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Short communication

Evidence for fatal collisions and kleptoparasitism while plunge-diving in Gannets

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Plunge-diving is a highly successful strategy for dealing with the challenges confronting birds feeding on pelagic prey. We tested for evidence of fatal injuries due to collision between conspecifics in plunge-diving Australasian Gannets *Morus serrator* and Cape Gannets *Morus capensis*, respectively, by performing post-mortem examinations of carcasses recovered from New Zealand waters and analysing video footage of Cape Gannet foraging events from South Africa. We found evidence of accidental collisions between Gannets and also observed a case of attempted kleptoparasitism, in which a diving Cape Gannet targeted a previously captured fish in the beak of a conspecific.

Keywords: accidental collisions, Australasian Gannet, Cape Gannet, injuries, kleptoparasitism, plunge-diving.

Pelagic prey of seabirds are able to evade predation by descending to depths beyond the reach of diving birds. Among the adaptations that have evolved for dealing with these challenges is plunge-diving. This is a highly specialized foraging technique, which often takes place in high-density assemblages of conspecific and heterospecific predators, in which the bird locates prey from the air and then plunges at high speed into the water for pursuit and capture (Cunningham 1866). Plunge-diving provides the advantage of surprise (Johnston 1989), by helping to prevent prey descending beyond reach, and is considered to be one of the most accurate foraging methods (Wanless *et al.* 2005). However, some authors have also noted possible disadvantages associated with plunge-diving. Feeding in high-density assemblages can involve fierce competition (Camphuysen & Webb 1999), and contact with the water at high dive speeds can be hazardous (Zillmer 2003), particularly for younger, less experienced birds (Tator *et al.* 1981).

An additional hazard associated with this foraging strategy is that diving at high speeds into dense assemblages of conspecific and heterospecific predators, sometimes in poor visibility, presents the risk of collision and associated injury or death. There is, furthermore, a two-fold risk of collision, because a given bird is at risk of both colliding and being collided with. Unintentional collisions in the water column have been reported from high-density feeding assemblages of water-fowl (Bailey & Batt 1974). Surprisingly, however, we are not aware of any existing records for any species of such collisions leading to injuries or death.

Here we report a study in which we tested for evidence of injuries due to collision in two plunge-diving seabirds, the Australasian Gannet *Morus serrator* and Cape Gannet *Morus capensis*. These birds feed in large groups (Nelson 1978), usually in multi-species feeding associations (MSFAs) involving dolphins *Delphinus* spp. and Bryde's Whales *Balaeonoptera brydei* (Burgess 2006), and are therefore at risk from this type of injuries. Owing to the difficulties involved in detecting collisions by direct observation, we analysed video footage of Gannet foraging events from South African waters and performed post-mortem examinations of carcasses recovered from New Zealand waters.

MATERIAL AND METHODS

Gannet carcasses

During 2009 and 2010, 50 Australasian Gannet carcasses were opportunistically collected from the waters of the Hauraki Gulf, New Zealand. Gannets were inspected for signs of injury due to collision while plunge-diving, including physical injuries to the beak, head or neck. Photographs were taken of any such injuries, and the birds were subjected to post-mortem examination following avian necropsy protocols (Work 2000). Stomach contents were analysed and fish were removed from the oral cavity, oesophagus and stomach for species identification. Otoliths were isolated and diagnostic features were used to enable identification to the lowest possible taxonomic level using published guides (Smale *et al.* 1995) and the reference collection

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held at Massey University, Albany. Digestion codes described in Meynier *et al.* (2008) were assigned to retrieved fish.

