Headbutting behaviour between sperm whales documented using unoccupied aerial vehicles

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"I turned around and saw him about one hundred rods [approx. 500 m] directly ahead of us, coming down with twice his ordinary speed of around 24 knots, and it appeared with tenfold fury and vengeance in his aspect. The surf flew in all directions about him with the continual violent thrashing of his tail. His head about half out of the water, and in that way he came upon us, and again struck the ship."

—Owen Chase; First mate, Essex

The use of the head by sperm whales (*Physeter macrocephalus*) to push and strike objects has been reported anecdotally since the open-boat whaling of the 18th and 19th centuries. The most famous example is that of *Essex*, a 27m sail-powered whaleship which was reported to have been sunk by two head-on strikes from a large bull sperm whale off the Galapagos in 1820 (Chase, 1821), and which inspired Herman Melville's novel 'Moby Dick'. Other similar accounts of whaling ships being sunk by sperm whales include the sinkings of *Ann Alexander* and *Kathleen* (Jenkins, 1902; Starbuck, 1878). Both contemporaneously with these reports and more recently, there have been scattered reports of intraspecific use of headbutting between sperm whales interpreted as aggression or competition between males (Eguiguren et al., 2023 and references therein). The hypothesis of headbutting combat in sperm whales has been challenged due to the scarcity of reported observations and effects it could have on the sound production & processing organs inside the anterior region of the sperm whale's head (Huggenberger et al., 2016). Mathematical modelling has indicated that the anatomical structures of the head are likely able to withstand the forces involved without significant injury (Panagiotopoulou et al., 2016) but this does not in itself provide evidence for the behaviour occurring in nature. The evolution of the salient features of sperm whale cranial anatomy (i.e., the large junk and spermaceti organ) are adequately explained by outgoing acoustic signal processing functions and associated acoustically mediated sexual selection (Cranford, 1999; Huggenberger et al., 2016). Moreover, to our knowledge, this behaviour has not previously been positively confirmed in sperm whales with supporting documentation, nor described scientifically.

Here, we present 3 UAV- (drone-) based observations of headbutting between young sperm whales in the Azores and Balearic archipelagos (Tables 1 & 2). Observations of these behaviours were collected opportunistically during dedicated fieldwork described in detail elsewhere (Brotons et al., 2024; Burslem, 2024; Burslem et al., 2025). In all cases the behaviour was observed after the UAV was launched for another purpose (e.g. blow sampling or body condition assessment). The UAV was then positioned to document the behaviour and was recovered either when the behaviour had ceased or when necessitated by diminishing battery level. Unless otherwise indicated, all video chunks occur back-to-back in the order indicated by the chunk number after an underscore, for example, when Case2_1.mp4 ends, Case2_1.mp4 starts on the next frame. The resulting videos were downloaded and scored qualitatively to describe the headbutting as well as other co-occurring behaviours which may provide additional context. Suitable stills were isolated from the footage and analysed using established photogrammetry methods (Torres and Bierlich, 2020) to establish lengths of the whales relative to each other and their head:body length ratio, intended to help distinguish mature males from other life-history classes. Head measurements were taken from the tip of the rostrum to the depression where the case attaches to the skull using the eyes as an additional reference, where visible (Huggenberger et al., 2016). Videos and associated photogrammetry measurements and behavioural audits are available as digital supplementary information through OSF (*'Headbutting behaviour between sperm whales documented using unoccupied aerial vehicles: digital supplementary information'*, http://doi.org/*10.17605/OSF.IO/GUDBK)*.

