Balancing under the high wire; a study into PTT antenna effects on the Common Guillemot *Uria aalge*

Sylvie P Vandenabeele, Emily LC Shepard, Adam Grogan, Richard Thompson, Adrian C Gleiss, Rory P Wilson

External tags fitted to diving birds can affect them in many ways with the most critical effect being an increase in drag. The effects of transmitters can be even more acute due to the presence of a protruding aerial. The study assesses the impact of PTT antenna on the behaviour and energetics of device-equipped guillemots (*Uria aalge*) in captivity. Birds with antenna-devices appeared to consume about 20% more energy than non-antenna birds during the descent phase of the dive. The balance of the birds while diving or resting on the water also appeared to be compromised by the presence of an antenna. Based on these first results and because transmitters are one of the most common methods used to track animals, it appears critical to determine what impact these devices, and particularly antenna, can have on their bearers and try minimize it.

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Balancing under the high wire; a study into PTT antenna effects on the Common Guillemot Uria aalge

Sylvie Vandenabeele[1], Emily Shepard[1], Adam Grogan[2],Richard Thompson[3] , Adrian Gleiss[4], Rory Wilson[1]

[1] Swansea Laboratory for Animal Movement, Biosciences, College of Science, Swansea University, Singleton Park, SA2 8PP, Wales, UK

[2] Royal Society for the Prevention of Cruelty to Animals, Wildlife Department, Wilberforce Way,
Southwater, Horsham, West Sussex, RH13 9RS, UK

[3] RSPCA Mallydams Wood Study and Wildlife Centre, Peter James Lane, Fairlight, Hastings, TN35 4AH, UK

[4] Centre for Fish and Fisheries Research, Murdoch University, 90 South Street, WA 6150, Australia

Corresponding Author:
Sylvie Vandenabeele[1]
Swansea Laboratory for Animal Movement, Biosciences, College of Science, Swansea University, Singleton Park, SA2 8PP, Wales, UK
Email address: s.p.s.vandenabeele@swansea.ac.uk

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Abstract

Background. External tags fitted to diving birds can affect them in many ways with the most critical effect being an increase in drag. The effects of transmitters can be even more acute due to the presence of a protruding aerial.

Methods. The study assesses the impact of PTT antenna on the behaviour and energetics of device-equipped guillemots (*Uria aalge*) in captivity.

Results. Birds with antenna-devices appeared to consume about 20% more energy than non-antenna birds during the descent phase of the dive. The balance of the birds while diving or resting on the water also appeared to be compromised by the presence of an antenna. **Discussion.** Based on these first results and because transmitters are one of the most common methods used to track animals, it appears critical to determine what impact these devices, and particularly antenna, can have on their bearers and try minimize it.

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Introduction

Oil pollution at sea is a major factor influencing seabird survival (Heubeck et al., 2003; Boulinier & Riffaut, 2008) and known to impact local populations around UK (Parr, Haycock & Smith, 1997; Votier et al., 2005). Many animal welfare groups attempt to minimize mortality by rehabilitation programs where affected animals are cleaned and released. However, there has been criticism of this since there is evidence that survival of even rehabilitated birds is unacceptably low (e.g. Sharp, 1996; Goldsworthy et al., 2000). Clearly, it is critical to be able to quantify animal well-being and fate following release and this is typically currently only done using ring/recapture procedures. This suffers from sporadic and unpredictable information and typically highlights mortality because recoveries are often birds that have died and been washed ashore (Walraven, 1992; Cooke, 1997). An effort to refine this would particularly benefit from tracking studies since the speed and range of movement in tandem with the success of birds returning to normal foraging or breeding areas could be verified. The only system currently available that allows wide-ranging seabirds to be tracked and have their position relayed back to researchers uses Argos technology and PTTs (Platform Transmitter Terminals; Howey, 1992; Kenward, 2001). Indeed, this approach has been used widely to elucidate space use by non-rehabilitated seabirds, particularly the larger ones such as albatrosses (e.g. Weimerskirch & Robertson, 1994; Fernández et al., 2001). However, devices attached externally to birds can affect them appreciably, for example in changing their behaviour (e.g. Wilson, Grant & Duffy, 1986; Ropert-Coudert et al., 2007a), energetics (e.g. Culik & Wilson, 1991; Godfrey, Bryant & Williams, 2003) and breeding/foraging success (e.g. Taylor et al., 2001; Ackerman et al., 2004). Of particular recent concern is the effect of external antennae, which appears to compromise the swimming energetics of diving birds, with predicted substantial knock-on effects on foraging efficiency and ultimately survival (Wilson et al., 2004). Thus, before studies involving PTTs on rehabilitated seabirds are fully implemented, it is germane that the potential deleterious effects of the devices on seabird be assessed.

