Notornis, 2013, Vol. 60: 255-257
0029-4470

SHORT NOTE

Can gannets (*Morus serrator*) select their diving profile prior to submergence?

GABRIEL E. MACHOVSKY-CAPUSKA*
The Charles Perkins Centre and Faculty of Veterinary Science and School of Biological Science, University of Sydney, Sydney, Australia, and Coastal-Marine Research Group, Institute of Natural and Mathematical Sciences, Massey University, Private Bag 102 904 North Shore MSC, Auckland, New Zealand

ROBIN L. VAUGHN-HIRSHORN
BERND WÜRSIG
Department of Marine Biology, Texas A&M University at Galveston, 200 Seawolf Pkwy, Galveston, Texas 77553, United States

DAVID RAUBENHEIMER
The Charles Perkins Centre and Faculty of Veterinary Science and School of Biological Science, University of Sydney, Sydney, Australia

Some predators face the problem of locating and capturing foods while at the same time avoiding a number of environmental hazards and even predation on themselves. These challenges can be more extreme for some species than for others (Raubenheimer 2010). For example, a number of marine predators forage specifically within the air-water interface (Thewissen & Nummela 2008). The need to function in both media imposes major constraints, evolutionary pressures and physiological trade-offs on the individual's morphology, physiology and sensory systems (Kröger & Katzir 2008). It has been suggested that air-breathing marine animals physiologically prepare for dives of a specific depth by loading oxygen prior to submergence (Thompson & Fedak 2001). These animals include penguins, which also apparently prepare their dives before entering the water with the aim of increasing prey capture success (Wilson 2003).

Australasian gannets (*Morus serrator*; hereafter gannets) are highly specialised marine predators that feed mainly on pelagic fish and squid at the air-water interface (Robertson 1992; Machovsky-Capuska *et al.* 2011a; Schuckard *et al.* 2012). Diving often occurs in multi-species-feeding associations (MSFA) that involve high densities of marine predators increasing competition for prey capture (Machovsky-Capuska *et al.* 2011 a, b). Gannets detect prey from the air and perform rapid plunge-dives to capture prey underwater using either U- or V-shaped dive profiles that have a significantly different level of prey capture success (95% vs. 43%, respectively, Machovsky-Capuska *et al.* 2011b; Machovsky-Capuska *et al.* 2012). We were therefore

Received 8 Mar 2013; accepted 17 May 2013
*Correspondence: *g.machovsky@sydney.edu.au*

interested in whether the dive profile of gannets is determined prior to submergence, or whether it evolves in response to events during the aquatic phase of the dive.

The study was carried out in Aug 2005 in Admiralty Bay (40° 57′S, 173° 55′E) in the Marlborough Sounds, New Zealand. A total of 20 min of aerial video footage of gannet dive behaviour was collected synchronously with underwater footage of a dusky dolphin (*Lagenorhynchus obscurus*) feeding bout using a Sony DCR-HC 1000 video camera in an underwater housing (for more details see Vaughn *et al.* 2007; 2008). The dolphin feeding bout occurred in a relatively stationary area which allowed us to simultaneously follow the diving behavior of the gannets. The study was conducted under Texas A&M Animal Use Protocol 2005-48.

Gannets were individually monitored from the moment they penetrated the water to the moment they surfaced. Shallow dives that involve mostly the underwater momentum of the plunge and are short in duration were categorised as V-shaped whereas deep dives that involve a long wing flapping pursuit were referred as U-shaped in accordance with Machovsky-Capuska *et al.* (2011b). The angle of penetration of the water surface and subsequent dive profile underwater were measured only for dives in the plane perpendicular to the camera optical axis, using the water surface as the horizontal plane. Footage was analysed frame by frame using Adobe Premiere Pro CS4 and dive angles were determined using Adobe Photoshop CS4 extended version 11.0.2. For statistical comparisons, data were tested using a *t*- test in *PAWS Statistics* version 18. We report data as mean ± SD.

