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Leg-attached data loggers do not modify the diving performances of a foot-propelled seabird

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Abstract

Global location sensors (GLS) are increasingly being used to determine animal position at sea. Their small size and weight means that they can be attached to the leg of volant birds with supposedly little impact on the flight ability. However, very few studies have investigated the impact that foot-attached devices may have on the diving ability of foot-propelled seabirds. We compared the diving activity of two groups of free-ranging great cormorants *Phalacrocorax carbo carbo*, both groups carrying identical time-depth recorders attached to the tail, and one group also having leg-attached GLS. Our results showed that there were no differences between the two groups in any of the diving parameters investigated, at least over the short term. Caution should be exercised when extrapolating to other species, especially those smaller than great cormorants, and also when deploying GLS over longer periods.

Introduction

The use of bio-logging devices (see Ropert-Coudert & Wilson, 2005) to monitor the ecophysiological activity of free-ranging animals is becoming increasingly widespread, especially in seabirds (Burger & Shaffer, 2008), but the number of studies that have investigated the impact of attaching data-recording devices onto the birds is comparatively less. Seabirds may be affected in several ways by external bio-loggers: the devices may, among other things, change their balance at sea (i.e. if the logger is positioned far from the centre of gravity, or if it is not parallel to the long axis of the birds, cf. Chiaradia *et al.*, 2005), increase the carried mass of volant seabirds and/or affect the streamlining of diving seabirds. While the former has been rarely investigated (but see Phillips, Xavier & Croxall, 2003), the alteration of the hydrodynamical characteristics of divers, especially penguins, has been relatively well studied. It is known, for instance, that externally attached data loggers modify the diving activity of king penguin *Aptenodytes patagonicus* (Ropert-Coudert *et al.*, 2000), Adélie penguin *Pygoscelis adeliae* (Ropert-Coudert *et al.*, 2007*a*) and little penguins *Eudyptula minor* (Ropert-Coudert *et al.*, 2007*b*). In the aforementioned studies, and related ones, devices were always attached onto the back of penguins. Yet, constant miniaturization has meant that minute devices can now be fixed on the leg of seabirds [e.g. 12-g global location sensor (GLS), Afanasyev, 2004]. Studies based on the GLS technology are expanding rapidly because of the extremely small size of the devices that allow researchers to investigate the utilization of the marine environment at large spatio-temporal scales (e.g. Croxall *et al.*, 2005; Shaffer *et al.*, 2006). It has been shown that a behavioural change due to the presence of a device occurs for loads $>3\%$ of the bird's body mass (Phillips *et al.*, 2003), which means that GLS should potentially induce little effect on seabirds. Yet, only a few studies have examined the effect of attaching a device on indirect indicators (e.g. trip duration, mass of food loads, etc.) of the foraging performances of lightweight seabirds, such as shearwaters (cf. Igual *et al.*, 2005; Sohle *et al.*, 2000), but the extent to which this new method can impair the swimming ability of seabirds remains to be investigated. A potential impact is especially important to consider in the case of diving species that use their leg to swim, such as cormorants (Phalacrocoracidae), especially because the energy costs of foot propulsion are thought to be much higher than those of wing propulsion, like in penguins (Spheniscidae) for instance (Lovvorn & Liggins, 2002).

In this study, we used tail-attached data-recording devices to monitor and compare the diving behaviour of two groups of great cormorants *Phalacrocorax carbo carbo*: one with a leg-attached GLS and one without. We tested the hypothesis that leg-attached devices had an impact, even in the short term, on the diving ability of this foot-propelled bird.

Materials and methods

The study was conducted on male cormorants raising chicks on Qeqertaq Island (69°30′N, 54°05′W) in the Diskofjord area, Disko, West-Greenland, during June/July 2004.