We conducted work on rehabilitated guillemots *Uria aalge* in captivity and examined the behaviour of birds according to whether they were equipped with dummy PTT packages with, and without, external antennae using a video surveillance system both below and above the water. In addition, in those birds equipped with dummy PTT packages, we used tri-axial accelerometers and depth transducers to help quantify behaviours more precisely. Measures of tri-axial acceleration have been shown to be very powerful for determining both behaviour (e.g. Yoda et al., 1999; Shepard & Halsey, 2008) and alluding the energy expenditure (Wilson et al., 2006; Halsey et al., 2009) of equipped animals. We present our findings and consider the extent to which deployment of PTTs is currently appropriate for diving seabirds the size of guillemots for studies of rehabilitated seabirds or otherwise.

Materiel & Methods

All work was conducted at the Royal Society for Prevention of Cruelty to Animals (RSPCA) facility at Mallydams Wood, Hastings, UK. The study was reviewed and approved by the RSPCA's Project Review Group, the Institutional Board which reviews all projects that are conducted within the wildlife centres. A total of 39 oil-affected and cleaned guillemots was housed on three external freshwater pools prior to release into the wild. All birds had been in care for at least 30 days and were scheduled for release at the time they were involved in the experimentation. For the study, 11 birds were selected and placed on a further freshwater holding tank (dimensions 7 m long x 5 m wide x 1.7 m deep) with access to land (a ledge of dimensions 1.3 m x 5 m). The composition of this flock varied during the course of the work because birds were brought in from the three other holding tanks to replace animals that had been equipped with devices (see below) but which were removed from the experimental set-up after a single deployment. Thus, no individual was equipped with a device more than once and all birds on the experimental tank were equipped for the first and last time.

During experiments, two naïve birds at a time were equipped with devices that mimicked a small, commercially-available PTT (12 gram solar birdborne PTT, North Star Science and Technology), with a facility to add, or remove, the antenna (L: 18.5 mm, W: 0.5 mm) that constitutes part of the device and is necessary for normal functioning. The devices were attached to feathers in the dorsal mid-line of the back (cf. Bannasch, Wilson & Culik, 1994) using tape (Wilson et al., 1997) and birds were typically equipped for a number of hours (range 139-1059 min) with, or without, the antenna, after which the situation was reversed (individuals previously equipped with the antenna had it removed and *vice versa*) for another period before the devices were removed. The devices were either loggers with tri-axial accelerometers (range 0-6 *g*, 22-bit resolution, sampling rate 16 Hz; JUV Elektronik, Borstel, Germany) or 'Daily Diaries' (Wilson, Shepard & Liebsch, 2008); loggers which contained, among other transducers, tri-axial accelerometers coupled with depth sensors (acceleration range 0-6 *g*, depth range 0-5 m, 22-bit resolution, sampling rate 16 Hz; JUV Elektronik, Borstel, Germany). The attachment devices of the different types; DD's and tri-axial accelerometers with, or without, antennae was undertaken randomly so as to preclude any systematic bias.

During this procedure, all birds, whether equipped with devices or not, were filmed by a splitter video system consisting of four cameras, three of which were located above the experimental pool and one of which was placed underwater. The base and sides of the pool had been marked with a 1 m grid to help in judging relative movement and calibrations of bird position were undertaken to correct for parallax error in which a life-sized model of a swimming guillemot was held at different positions underwater while filming.

Due to inclement weather which led to poor quality video recordings, none of the filmed data was used for proper quantitative analysis although it did help to assess the behaviour of the birds visually and in correspondence with the acceleration data recorded. The acceleration data recorded by the devices were used to derive a proxy for energy expenditure, the Overall

Dynamic Body Acceleration (ODBA), following methods described in Wilson *et al.* (2006). In brief, this method uses a running mean (over 1s; cf. Shepard et al., 2008) on the raw data from each of the three orthogonal acceleration axes to derive the static acceleration for each channel. These static values are then subtracted from the raw values of acceleration to provide values for the dynamic acceleration of all three axes. The absolute value of all dynamic values are then summed to provide the ODBA. Dives events were identified based on the depth profile and/or tri-axial acceleration signature (Figure 1). For each dive, we extracted information about maximum depth (m) and descent duration (s) to then calculate the vertical velocity during the descent phase (m/s). The average, minimum and maximum values of ODBA during the descent were also determined from the DD data.