Our analysis of the angle of entrance into the water for a total of 25 dives showed that during U-shaped dives, gannets entered the water at a significantly steeper angle (70.50 ± 12.30 degrees) than during V-shaped dives (53.70 ± 7.30 degrees; *t*-test, t = -3.84, df = 23, P < 0.001, Fig. 1). These results suggest that dive profiles were determined before the birds had entered the water, suggesting that gannets might predict their dive performance and also confirming that dive depth is assessed in the aerial phase of the plunge dive as suggested by Ropert-Coudert *et al.* (2009). Among seabirds, penguins apparently assess the likelihood of prey capture while they are on the water surface and before they initiate the dives (Wilson *et al.* 1996; Wilson 2003). It has been suggested that U-shaped dives in gentoo penguins (*Pygoscelis papua*) are used to forage in suitable habitats, whereas V-shaped dives are used to assess prey density (Wilson *et al.* 1996). In gannets, the significantly greater proportion of prey capture success in U-shaped than in V-shaped dives suggests that they may also use their dive profile to assess prey density and increase their prey capture rates (Machovsky-Capuska *et al.* 2011b). These results demonstrate that gannets, like penguins, are also able to efficiently make complex decisions that enable them to maximise the time they spend foraging.

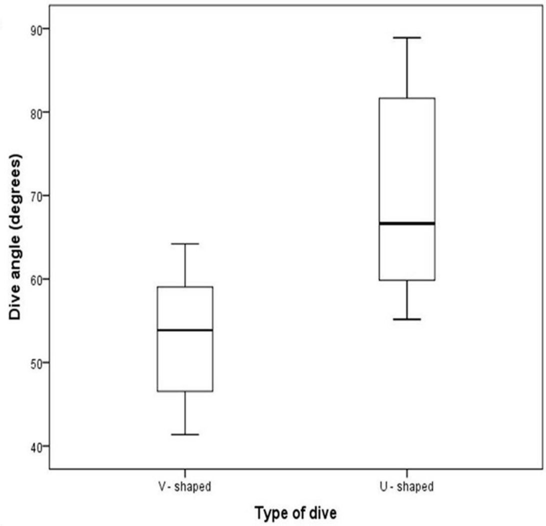

Fig. 1. Dive angles relative to the horizon during V-shaped and U-shaped dives (n=25) in Australasian gannets (*Morus serrator*). Box plots show the medians, 25% and 75 % quartiles and error bars, which represent standard deviations.

Birds have evolved complex visual systems that play an important role in orientation and foraging (Aidala *et al.* 2012). Although gannets are visual predators (Lee & Reddish 1981; Machovsky-Capuska *et al.* 2012) that are able to see in the violet-sensitive range of the spectrum (Machovsky-Capuska *et al.* 2011c), it is still unclear how their visual mechanisms enable them to detect prey from the air. Further studies are needed to understand the decision making process in gannets while foraging in complex marine environments.

ACKNOWLEDGEMENTS

We thank D. and L. Boulton and numerous volunteers for assistance in the field, and Texas A&M University Department of Wildlife and Fisheries Sciences, Texas A&M University at Galveston's Department of Marine Biology and the New Zealand Department of Conservation, Marlborough District Council. D.R. and G.M.C. are recipients of a grant from the Massey University Research Fund.

LITERATURE CITED

Aidala, Z.; Huynen, L.; Brennan, P.L.R.; Musser, J.; Fidler, A.; Chong, N.; Machovsky-Capuska, G.E.; Anderson, M.G.; Talaba, A.; Lambert, D.; Hauber, M.E. 2012. Ultraviolet visual sensitivity in three distinct avian lineages: paleognaths, parrots, and songbirds. *Journal of Comparative Physiology A 198*: 495-510.

Kröger, R.H.H.; Katzir, G. 2008. Comparative anatomy and physiology of vision in aquatic tetrapods. In: *Sensory evolution on the threshold: Adaptations in secondarily aquatic vertebrates* (Ed., Thewissen, J.G.M.; Nummela, S.). Berkeley, Los Angeles: University of California Press, 121-147 pp.

