of the bird body mass. The use of data loggers was approved by the government of Upper Bavaria, "Sachgebiet 54 – Verbraucherschutz, Veterinärwesen, 80538 München" with the record number: Gz.: 55.2-1-54-2532-86-2015.

SI 4

The data presented in Fig. 3 were selected from back-mounted tags on Imperial Cormorants breeding at the Punta Leon colony. Each bird had two tags attached with tape (Wilson *et al.* 1997). One was a video camera and another recorded acceleration at 25 Hz (Gómez-Laich *et al.* 2015). The video data allowed us to see the sea state to be able to rank it while the accelerometers allowed recording of the DBA metrics.

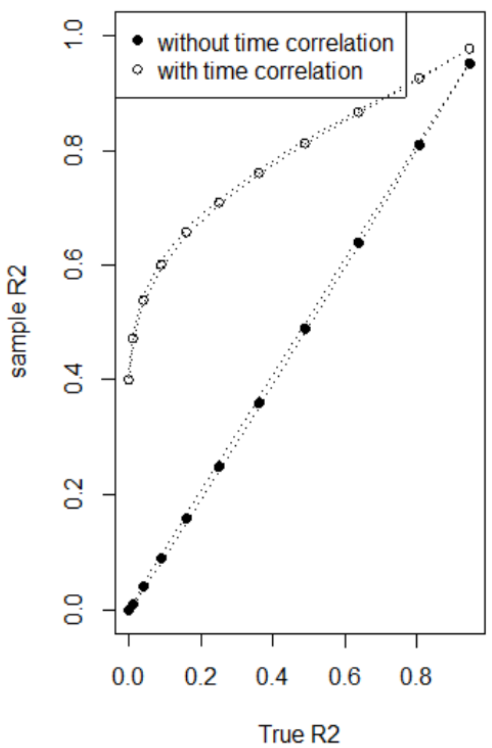
SI 5

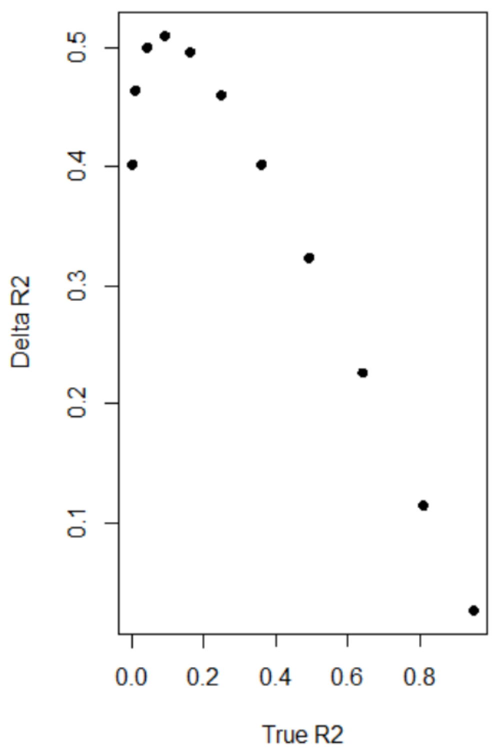
Procedures used for the unpublished data were identical to those described in Graf *et al*. (2016) for beavers in the Telemark area of Norway. Briefly, accelerometers recording at 8 Hz (15 × 90 mm, 62 g; JUV Elektronik, Schleswig-Hollstein, Germany) were attached to the lower-back using glue for periods of up to 3 weeks. The procedure was approved by the Norwegian Experimental Animal Board (FOTS id 742, 2170, 2579, 4387, 6282) and the Norwegian Directorate for Nature Management (archive code 444.5, 446.15/3), which also granted permission to conduct fieldwork in the study area.