For the statistical analysis, we differentiated between two major bird groups; (1) birds equipped with devices with antennae and (2) birds equipped with devices without antenna hereafter referred to as ‘antenna-equipped’ birds and ‘non-antenna-equipped’ birds, respectively. The diving behaviour and energy expenditure of the birds were compared between the two groups. Firstly, the relationship between the ODBA and the vertical velocity during the descent was assessed using Spearman rank correlation. ODBA statistics (mean, minimum and maximum) were then compared between the non-antenna birds and the antenna birds using a Mann-Whitney test. Finally, since visual inspection of the video footage indicated differential rolling behaviour for birds resting on the water surface according to whether they were antenna-equipped or not, we examined the frequency distribution of both the static and dynamic components of the sway acceleration (corresponding to acceleration recorded in the lateral axis).

Results

The masses of equipped birds varied between 876 and 944 g and devices were deployed for periods between 139 and 1059 mins (Table 1). The removal of the units by unpeeling the Tesa tape resulted in a mean of 17 feathers being lost (sd = 9.4, range 4-34, n = 9; Table 1) per bird although not all these feathers were lost during the process of device removal, some being pulled out during the wearing period.

A total of 26 dives displayed by eight out of the 11 birds could be identified from the acceleration data and depth profile (3 birds did not dive at all during the periods they were equipped). There was no significant difference in the diving rate between the antenna- and non-antenna-equipped birds (Mann Whitney $z = 0.447$, $P > 0.05$). The vertical velocity during the descent could be calculated for only 13 dives (the ones extracted from the DD loggers with the depth profile) of which 11 were from non-antenna-equipped birds (mean ± sd = 0.40 ± 0.06) and 2 from antenna-equipped birds (mean ± sd = 0.37 ± 0.08) yielding no significant relationship between vertical velocity and mean ODBA ($rs = 0.12$, n =13, $P > 0.05$). However, the mean and maximum ODBA values obtained for the descent phase from all 26 dives were approximately 20% higher for the antenna-equipped birds than for the non-antenna-equipped birds (Mann–

Whitney $z = 2.82$, $P = 0.003$; Mann–Whitney $z = 2.43$, $P = 0.01$ respectively for mean and max ODBA, Figure 2).

Consideration of the frequency distribution of static and dynamic sway between antenna-equipped and non-antenna-equipped birds showed broadly similar patterns but statistically significant differences in peak position (Mann–Whitney $z = 7.844$, $P < 0.001$; Mann–Whitney $z = 23.7$, $P < 0.001$ respectively for static and dynamic sway, Figure 3 and Table 2). Our subjective impression from the video recordings was that the antenna-equipped birds tended to roll to a greater degree than the non-antenna-equipped birds.

Discussion & Conclusions

Radio and satellite telemetry are important tools in understanding the biology of wild animals and the use of satellite tracking, in particular, has provided substantial insights into the life and distribution of many elusive and wide-ranging species including seabirds (Burger & Shaffer, 2008). The success of wildlife telemetry is, however, tempered by potential negative impacts that tracking devices can have on their bearers (Wilson & McMahon, 2006), (Vandenabeele, Wilson & Grogan, 2011). Device effects on birds range from behavioural disturbance to physical injuries (Calvo & Furness, 1992; Phillips et al., 2003; Barron, Brawn & Weatherhead, 2010) which can ultimately compromise survival (e.g. Peery et al., 2006; Steenhof et al., 2006). Ongoing research into miniaturization is allowing devices to become ever smaller and lighter, reducing potential impact (Ropert-Coudert & Wilson, 2005; Bridge et al., 2011), a process which is enhanced by consideration of device shape so as to reduce drag (Obrecht, Pennycuick & Fuller, 1988; Bannasch, Wilson & Culik, 1994; Culik, Bannasch & Wilson, 1994). In a demonstration of the importance of drag, a recent study by Pennycuick et al. (2012) showed that even the minimal cross-sectional area of a harness increased the drag coefficient of starlings (*Sturnus roseus*) flying in a wind tunnel by nearly 50%. This reinforces the idea that any protuberance, even if relatively small, can disrupt air flow around a body, resulting in increased drag. The density of water makes diving animals particularly susceptible to this, as evidenced by recent studies on penguins wearing flipper bands (Gauthier-Clerc & Le Maho, 2001; Saraux et al., 2011).

Importantly though, and often ignored, drag is not just affected by the shape and size of the main body of transmitters but also by the attached antennae (Wanless, Harris & Morris, 1988; Wilson et al., 2004; Latty et al., 2010) and this may be partially responsible for observed impacts of PTTs on bird wearers (Phillips et al., 2003). In fact, in general, relatively few studies have documented the effects of antenna-bearing transmitters including PTTs and even fewer have specifically looked at the effect of antennae (Wanless, Harris & Morris, 1988; Wilson et al., 2004). This study sought to address this important issue under controlled conditions by examining antenna-related behavioural and energetic changes in an often satellite-tracked species, the common guillemot.