Video footage analysis

Only aerial footage of Australasian Gannets plunge-diving in the Hauraki Gulf was included in this behavioural analysis. A total of 40 min of high-resolution video footage was collected in October 2009 using a Canon XH A1S handycam with 20-mm zoom on board *Dolphin Explorer*, a 20-m dolphin tour catamaran, at 5 m observer eye-height. Additionally, 10 min of aerial and 15 min of underwater video footage (25 frames / s) of Cape Gannet foraging was analysed frame by frame using ADOBE PREMIERE PRO CS4. This footage, collected on 4 June 2008, 24 and 30 June 2009, and 8 July 2009 from the waters of Port Saint Johns, Eastern Cape, South Africa, was loaned from Earth-touch (http://www.earth-touch.com). The following categories of accidental collisions were recorded: (1) Gannets colliding with Gannets (G-G), or (2) Gannets colliding with Sharks, Whales and/or Humans (G-SWH). The G-G category was classified into two sub-categories: (a) collision while powered by underwater momentum alone (i.e. no wing flapping), or (b) collision during underwater wing flapping. Numbers of Gannets diving were recorded to estimate the frequency of accidental collisions.

RESULTS

Gannet carcasses

Two of the 50 Gannet carcasses examined had injuries consistent with death due to accidental collision. Both carcasses were found floating in the water, one on 2 May (G2M) 2010 (G17M) and the other on 17 May 2010 (at 36°35.409′S, 175°01.369′E and 36°34.030′S, 175°20.400′E, respectively). The carcasses considered to be fresh, based on the presence of eye moisture and absence of rigor mortis (Stockin *et al.* 2007). The necropsy of bird G2M revealed a circular wound 3–4 mm in diameter, penetrating approximately 3.5 mm into the left dorsal side of the cranium (Fig. 1a). This injury extended through the cranium into the meninges of the right cerebral cortex and cerebellum, producing peripheral haemorrhaging and a severely reddened left frontal lobe (Fig. 1b). The peripheral diameter of the wound closely fitted the circumference of the bill at 3.5 mm caudal to the tip of an adult Australasian Gannet (Fig. 1c), suggesting penetration by a Gannet bill as a likely cause of the injury. A large Jack Mackerel *Trachurus novaezelandiae* measuring 25 cm occupied almost the entire oesophagus from immediately below the pharynx caudally, while a second smaller (15 cm) fish of the same species was present in the proventriculus. The fish were intact with no flesh digested, suggesting that they were ingested shortly prior to the Gannet's death.

Post-mortem examination of bird G17M revealed a 3–4-mm-diameter × 4-mm-deep circular penetrating wound in the left side of the neck (Fig. 2). The region of the first cervical vertebra connected to the occipital side of the skull was severely reddened, containing a 6 × 10-mm-wide area of peripheral haemorrhaging. Two fresh and undigested Pilchards *Sardinops neopilchardus*, measuring 17.3 and 18.4 cm, occupied almost the entire oral cavity and the oesophagus, from immediately below the pharynx caudally. A third large fresh Jack Mackerel was present in the proventriculus and four additional Pilchards, which could not be classified as fresh due to the partial absence of flesh, were found in the stomach.

