*The following supplements accompany the article*

# Foraging behaviour of common murres in the Baltic Sea, recorded by simultaneous attachment of GPS and time-depth recorder devices

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## **Supplement 1.** Detailed methods

## Bird-borne data loggers

We used 2 different devices together, (1) a back-mounted GPSD and (2) a leg-mounted TDR, to record the foraging movements and diving behaviour of *Uria aalge*.

1. The GPSD was an unmodified commercial unit (Model GT-120 by Mobile Action Technology, Inc.) which included a SiRF Star III Low Power chipset and a 230 mAh battery. This was prepared for deployment by replacement of an outer housing with a heat-sealed plastic sleeve (HSP1-25.4/12.7-X, Hilltop Products Ltd; method after Guilford et al. 2008), resulting in a cross-sectional area of 3 $cm^2$ (cf. Elliott et al. 2007). The precision of the GPSD was tested by placing it on a windowsill in a building imitating poor signal conditions and run for 2 d at 50 s intervals; 95% of positions lay within 65 m latitude and 46 m longitude and 50% of positions lay within 12 m latitude and 10 m longitude. Instantaneous ground speed recorded by GPSDs is very accurate, often within 0.1 m $s^{-1}$ and a very high proportion within 1 m $s^{-1}$ (e.g. Witte & Wilson 2004).

2. TDRs were configured on a conditional logging mode to log pressure only when a saltwater switch was on, indicating submergence. Log intervals were set to 4 s for all but one device which was set to 5 s, providing sufficient resolution of dives, usually of 30 to 120 s duration (e.g. Thaxter et al. 2009).

We attached TDRs to an aluminium ring (I.Ö. Mekaniska) mounted on the bird's left leg. GPSDs were attached dorsally along the midline over the bird's centre of gravity, minimising potential effects on balance (Ropert-Coudert et al. 2007). Black Tesa marine tape (Product 4651 from Tesa SE), sealed with a small dab of cyanoacrylate glue, was used to attach devices to body feathers. After device attachment, of ca. 15 min duration, birds were released near the ledge. When the common murres were released after deployment, most flew a few hundred metres out to sea, landing on the water surface (TDR and observational data), and then returned to the breeding ledge (<15 min). We recaptured the common murres after 2 to 10 d.

On average, 4.5 ± 3.7 trips were tracked per individual. This resulted in 3281 GPS positions from foraging trips. From these GPS-tracked foraging trips, we recorded 105 flights, with a mean number of GPS fixes per flight of 5.6 ± 5.8. This number comprised 26 outward, 20 foraging, and 36 inward flights. The remaining flights were not classified and were shorter, non-foraging trips.

TDRs recorded for the complete deployment periods, which averaged 4.6 ± 2.4 d (range: 2.9 to 9.5 d), resulting in a total of 765.5 h of records. We recorded 3326 dives from 7 individuals, 2866 excluding the tag with 50 m depth limit. In total, 408 dive bouts were recorded, of which 120 had GPS positions and 23 were the final dive bouts of foraging trips.

## Data treatment and statistics

Flight was classified as GPS speeds of >5 m $s^{-1}$; this speed was chosen in accordance with the bimodal distribution (Fig. S1). Flight duration was calculated as the length of time from the first to the final GPS fix where speeds were >5 m $s^{-1}$. Then, to adjust for sampling interval, half the interval to the next fix and to the previous fix was added. Dive bouts were identified as described above. Surface resting was classified as any time that did not display the other 3 behaviours. Time activity budgets were calculated as the mean proportion of time spent involved in each type of behaviour for each trip. GPS signals were impaired at the breeding ledge, due to the high cliff. Hence, recognition of trip start times used a combination of GPSD speed (identifying flight) and wet–dry data (for splashdowns).