Our study was limited by the low number of dives recorded which could not be specifically related to device effects due to lack of unequipped controls although we note that previous studies have observed this phenomenon (Ropert-Coudert et al., 2000; Ropert-Coudert et al., 2007a). However, even with the low number of dives executed by equipped birds, and in accordance with the predictions made by Wilson et al. (2004) on penguin models, we found that the presence of an antenna did indeed appear to increase the energy expenditure, with a higher ODBA occurring during the descent phase of shallow dives. ODBA has been shown to be linearly related to metabolic rate for a number of species of birds (Halsey et al., 2009), including diving birds swimming underwater (Gómez Laich et al., 2011), and although lack of a calibration between VO_2 and ODBA precludes us from deriving the precise increment in power associated with diving, it seems safe to conclude that antennae do increase the metabolic costs of diving auks during the descent phase of dives, even at the low descent speeds (*ca.* 0.4 m/s) observed in our study. Given that drag is proportional to the square of the speed (Loworn, Jones & Blake, 1991; Lovvorn, Croll & Liggins, 1999) and that wild guillemots descend the water column at 1.5-2 m/s (Piatt & Nettleship, 1985; Watanuki & Sato, 2008), we would expect free-living birds to experience much higher energetic costs if they maintained normal foraging patterns. Similarly, wild birds have an extended bottom phase to their dive (Croll et al., 1992; Thaxter et al., 2010), something that was not exhibited by our birds, which, being powered, would presumably also incur higher energetic costs in antenna-equipped birds. The ascent phase in guillemots is, however, passive, with birds being forced to the surface by their buoyancy (Lovvorn, Croll & Liggins, 1999) so we do not expect the power costs associated with it to increase although over long ascent phases the increased drag of antenna-equipped individuals may reduce vertical velocity and hence increase transit time.

In addition to energetic considerations, the balance of the antenna-equipped birds when diving or resting at the surface appeared to be compromised, even in the still pool in which the birds were housed, with birds exhibiting a tendency to roll more than the non-antenna-equipped birds. Balance problems have already been observed in Little penguins *Eudyptula minor* fitted with dorsally-mounted loggers and are presumed to increase energy expenditure as birds attempt to correct for this. (Healy et al., 2004; Chiaradia et al., 2005). We assume that such problems would be exacerbated for birds resting at the surface of an unstable ocean. Although projecting antennae normally have small mass compared to the main tag body, the farther they project from the carrier's centre of gravity, the greater the force they exert due to the moment arm effect and we believe that our observations of increased rolling were primarily due to this. This moment arm effect may also be important underwater where the projecting antenna could act as a rudder tending to make the bird's trajectory angle more towards the surface. Finally, we also note that antennae in moving fluid systems can sometimes be meta-stable, tending to vibrate with movement (Weaver Jr, 1964). We do not know if this is a problem but it deserves consideration. Beyond the specifics of our study, external antennae may result in entanglement and occasionally bird mortality in passerines (Dougill et al., 2000; Hill & Elphick, 2011).

Quite how wild guillemots might respond to the increasing energy expenditure effects associated with antennae is unclear. Among the most common compensatory behaviours displayed by wild diving birds equipped with various external units are reduced swim speeds (see above), decreased dive depths and/or duration, and increased in surface pause, all of which lower foraging efficiency (Wilson, Grant & Duffy, 1986; Croll, Osmek & Bengtson, 1991; Taylor et al., 2001; Ropert-Coudert et al., 2007b). As a presumed knock-on consequence of such behaviours, reproductive success (Paredes, Jones & Boness, 2005; Whidden et al., 2007; Beaulieu et al., 2010) and survival rate can be altered (Calvo & Furness, 1992; Peery et al., 2006; Saraux et al., 2011).

Given the necessity of external antennae for the proper functioning of so many VHF-dependent systems such as PTTs (Fancy et al., 1988; Mech & Barber, 2002), we accept that some researchers may regard them as a 'necessary evil' in some studies, but it is hard to justify if the device itself causes the bird to behave abnormally., Recommendations can be made that should reduce their deleterious effect based on our understanding of external antennae increasing drag and producing a force which tends to make birds roll more due to the moment arm effect. In both cases, the deleterious effects should be reduced with shorter antennae as well as by having antennae that are angled backwards rather than projecting perpendicularly. Where length and perpendicular projection are critical for appropriate signal transmission, antennae could be constructed to be thinner (which should decrease both drag [cf. Wilson et al. 2004] and the force developed by the moment arm) and made flexible so that as the birds swim underwater (or fly), the antennae tend to lie backwards, thus decreasing drag by having a reduced projecting cross-sectional area. Indeed, it would seem appropriate in these times that are so defined by exciting technological advances in animal telemetric systems (e.g. Ropert-Coudert & Wilson, 2005), that we maintain similarly progressive views on animal well-being (Calvo & Furness, 1992, Wilson & McMahon, 2006, Vandenabeele et al., 2011).