The swimming and diving activity were examined using cylindrical (50 × 15 mm, 14 g, *c*. 0.4% of the birds' body mass), two-channel depth data loggers (UME-DT, Little Leonardo, Tokyo, Japan). The depth resolution was 0.05 m and data were sampled every second. Birds were caught at the nest site using a noose mounted onto a telescopic pole. We covered the head of each individual with a black hood to reduce stress. Birds were weighed with a spring balance to the nearest 10 g, and morphometrics were measured. Handling lasted <10 min in all cases. The device was attached to the cormorants with four strips of waterproof TESA tape (Tesa, Hamburg, Germany) under the central feathers of the tail, a position that minimizes the drag caused by the device (Bannasch, Wilson & Culik, 1994). The small size of the device and its placement in a position that preserves the streamlined shape of the cormorant led us to assume that it did not have a substantial impact on the birds' swimming ability. These tail-mounted loggers were deployed onto 12 breeding birds; six of them also received a GLS fixed onto a darvic ring that was attached to their left leg (birds with only a tail-attached logger did not have a darvic ring). The GLS were 14 × 45 mm (GeoLT, Earth and Ocean Technologies, Kiel, Germany) and weighed 8.2 g (*c*. 0.23% of the birds' body mass). Birds were released in the vicinity of the colony. All of them were back onto the nest within 5 min. They were then observed from a point situated 50 m away from the nests, using binoculars, for several hours to investigate possible behavioural changes. Because of logistical constraints, we had to recapture the birds 2–4 days after the deployment. Tail-attached data loggers were retrieved but the GLS remained on the leg, with the data collected being subsequently used to study the movements of Greenland great cormorants during the 2004–2005 Arctic winter (White *et al*., 2008).

Following recovery, data were downloaded onto a computer and analysed using purpose-written macro in Igor pro (Wavemetrics v. 6.0.4.0), which automatically processes the following dive parameters: dive depth, dive duration, descent and ascent rates, percentage of time spent at the bottom phase of the dives and dive efficiency. The bottom phase started and ended the first and the last time the depth change between two consecutive depth measurements was $>0.25\,\mathrm{m\,s^{-1}}$ (cf. Ropert-Coudert, Grémillet & Kato, 2006). Dive efficiency was defined as the ratio between the duration of the bottom phase and the duration of the dive cycle (i.e. the dive duration and the subsequent time spent at the sea surface, PDT). For the calculation of the dive efficiency, dives with no bottom phase and with PDT > 1800 s were excluded from the analysis as they represented exploratory dives and the last dive in a series of foraging dives, respectively.

Data were log transformed (or arcsine transformed in the case of percentage) when they did not follow a normal distribution. We compared dive parameters between the two groups of birds with general linear mixed models (GLMM) where bird identity was included as a random factor. Apart from dive depth, all other variables are dependent on the depth of the dive, and thus we included dive depth as a covariate in all the tests. Where there was a single variable per individual, Student's *t*-tests were used. Here, the power of the *t*-tests to detect a significant difference between the groups may be negatively affected by the small sample size ($n = 6$ birds in each group). Although a posteriori power analysis can be regarded as providing little information because it consists of a transformation of the *P*-value (Hoenig & Heisey, 2001), we calculated the percentage of chances of not detecting a 30% ($P_{0.30}$) and 10% ($P_{0.10}$) difference between the groups in all *t*-tests. In comparison, the GLMM takes into account the inter-individual variability and also includes a huge number of repetitions for each individual, which makes the model more robust. In addition, there is, to our knowledge, no (*a posteriori*) power analysis for models including both fixed and random factors with repeated covariates. The statistical threshold was 0.05. Results are presented as means ± 1 standard deviation. Statistical tests were conducted using JMP (SAS Institute Inc., Cary, NC, USA, version 5.1.1J).

Results

All tail-attached bio-loggers recorded data. The body mass of the males in the two groups did not differ statistically before the deployment ($t_{10} = -1.63$, $P = 0.13$, group 1 = 3491.7 ± 99.6 g; group 2 = 3637.5 ± 195.4 g, $P_{0.30} < 0.001$, $P_{0.10} = 0.434$), and they raised the same number of chicks ($t_{10} = -0.29$, $P = 0.78$, group 1 = 3.67 ± 1.03; group 2 = 3.83 ± 0.98, $P_{0.30} = 0.661$, $P_{0.10} = 0.936$), which, on average, had similar body masses ($t_{10} = 1.22$, $P = 0.25$, group 1 = 3962.5 ± 3170.0 g; group 2 = 2262.5 ± 1253.9 g, $P_{0.30} = 0.598$, $P_{0.10} = 0.742$). Thus, the control and experimental groups comprised individuals of similar body masses and breeding requirements (same brood size). Over the 12.2 ± 2.9 h of observation per individual, no birds were seen preening extensively around the logger and GLS and none attempted to remove it.

The recording period was also similar between the two groups ($t_{10} = 0.53$, $P = 0.51$, group 1 = 3.05 ± 0.09 days; group 2 = 3.03 ± 0.07 days, $P_{0.30} < 0.001$, $P_{0.10} < 0.001$). The comparison between the two groups showed that the birds performed a similar number of dives per trip ($t_{10} = 1.00$, $P = 0.92$, group 1 = 416.5 ± 168. 9; group 2 = 407.0 ± 160.0), and yet the power analysis indicates that this result should be considered with care ($P_{0.30} = 0.744$, $P_{0.10} = 0.921$). There was no difference in any of the dive parameters between the two groups (Table 1).