Table 1. Key summary information on each observation event

Case	Whale	Sex	Sex cue	Relative length	Absolute length (approx. m)	Head: total length ratio	Platform and frame rate	Synchronized altimetry available
Case 1	1	U	-	0.99	7.4	0.26	DJI Phantom 3 (24 fps)	Barometric
	2	U	-	1	7.5	0.23		
	3	U	-	1.16	8.7	0.26		
Case 2	1	M	Penile extension	1	-	0.22	DJI Phantom 4 Pro (24 fps)	None
	2	M	Penile extension	1.02	-	0.24		
	3	F	Mammary slits - Case2_1.mp4 at 00:45	0.78	-	0.21		
Case 3	1	M	Genital slit; Case 3_2.mp4 2:48	1	-	0.26	DJI Mavic pro (30 fps)	None
	2	U	-	1.07	-	0.28		

Table 2. Headbutting contacts visible in video recordings
Closing velocity was not calculated for Case 3.2 because the contact between animals occurred at an oblique angle while the whales were still turning towards each other, so closing velocity was not indicative of force delivered.

Case	Time in video	Type	Whale(s) involved	Approx closing velocity at impact (m/s)	Associated behaviours
1	09:19, Case1.mp4	Head-head	1,2	2.2	Codas, buzzing, fast clicktrains, moaning, rasping, jaw gaping, rolling, surface travel
2	07:39, Case2_3.mp4	Head-body	1,3	3.6	Jaw gaping, rolling, penis extension, surface travel
3.1	03:03, Case3_1.mp4	Head-head	1,2	1.5	Jaw gaping, peduncle strike, rolling, surface travel
3.2	01:53, Case3_2.mp4	Head-head & head body	1,2	-	
3.3	01:54, Case3_3.mp4	Head-head	1,2	0.8	

The first example (12 Aug 2020, Azores, digital supplementary folder 'Case 1') involved two individuals (hereafter whales 1 and 2) of similar size and one larger individual (whale 3). The larger animal was not involved in headbutting or any other kind of body contact during our observation period (Figs. 1 and 2) but was bearing a DTag which recorded the acoustic behaviour of all three animals. The acoustic recording from the tag was synchronised with the video from the UAV data using OpenShot Video Editor (OpenShot, n.d.). To synchronise drone footage with DTag recorded audio, we identified conspicuous visual cues that corresponded with audio, pressure or accelerometery data recorded by the tag (e.g., waves breaking on the tag, the tag moving between air and water, or the tagged animal making identifiable movements such as rolling or diving). Because the tag remained on the whale while the drone had to return to the research vessel for replacement batteries, the resulting synchronised video (with recorded sound) contains periods with acoustic but not video recordings. To preserve synchronisation, such periods are represented by a black screen in the combined recording file (Case1.mp4). As in this case synchronised barometric altimetry was available, we were able to estimate the absolute length of all three whales using established photogrammetry methods. Still images were taken using the same DJI Phantom 3 used to record video, with the camera pointing straight down. Height was obtained from the metadata embedded in each image and derived from the drone's barometric altimeter and adjusted for known take-off height (mean height 9.7 m). Three photos for each animal were selected based on established quality scoring criteria (Christiansen et al., 2016), and measurements performed in Arago J (Aleixo et al., 2020). The arithmetic mean of the three measurements was used as the estimated size for each individual (Table 2). Sex could not be positively identified but head:total body length ratios were consistent with either females or immature males (Table 1). The headbutting behaviour took place after a period of at- and near-surface swimming during which coda exchanges and rapid click trains (faster than regular clicking but slower than a buzz; Case1.mp4 and accompanying acoustic audit) were audible on the tag at received levels and rate of overlap at times indicating they were likely to be coming from all three whales. Whales 1 and 2 swam towards each other at the surface and collided head-to-head (Fig. 3), before whale 2's head made contact with the body of whale 1. This was followed by another period of underwater movement and coda production.