Acknowledgements

We thank the Royal Society for Prevention of Cruelty to Animals (RSPCA) for having provided equipment and access to their facilities at the Mallydams Wildlife Centre (Hastings, UK). We are grateful to all the people who helped with the project.

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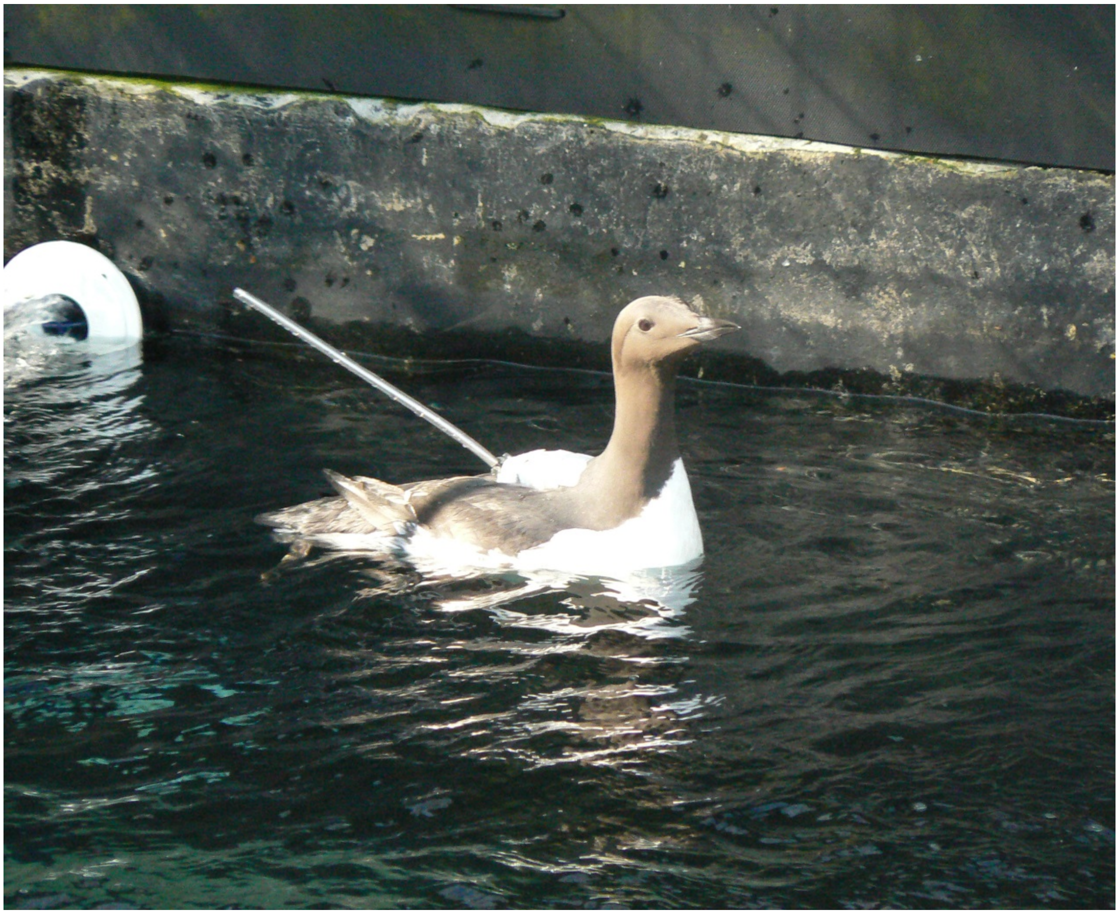

Figure 1. Photo of a captive guillemot fitted with a data- logger plus antenna resting at the water surface in an outdoor pool facility at the RSPCA wildlife centre, Mallydams woods, Hastings, UK.