Lee, D.N.; Reddish, P.E. 1981. Plummeting gannets: a paradigm of ecological optics. *Nature 293*: 293-294.

Machovsky Capuska, G.E.; Dwyer, S.L.; Alley, M.R.; Stockin, K.A.; Raubenheimer, D. 2011a. Evidence for fatal collisions and kleptoparasitism while plunge diving in Gannets. *Ibis 153*: 631-635.

Machovsky Capuska, G.E.; Vaughn, R.L.; Würsig, B.; Katzir, G.; Raubenheimer, D. 2011b. Dive strategies and foraging effort in the Australasian gannet *Morus serrator* revealed by underwater videography. *Marine Ecology Progress Series 442*: 255-261.

Machovsky-Capuska, G.E.; Huynen, L.; Lambert, D.; Raubenheimer, D. 2011c. UVS is rare in seabirds. *Vision Research Journal 51*: 1333-1337.

Machovsky-Capuska, G.E.; Howland, H.C.; Vaughn, R.L.; Würsig, B.; Raubenheimer, D.; Hauber, M.E.; Katzir, G. 2012. Visual accommodation and active pursuit of prey underwater in a plunge-diving bird: the Australasian gannet. *Proceedings of the Royal Society of London Series B: Biological Sciences 279*: 4118-4125.

Raubenheimer, D. 2010. Foraging modes. In: Breed, M.D.; Moore, J. (Ed.), *Encyclopedia of animal behaviour, Vol. 1.* Oxford: Academic Press, 749-758 pp.

Ropert-Coudert, Y.; Daunt, F.; Kato, A.; Ryan, P.G.; Lewis, S.; Kobayashi, K.; Mori, Y.; Grémillet, D.; Wanless, S. 2009. Underwater wingbeats extend depth and duration of plunge dives in northern gannets (*Morus bassanus*). *Journal of Avian Biology 40*: 380-387.

Robertson, D. 1992. Diet of the Australasian gannet *Morus serrator* (G.R. Gray) around New Zealand. *New Zealand Journal of Ecology 16*: 77-81.

Schuckard, R.; Melville, D.; Cook, W.; Machovsky-Capuska, G.E. 2012. Diet of the Australasian gannet (*Morus serrator*) at Farewell Spit, New Zealand. *Notornis 59*: 66-70.

Thewissen, J. G. M.; Nummela, S. (Ed.) 2008. *Sensory evolution on the threshold: Adaptations in secondarily aquatic vertebrates*. Berkeley, Los Angeles, London: University of California Press, 358 pp.

Thopson, D.; Fedak, M.A. 2001. How long should a dive last? A simple model of foraging decisions by breath-hold divers in a patchy environment. *Animal Behaviour 61*: 287-296.

Vaughn, R.L.; Shelton, D.E.; Timm, L.L.; Watson, L.A.; Würsig, B. 2007. Dusky dolphin (*Lagenorhynchus obscurus)* feeding tactics and multi-species associations. *New Zealand Journal of Marine and Freshwater Research 41*: 391- 400.

Vaughn, R.L.; Würsig, B.; Shelton, D.S.; Timm, L.L.; Watson, L.A. 2008. Dusky dolphins influence prey accessibility for seabirds in admiralty bay, New Zealand. *Journal of Mammalogy 89*: 1051-1058.

Wilson, R.P.; Culik, B.M.; Peters, G.; Bannasch, R. 1996. Diving behaviour of gentoo penguins, (*Pygoscelis papua*): factors keeping dive profiles in shape. *Marine Biology 126*: 153-162.

Wilson, R.P. 2003. Penguins predict their performance. *Marine Ecology Progress Series 249*: 305-310.

Keywords seabirds; *Morus serrator*; dive behaviour; dive profiles; New Zealand