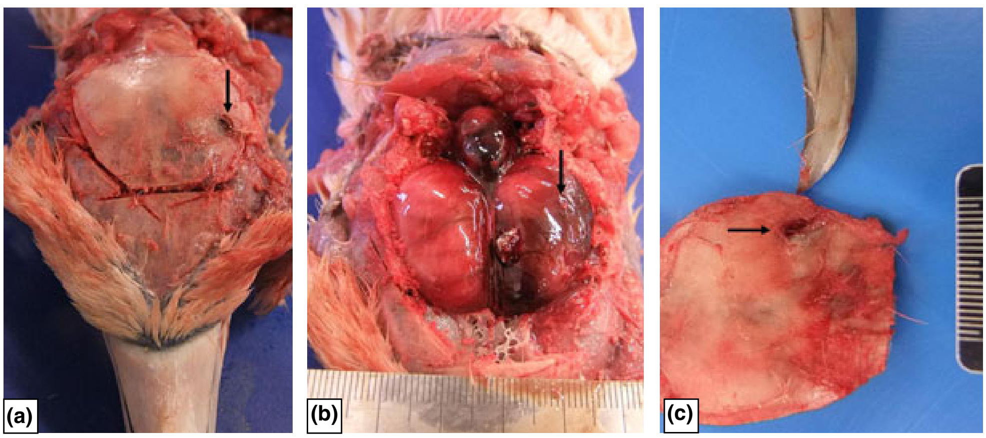

Figure 1. (a) A 3- to 4-mm-diameter circular penetrating wound on the left dorsal surface of the cranium of a male Australasian Gannet *Morus serrator*. (b) Peripheral haemorrhage and a severely reddened left frontal lobe of the brain. (c) The head wound diameter exactly fitted the dimensions of the bill tip of an adult Australasian Gannet at the inferred depth of penetration. Photographs by M. Alley.

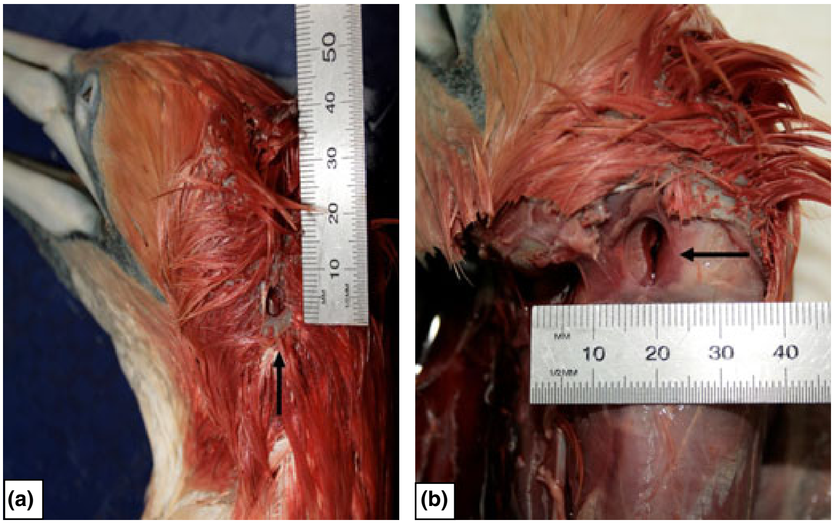

Figure 2. (a) A 3- to 4-mm-diameter circular penetrating wound in the left side of the neck of a male Australasian Gannet *Morus serrator*. (b) The injury extended 4 mm deep into the neck. Photographs by S. L. Dwyer.

Video footage analysis

No accidental collisions were recorded during detailed analysis of aerial video footage of Australasian or Cape Gannets foraging. However, a large number of Gannets were seen manoeuvring and repositioning during the momentum of plummeting into the water, although we were unable to distinguish repositioning associated with prey capture and collision avoidance.

In contrast, analysis of 15 min of underwater footage revealed 3375 Cape Gannets diving and 25 cases of collisions. Of these, 20 were from G-G events and five from G-SWH events. The estimated frequency of collisions per dive was 0.007, while the frequency of collisions between Cape Gannets was 0.006. Of the impacts between Cape Gannets, 18 took place during what appeared to be the wingflapping stage, with two clear cases of collision during the underwater momentum phase (see Supporting Information, Appendix S1).

A descending bird orientating towards a second bird holding a captured fish in its beak provided evidence of kleptoparasitism by foraging Cape Gannets (see supporting Appendix S2). The birds made contact, competing for the previously captured fish. The interaction lasted for 6 s, whereafter both Gannets, still joined at the beak, disappear from the frame. Such events might heighten the risk of accidental collision, through stimulating plunging Gannets to orient towards other birds in the water column.

DISCUSSION

The advantages of plunge-diving as a foraging strategy include the benefit of surprise (Johnston 1989) and the accuracy of approach to prey (Wanless *et al.* 2005). Plummeting into the water is a highly effective strategy, as evidenced by the success of four families of seabirds (Sulidae, Phaenthonidae, Laridae and Pelecanidae) that feed in this way (Nelson 1978). Our analysis of video footage demonstrated that collisions between diving Gannets occur infrequently in MSFAs (0.007 collisions per dive) and necropsy results of carcasses suggest that collisions between foraging Gannets can potentially result in severe head and neck trauma.