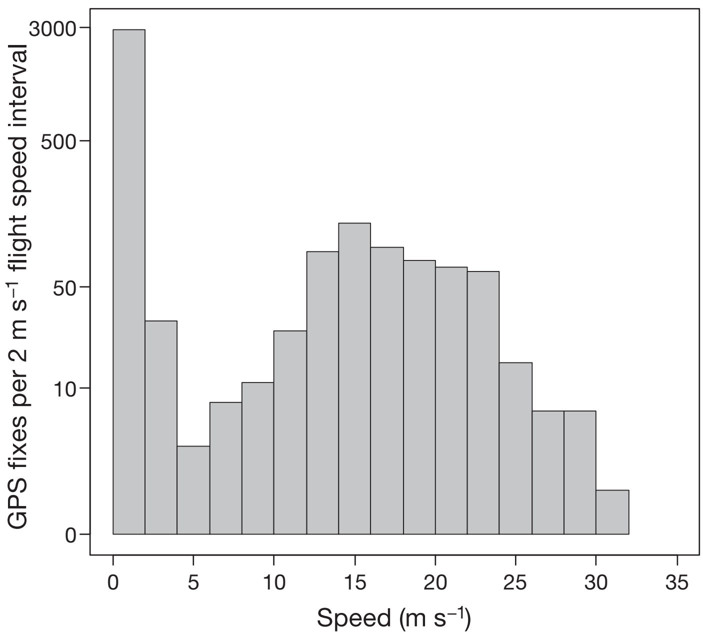


Fig. S1. *Uria aalge.* Log-frequency of recorded speeds for all GPS fixes within foraging trips of common murres, showing a bimodal distribution. Speeds >5 m $s^{-1}$ likely represent flight

Data from the GPSDs were mapped in ArcMap (9.3 and 10.0, Environmental Systems Research Institute), with which all map figures were produced. Data were initially analysed using the Hawth's Analysis Tools add-in (URL: www.spatialecology.com/htools), calculating the distance and bearing between GPS fixes and the distance from the breeding ledge. Dive bout positions were calculated from the mean of GPS locations during the bout period. Where no GPS locations were available, the closest (in time) GPS location was used, provided that it was <300 s before or after the bout and that no large movement had occurred (>250 m between pre- and post-bout position) or birds were in flight.

Flight segments were separated from the GPS data, where a flight segment included consecutive fixes with speeds of >5 m $s^{-1}$ plus the position fix before and after this period. For calculations based on speed, only the flight fixes were used; for those involving distance and bearing, the full flight segment was used. Mean speed is the mean of GPS-recorded instantaneous ground speeds. Rhumb-line bearing and great circle distance were calculated between the first and final positions using the functions 'bearingRhumb' and 'distHaversine' (Earth's radius: 6378137 m) from the R package 'geosphere' (Hijmans et al. 2011).

We classified flights into 3 groups: (1) outward flight, (2) foraging flights, and (3) inward flights. For outward and inward flights, we calculated mean speeds and directions which were tested for uniformity with the Rayleigh test (Batschelet 1981). Outward and inward flight speeds were compared for each trip using a paired *t*-test. The summary of wind conditions provided here (Fig. 7E,F and 'Results' in the main text) is for the mean of the conditions experienced at all GPS fixes obtained during flight.

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## **Supplement 2.** Device effects.

To assess effects of the device on study birds, we compared (1) the breeding success of tracked birds with neighbouring untracked pairs and (2) the bird weights before and following device deployment.

## Method

(1) Throughout the study period, daily observations were made of all pairs breeding on the study ledge to determine the presence of a chick and continuation of breeding. From this the minimum chick age at fledging was calculated (observations began after hatching). Study pairs and control pairs (those not tracked) were compared statistically using Welch's 2-sample *t*-test, with data checked for normality by the Shapiro-Wilk test. (2) At capture ($n = 9$) and recapture (not all birds were weighed, $n = 4$) we weighed the murres to ±5 g using a 1 kg Pesola® spring balance.

## Results

(1) The mean minimum chick age at first absence was not significantly different between the study (mean = 12.9 ± 3.0 d, $n = 9$) and the control (mean = 12.2 ± 3.0 d, $n = 37$) pairs (Welch's 2-sample *t*-test, $t = 0.55$, $p = 0.59$, df = 11.7), suggesting that fledging success was unaffected.

(2) The mean body mass at deployment for all individuals was 921 ± 62 g ($n = 9$). For 4 birds for which re-capture weight was also recorded, the start weight was 889 ± 73 g and the end weight was 869 ± 28 g. The rate of weight change was –12 g $d^{-1}$; although 1 bird gained weight (16 g $d^{-1}$), the other 3 lost weight (–21 ± 11 g $d^{-1}$).

## Interpretation

Breeding success did not differ between study and control birds. However, weight losses were recorded, although these were similar to those reported in other studies using biologgers (e.g. Benvenuti et al. 2001, Paredes et al. 2008) and may reflect normal adaptive weight loss (Elliott et al. 2008, Jacobs et al. 2011). Similar device weights were not found to affect dive behaviour (Camphuysen 2005) in a comparison of murres carrying either a 5 or 23 g, though flight behaviour could be affected (Vandenabeele et al. 2011).

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