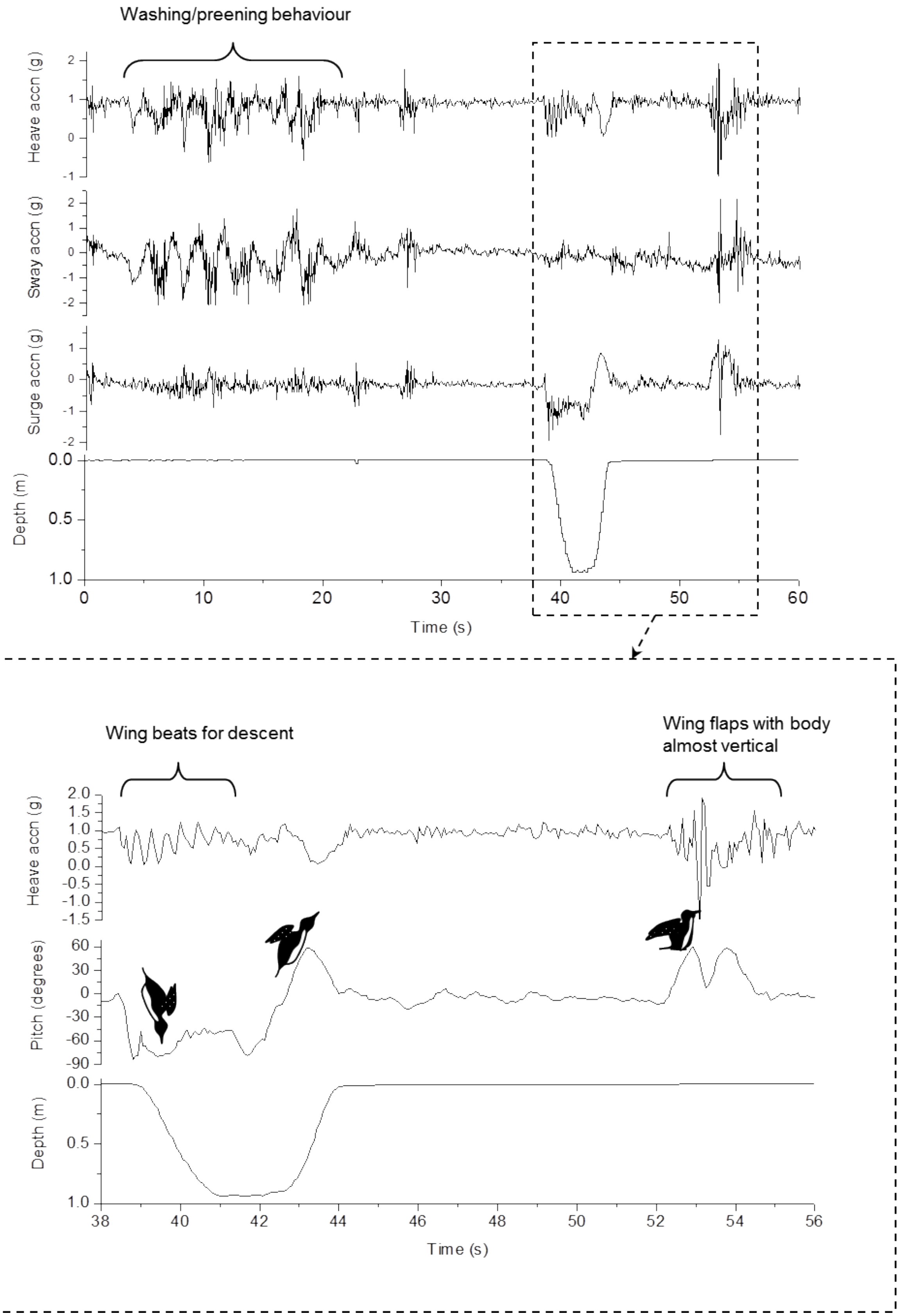
Washing/preening behaviour
Heave accn (g)
2
1
0
-1
Sway accn (g)
2
1
0
-1
-2
Surge accn (g)
1
0
-1
-2
Depth (m)
0.0
0.5
1.0
0
10
20
30
40
50
60
Time (s)
Wing beats for descent
Wing flaps with body almost vertical
Heave accn (g)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Pitch (degrees)
60
30
0
-30
-60
-90
Depth (m)
0.0
0.5
1.0
38
40
42
44
46
48
50
52
54
56
Time (s)

Figure 2. Example of guillemot behaviour recorded by a Daily Diary logger (Wilson *et al.* 2008) showing the tri-axial acceleration signature during a single dive as well as washing, preening and wing-flapping.