SI 6

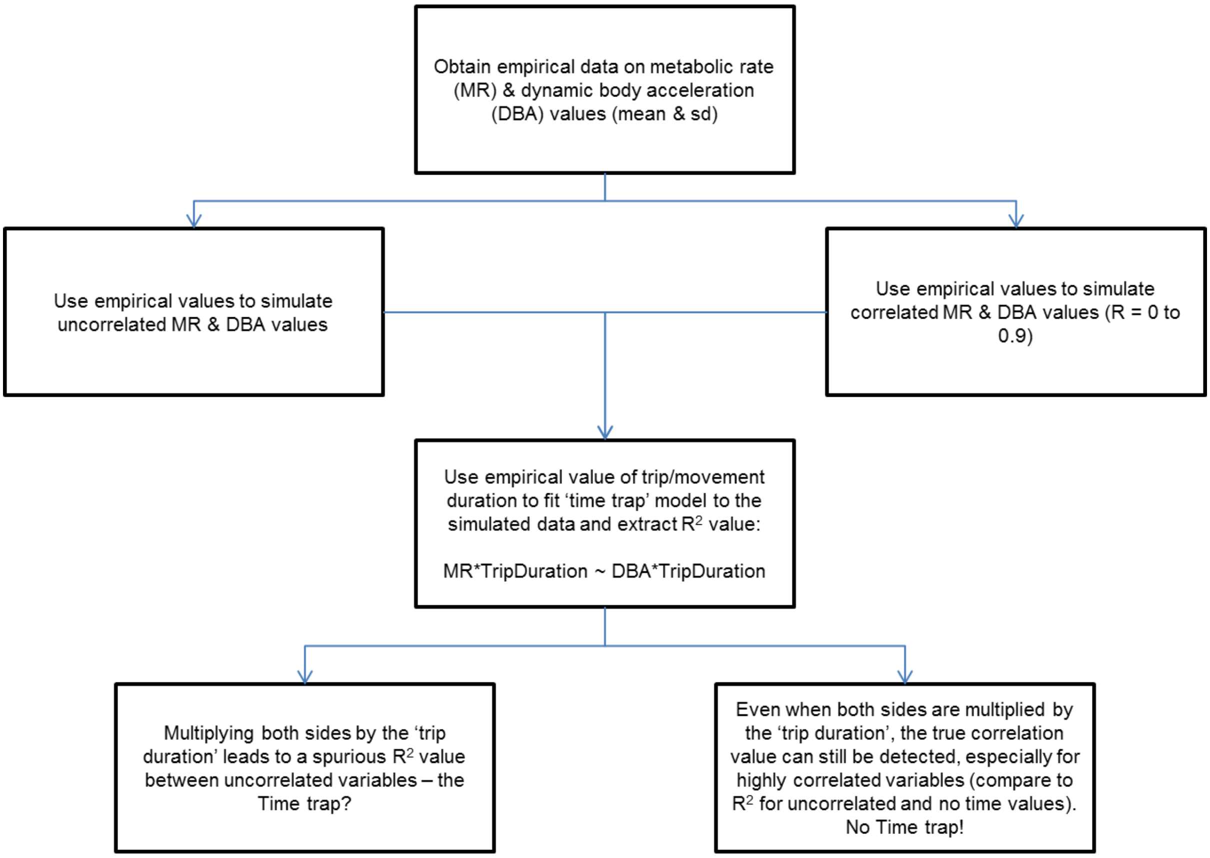
The simulation procedure adopted by Halsey (2017) was repeated in R (version 3.5.1 (2018-07-02) R Core Team (2018)) using his distribution of DBA and metabolic rate (MR), maintaining a random distribution and ensuring that the two metrics were not correlated. We then simulated a distribution of times ('days at sea', from Jeanniard-du-Dot *et al*. (2016), as did Halsey (2017)) and calculated the r^2 of the relationship between the two variables. This was performed with, and then without, the time vector. As reported by Halsey, we obtained an average r^2 of 0 for the two uncorrelated variables, which increased to around 0.4 when both variables were multiplied by the same time vector. We then extended this, in order to examine the change in r^2 for scenarios where the two variables were increasingly (and truly) correlated. For this, we adapted R code by Elseberry (2013, R Core Team (2018)) to use the Cholesky decomposition to generate sets of random continuous data and the Cholesky transformation to generate sets of correlated variables with precisely defined correlation values. Specifically, we added a true correlation between the two random vectors of simulated MR and DBA values, ranging from 0.1 to 0.975; i.e. up to a true R-squared of around 0.95. Each time, we simulated two vectors with 100,000 values each and calculated the r^2 between the two vectors, with and without multiplying both by the same time variable (days at sea). We repeated these simulations 10,000 times, for each value of true correlation, and extracted the minimum, maximum mean and quartiles of the distribution of r^2 values obtained. For each value of true correlation, we also calculated the difference in r^2 between the r^2 of the 'raw' variables and the r^2 value of the variables multiplied by time. Importantly, the large number of simulated values meant that we could exclude the confounding effect of sampling stochasticity (which led to the high variability obtained by Halsey (2017) in his simulations).

The graphs below show the mean (points) and min-max (dotted lines) r^2 values obtained, against the true simulated correlation value between the two simulated variables. The right-hand plot shows the increase in R caused by multiplying both sides by the same variable.





The graphs below shows the simulation procedure used by Halsey (2017) to raise the 'time trap' problem (left hand side of the flow chart) and the new simulation procedure used by us to exemplify that if there is true correlation between the variables (as opposed to the case of completely uncorrelated variables, used by Halsey 2017), the correlation values obtained can still reveal a higher correlation as what expected from the 'time trap' issue alone (compare to previous figure, too).



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