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INTRODUCTION

Working beneath the surface: interplay of biomechanics, physiology and behavioural ecology in diving seabirds

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ABSTRACT: This Theme Section looks at new approaches in the study of seabird foraging ecology, with particular emphasis on the use of recently developed recording devices attached to birds. It includes studies with energy as a theme, such as the energetics of foraging in Magellanic penguins, how dive efficiency varies with depth in emperor penguin, optimality of stroke frequency in diving seabirds, and how using energy to counteract depth-dependent buoyancy may limit pursuit speeds in hunting imperial shags. A more physiological approach is adopted in two studies, one on the dive capacity of emperor penguins and one on planktivorous auklets. Foraging ecology is examined more broadly in a study on the foraging behaviour of breeding thick-billed murres while a modelling approach is used to describe foraging profitability in aucklets (the smallest marine endotherms) feeding on pelagic patches. Finally, consideration is given to bird-attached instrument artefacts in path reconstruction of diving birds using dead-reckoning.

KEY WORDS: Diving seabirds · Biomechanics · Energy efficiency · Foraging ecology · Recording devices

Many seabirds dive — some to more than 100 m — to exploit prey in places where they cannot access oxygen (Kooyman 1989, Boyd 1997) while being subject to the severe physical constraints of buoyancy, drag (Wilson et al. 1992, Lovvorn 2001), temperature (Butler & Jones 1997) and pressure (Kooyman 1989). Physiological adaptations for the parsimonious use of oxygen during submergence have been explored extensively by way of laboratory experiments. Recently developed silicon chip technology now enables us to study physiological and behavioural mechanisms used by free-living, diving seabirds.

The Pacific Seabird Group is dedicated to studying all aspects of Pacific seabirds. The group's most recent conference during February 2009 in Hakodate, Japan, attended by 180 people from 11 different countries, included a symposium on the foraging behaviour and movements of free-living seabirds underwater, with emphasis on data obtained using recording devices attached to birds. This Theme Section considers how data derived from such devices can help us understand seabird foraging ecology through specific case studies, including a keynote presentation (Wilson et al. 2010), five papers presented at the symposium and four

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related papers. The first paper looks at power use during the descent and ascent phases of dives made by Magellanic penguins *Spheniscus magellanicus*, where buoyancy is the primary modulator of energy expenditure (Wilson et al. 2010). The second, by Lovvorn et al. (2010), notes that although the size of the smallest marine endotherms, the auklets, currently makes them unsuitable for an animal-attached device approach, judicious modelling can help make predictions about the way these animals must operate in their cold, marine environment. Small, planktivorous alcids are also the subject of the work by Elliott et al. (2010), which examines how oxygen storage capacity relates to foraging behaviour in two sympatric species, while, in stark contrast, Ponganis et al. (2010) focus on how oxygen store depletion and the aerobic dive limit relate to dive performance in the world's largest diving seabird, the emperor penguin *Aptenodytes forsterii*. Dive performance is also affected by stroke frequency in diving seabirds and in the fifth paper, Mori et al. (2010) consider optimization of this in South Georgian shags *Phalacrocorax georgianus*. This is followed by Shepard et al. (2010), who propose that swim performance is affected by depth-related buoyancy, which may modulate the pursuit speed of foraging imperial shags *Phalacrocorax atriceps* and thus constrain the size of prey taken. How efficiency relates to depth is also the subject of work by Zimmer et al. (2010) using data from emperor penguins, the deepest diving seabirds. The foraging behaviour of the deepest diving alcid, the thick-billed murre *Uria lomvi*, is documented by Ito et al. (2010), while Kokubun et al. (2010) consider the specifics of diving in this species with respect to the thermal structure of the ocean. The final contribution is by Shiomi et al. (2010), and highlights that artefacts in dive path reconstruction can occur if care is not exercised in dead-reckoning studies.

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