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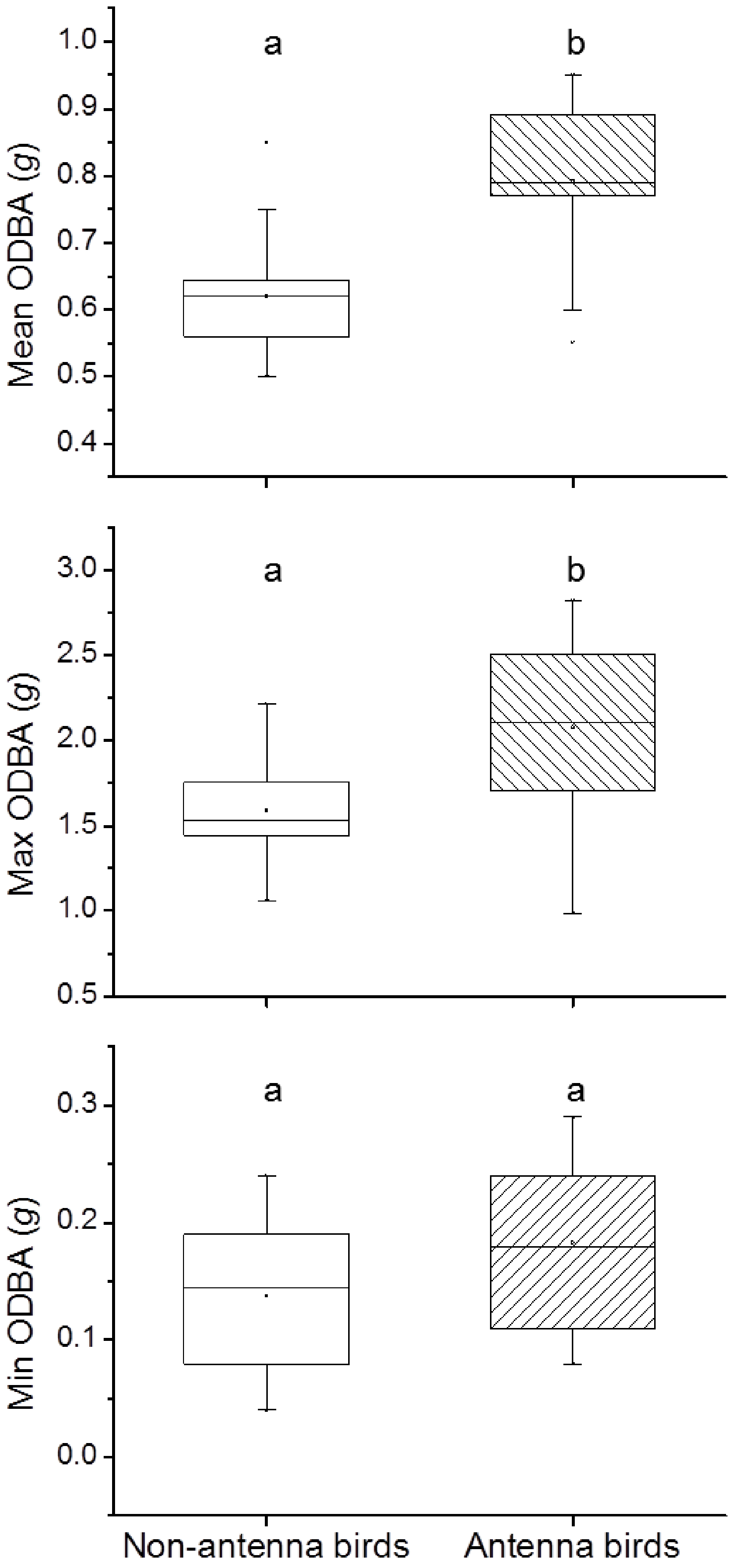
Table 1. Details about the captive guillemots their diving activity during the experiment.

Bird ID	**Treatment**	**Mass (g)**	**Deployment duration (h)**	**Total nb dives**	**Diving rate (nb dives /h)**
1	No antenna	944	2h30	1	0.4
2	No antenna	922	9h18	10	1.1
3	No antenna	903	1h49	2	1.1
4	No antenna	937	15h31	2	0.13
5	No antenna	876	15h31	1	0.06
6	Antenna	937	2h01	1	0.5
7	Antenna	903	15h42	7	0.45
8	Antenna		2h07	2	0.94



443

444 Figure 3. Box-plots of the minimum, maximum and mean values of the Overall Dynamic
445 Body Acceleration (ODBA, proxy for energy expenditure derived from acceleration data)

calculated for guillemots fitted with devices with and without antenna. Two different letters indicate a significant difference between the two groups (Mann-Whitney U test, see text). Acceleration unit is in *g* force or m/s^2.