Post-mortem analysis of Australasian Gannets G2M and G17M revealed penetrating wounds as might result from the high-speed impact of an adult Australasian Gannet beak. The momentum gained during a plunge-dive allows Gannets to reach a depth of 10 m without wing flapping, at which point they achieve neutral buoyancy (Wilson *et al.* 1992). Velocities generated by this momentum are higher than in the wing-flapping phase (Ropert-Coudert *et al.* 2009) and are likely to be sufficient to cause significant damage to an object upon impact. Furthermore, our observations indicate that these Australasian Gannets were involved in foraging during or shortly prior to death, as would be expected if accidental collision in MSFAs was the cause of the injuries. Complete digestion of fish takes a Gannet between 2 and 6 h (Davies 1956), suggesting that the undamaged fish with skin intact, found in the beak and oesophagus of these birds, were ingested well within this period.

Although we assumed high-velocity impact was required to penetrate the 2.5-mm-thick skull of Australasian Gannet G2M, the penetration to soft tissue observed in the neck of G17M could plausibly have resulted from less force. One possibility is that the bird was injured during aggressive interactions with other

Gannets while foraging below or above or below the water. We did observe, during the analysis of underwater video footage, an aggressive interaction associated with attempted kleptoparisitism. Whether sufficient force to create such a wound could be generated by the neck muscles of a swimming bird is uncertain. Alternatively, this injury might have resulted from the interactive effects of plunge-diving and kleptoparasitism, whether deliberate or accidental.

As far as we are aware, this study is the first to report attempted kleptoparasitism in Gannets. Kleptoparasitism is potentially a profitable way of obtaining food. It might, on the other hand, involve fierce interactions and fighting over prey (Nilsson & Brönmark 1999), with associated fitness costs and even a risk of fatal injuries (Broom & Ruxton 2003).

Aerial video footage analysis indicated no accidental above-water collisions between Gannets, possibly due to adept manoeuvring by the birds in flight. A small number of underwater collisions were recorded among Cape Gannets, with a total frequency of 0.007 accidental collisions per dive. The majority of underwater collisions (23 of 25) were observed during the slower wing-flapping phase of the dive, with only two observed in the fast momentum phase of the plunge. As with the lack of observed aerial collisions, this might reflect the evolution of motion-sensitive mechanisms for collision avoidance. Although these mechanisms in animals have evolved to prevent collisions (Horridge 1987), every fast-moving animal is at risk of injury by impact with objects (Ashby 1960). In Gannets, the risk of accidental collisions is clearly density-dependent (Masotomi *et al.* 2007) and could be related to the very small degree of binocular parallax and the absence of invariance features in their field of view, in which case birds may not be able to detect their height and velocity with sufficient accuracy (Lee & Reddish 1981).

Finally, our analysis revealed several collisions of diving birds with marine mammals and predatory fishes, but post-mortem analysis revealed no cases of damaged beaks, broken skulls or broken necks that might be expected from such collisions. Even though the ratio of fatal injuries due to collisions was two in 50 carcasses, our video footage analysis provided evidence that accidental collisions between Gannets are not uncommon. Our priorities for the future are to use the ongoing survey of Gannet carcasses to obtain a more accurate quantitative estimate of the risk of injury resulting from collisions, and to better understand the relationship between Gannet vision, the detection of prey and the need to avoid dangerous collisions with other foragers.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Accidental collisions between Cape Gannets (see, for instance, the sequence extracted from the video of Cape Gannets while foraging in South African waters). http://www.earth-touch.com/result.php?i=Gannets-steal-the-shoal.

Appendix S2. Kleptoparasitism between Cape Gannets (see, for instance, the sequence extracted from the video of Cape Gannets while foraging in South African waters). http://www.earth-touch.com/result.php?i=Gannets-plunge-deep-to-snatch-sardines-.

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