Journal of Experimental Marine Biology and Ecology 358 (2008) 14–19

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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Ecophysiological response to an experimental increase of wing loading in a pelagic seabird

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Received 13 November 2007; received in revised form 12 January 2008; accepted 16 January 2008

Abstract

The knowledge of ecophysiological responses in relation to foraging effort is crucial to understanding feeding strategies, survival and reproductive trade-offs, as well as to obtain reliable indicators of an excessive workload. We present an integrative approach that examines a suite of ecophysiological parameters in relation to increased workload. We experimentally increased wing loading of 10 Cory's shearwaters *Calonectris diomedea*, a medium-sized pelagic seabird, by adding 45 g extra weight and compared their ecophysiological responses with 10 control birds. Among all the parameters analysed, the only significant response to overloading was a longer foraging trip, a lower rate of mass gain whilst at sea, and an increase in plasma levels of creatine kinase and lactate dehydrogenase activity indicating muscular damage. The analyses on these muscular enzymes open new opportunities to measure the impact of instruments on birds and to understand physiological responses in relation to foraging activity.

Keywords: Foraging activity; Nutritional state; Physiological stress; Stable isotopes

1. Introduction

Foraging activity is a major component of reproductive effort in most of a vertebrate's life. Foraging implies an effort which influences behaviour, reproductive success and physiological condition. In the last decade, foraging ecology has been mainly studied by deploying a wide array of instruments, particularly in seabirds and mammals, despite the potential changes in behaviour resulting from the additional weight and increased drag associated with these external devices (Gentry and Kooyman, 1986; Gaunt and Oring, 1998; Murray and Fuller, 2000; Phillips et al., 2003). Nevertheless, what initially arose as one of the main problems of instrumenting animals has become an experimental manipulations of foraging effort, bringing insights into understanding the impact of foraging costs on flying and diving performance, rate of energy delivery or offspring condition (*i.e.* Boyd et al., 1997; Weimerskirch et al., 2000; Paredes et al., 2005). To examine responses of an increase of foraging effort in free-living animals, researchers have traditionally measured changes in body mass and trip duration, whereas physiological responses have hitherto received little attention (Navarro and González-Solís, 2007). Such responses are crucial to understanding foraging strategies and survival and reproductive trade-offs, as well as to obtain reliable indicators of an excessive workload.

Foraging effort in birds is closely related to the flying exercise. Physiological responses to exercise have been widely studied in sports sciences and in domestic animals (*i.e.* Hinchcliff et al., 1998; Clarkson and Hubal, 2002). While energetic aspects of bird flight are relatively well known (Whittow, 2000), comprehensive studies on ecophysiological responses to an endurance flight are still scarce. Moreover, most existing studies focus on specific parameters and on migration rather than on foraging activity (Guglielmo et al., 2001). In endurance exercise, such as long distance flights performed by many bird species, muscles are damaged, showing an ultrastructural disruption and an increase in levels of specific-muscle enzymes, such as creatine kinase and

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doi:10.1016/j.jembe.2008.01.005

lactate dehydrogenase (Fudge, 2000). Muscular damage can entail difficulties in obtaining enough quantity or good quality food, depleting nutritional condition and consequently it could affect some components of the immune system, such as the T-cell mediated immune response (Field, 2000; Alonso-Álvarez and Tella, 2001). Moreover, effort can provoke a stressful situation by increasing rapidly the levels of corticosterone hormone in plasma (review in Wingfield and Sapolsky, 2003). This hormone has also been directly involved in the regulation of foraging behaviour (Kitaysky et al., 2001; Angelier et al., 2007). In addition, foraging costs can influence diet choice and physiological state, modifying stable isotope signatures of C and N in plasma (Cherel et al., 2005), plasma biochemistry (Jenni-Eiermann and Jenni, 1998), and haematological parameters (Jenni et al., 2006).