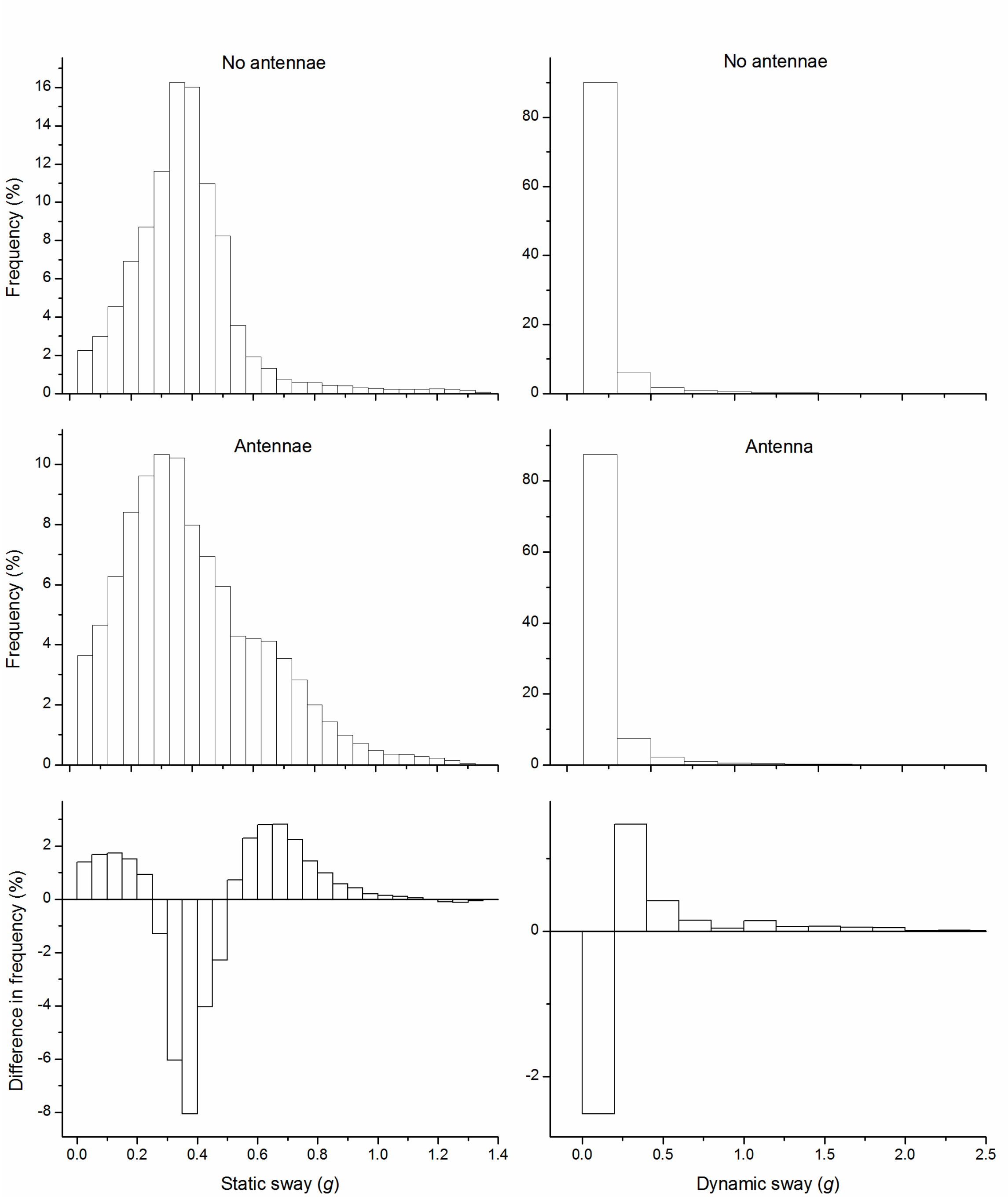


Figure 4. Frequency distribution of the static (left column) and dynamic (right column) components of the lateral acceleration (i.e. sway) recorded on guillemots fitted with devices that included, or not, an antenna. The static sway informs about the posture whereas the dynamic sway indicates movement. The difference between antenna-equipped birds and non-antenna-

equipped graphically represented at the bottom row appeared significant (see text and Table 2 for details).

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Table 2. Statistics for the static and dynamic components of sway (i.e. lateral acceleration) calculated for birds equipped with devices but no antenna or devices with antenna. This is to look at the difference in rolling behaviour between the two groups of birds during periods of motion (dynamic sway) and resting (static sway).

Treatment	**Acceleration component**	**Mean**	**Standard deviation**	**Minimum**	**Median**	**Maximum**
Non-antenna equipped birds	Static Sway (*g*)	0.35	0.18	0.00	0.34	1.35
	Dynamic Sway (*g*)	0.09	0.18	0.00	0.04	2.99
Antenna-equipped birds	Static Sway (*g*)	0.38	0.23	0.00	0.33	1.37
	Dynamic Sway (*g*)	0.11	0.21	0.00	0.05	3.03

Note: Acceleration unit is in *g* force or m/s^2.