Table 1 Dive parameters of the two groups of great cormorants *Phalacrocorax carbo carbo*: one with leg-attached devices and one without

Dive parameters	Leg-attached group	Control group	Statistics
Mean dive depth (m)	5.87 ± 5.17 (0.6–37.9)	5.77 ± 5.14 (0.6–30.2)	$F_1 = 0.26$, $P = 0.622$
Mean dive duration (s)	18.91 ± 12.97 (3–77)	19.90 ± 12.65 (3–74)	$F_1 = 0.89$, $P = 0.367$
Bottom phase duration (ratio)	0.51 ± 0.23 (0.03–0.96)	0.55 ± 0.25 (0.04–0.97)	$F_1 = 1.06$, $P = 0.328$
Dive efficiency (see text, no units)	0.27 ± 0.17 (0–0.92)	0.32 ± 0.19 (0–0.88)	$F_1 = 0.92$, $P = 0.361$
Descent rate (m s^{-1})	1.12 ± 0.41 (0.51–4.25)	1.22 ± 0.46 (0.55–4.68)	$F_1 = 3.75$, $P = 0.08$
Ascent rate (m s^{-1})	1.38 ± 0.54 (0.48–4.65)	1.41 ± 0.52 (0.50–4.20)	$F_1 = 0.68$, $P = 0.432$

Except for maximum depth, all parameters were significantly related to dive depth (which was used as a covariate in the tests) with $P < 0.0001$. Results are means ± SD (range within parentheses).

Discussion

One of the main difficulties in evaluating the impact of animal-attached devices is the lack of genuine controls, as it is impossible to monitor the diving capacity of uninstrumented birds. To overcome this problem, several studies have compared performances between groups of divers either instrumented with data-recorders of various sizes (e.g. Wilson, Grant & Duffy, 1986) or with implanted versus externally attached devices. All these studies showed that the diving activity of birds with the greater level of encumbrance differed from that of the less encumbered ones, either in the capacity to sustain deep diving activity (Ropert-Coudert *et al.*, 2000) or in the dive duration and swim speed (Ropert-Coudert *et al.*, 2007*a*,*b*). In this regard, the diving activity of cormorants with loggers attached to the tails surely differs from that of uninstrumented birds but we can assume that the disturbance is kept to a minimum as the birds' streamlining is not affected and that the two groups were similarly handicapped by the tail loggers. This idea is actually re-inforced by the fact that the addition of a leg-attached GLS did not result in differences in the diving performance of great cormorants. Although the hydrodynamic alteration due to the GLS may indeed be minor compared with that induced by the tail logger, we expected that it could have altered either the ability of the bird to use its leg efficiently underwater or its balance, as it has been observed on little penguins *E. minor* (Chiaradia *et al.*, 2005, but see also Ropert-Coudert *et al.*, 2007*b*). Yet, this was apparently not the case in the present study. Based on this, our results suggest that attaching a GLS does not profoundly impair the diving ability of birds. Another aspect to consider is that a greater encumbrance can also decrease the prey capture rate or increase the energy expenditure, which would both lead to a greater body mass loss by equipped adults and/or a decrease in the meal delivery rate. As we did not gather such information, we may have overlooked a potential effect. Note that our results only apply to species similar in size to the great cormorants and with devices similar to those used in the present study. Nonetheless, since the first time GLS have been considered to record the position of marine divers (Hill, 1994), devices have become lighter and smaller with time so that a potential effect can confidently be expected to decrease as miniaturization progresses.

Caution should still be exercised, because we only investigated the potential impact of carrying a GLS on the diving performances of cormorants over the short term. Hence, some other components of the birds' fitness may be affected over the long term, even through small differences that were not significant in our study. It is indeed difficult to predict whether long-term GLS deployment would lead to a habituation or, in contrast, to an aggravation. Investigations on the effect of applying flipper band to little penguins have shown that birds would show no immediate difference in their diving ability following banding, while differences would be visible over the very long term (at years' scale, Fallow *et al.*, in press). Besides, a negligible impact detected during periods when prey availability is not limiting can have disastrous consequences when it occurs during the end of the winter period when the energy stores of cormorants may be completely depleted (Grémillet *et al.*, 2005).

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