Petrels are particularly appropriate to study ecophysiological responses to foraging effort because most species regularly perform sustained flights requiring a great endurance in muscular activity: they engage in long distance trips during several days or even weeks often covering thousands of kilometres (Brooke, 2004; González-Solís et al., 2007). Moreover, the large size of many petrel species allows the extraction of enough blood volume to perform a variety of haematological and biochemical analyses with ecophysiological interest. Here, we present a comprehensive approach on the ecophysiological responses to a workload increase, as indicated by changes in nutritional condition (plasma metabolites and body mass), oxygen carrying capacity (hematology), food resources exploitation (stable isotopes of N and C), muscle damage (creatine kinase and lactate dehydrogenase), immune system state (PHA assay) and physiological stress (corticosterone hormone). For this purpose, we experimentally increased wing loading with an extra weight during one foraging trip of 10 Cory's shearwaters, and compared their ecophysiological responses with 10 control birds.

2. Materials and methods

2.1. Model species

The Cory's shearwater is a colonial pelagic Procellariiform breeding on the northeast Atlantic and Mediterranean islands. Birds nest in rock crevices and burrows under rock or soil. The species shows a high reproductive investment (8 months), long incubation (54 days) and chick-rearing (90 days) periods and a life span of over 30 years. The species show long and slender wings adapted to combine gliding and active flight (Rosén and Hedenström, 2001). Incubation duties are shared by both sexes and when one partner is incubating the other one is foraging (see Thibault et al., 1997 for more details), mainly on areas located hundreds of kilometres from their breeding site (Mougin and Jouanin, 1997; Navarro and González-Solís, 2007).

2.2. Experimental procedure

We conducted the field experiment in Gran Canaria (15°47′ 18″ N; 27°50′41″ E, Canary Islands, Spain) during the incubation period of 2005 (May–July) at a breeding colony of about 150 pairs of Cory's Shearwaters that we were studying since 2002. Among all breeding pairs, we selected 20 females and randomly assigned half of them to the control group and the other half to the experimental group using a random number function (SPSS 15.0, 2006). We monitored the incubation routine (duration of incubation shifts and foraging trips) since the egg-laying (see Fig. 1). We carried out the experiment only on females to avoid potential sex related variability of the response. At the end of one foraging trip (referred as the first foraging trip, Fig. 1) we sampled 2 mL of blood and weighed the 20 females. Among them, the 10 experimental females were overloaded with 45 g of extra mass placed on the right leg using a plastic ring. This extra mass increased about 6% the wing loading (weight divided by wing area) of female Cory's shearwaters (body mass = 0.716 ± 0.05 kg, wing area = 0.13 ± 0.01 m^2, n = 44, authors unpublished data, see Pennycuick, 1989). Afterwards, we continued monitoring incubation routine since each bird returned from the subsequent foraging trip (referred as second foraging trip, see Fig. 1). At the end of the second trip, we sampled again 2 mL of blood, weighed all birds and removed the extra mass of overloaded females. To minimize potential interferences of circadian-rhythms on the variability of blood chemistry values, birds were sampled between 9:00 and 11:00 (GMT). Similarly, to minimize potential effect of manipulation on corticosterone and muscular

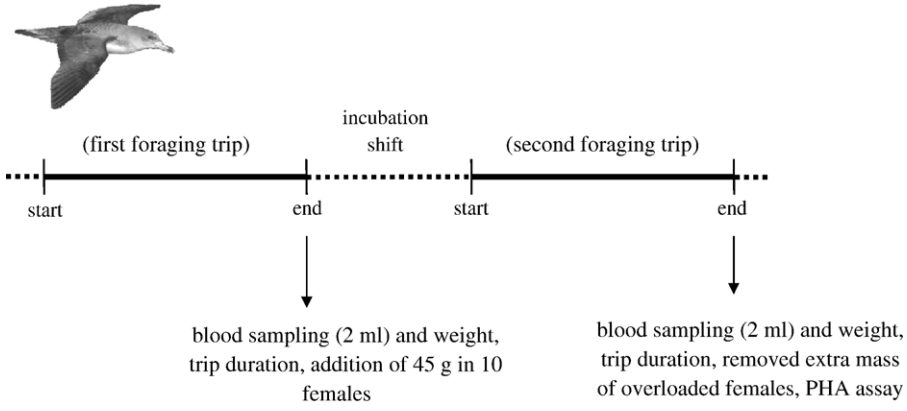

Fig. 1. Sampling protocol conducted throughout the experimental study.