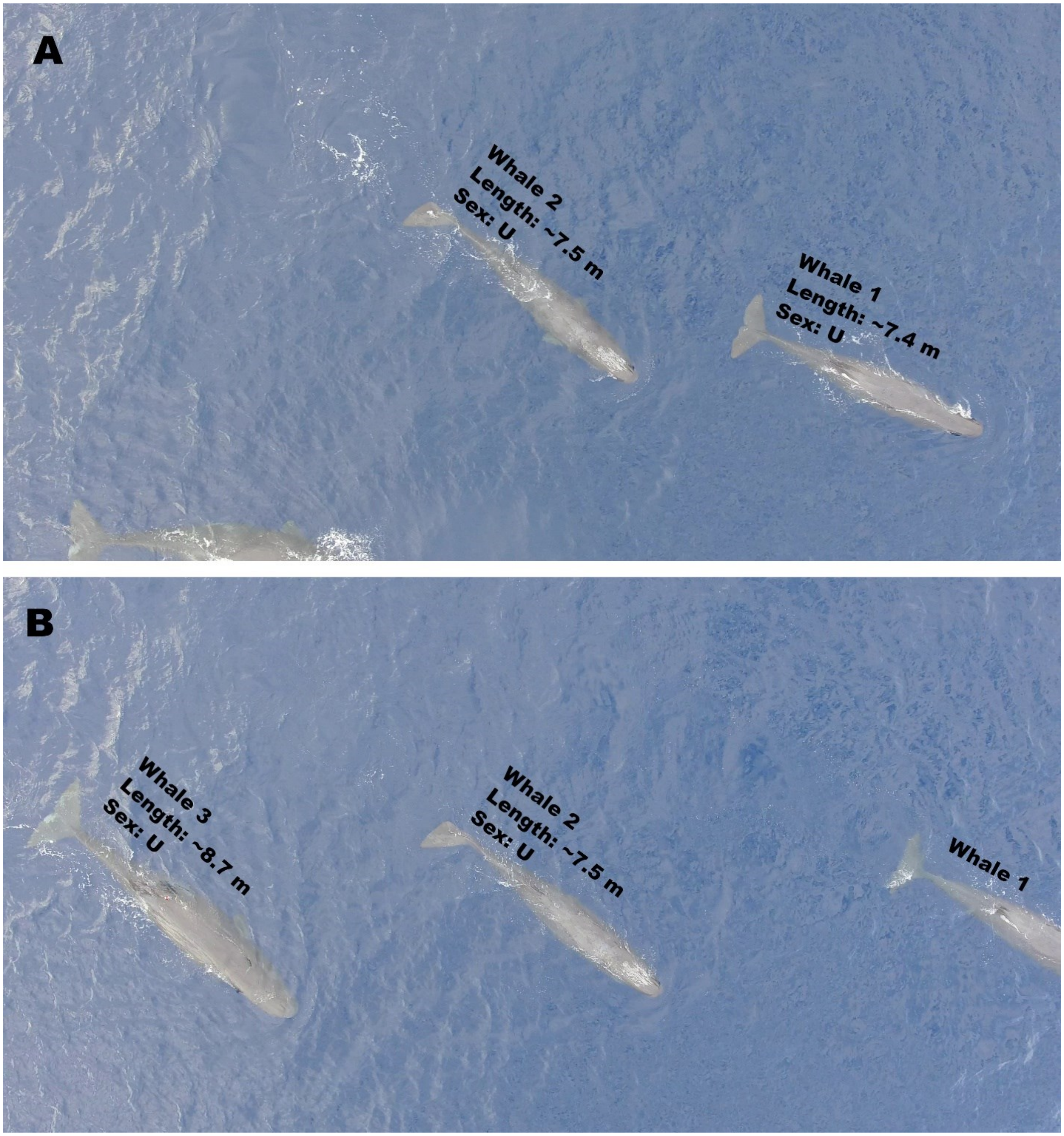

Fig 1. Size comparison among individual whales observed in Case 1.
A: Comparison of whale 1 and 2 (note head colouration and missing half of tail fluke). B: Whales 2 and 3.

Fig 2. Head-to-head contact between the whales 1 and 2 at 09:19 in Case 1.mp4.

In the second example (19 August, 2022, Balearics, digital supplementary folder ‘Case 2’) the group consisted of two young males these whales extended their penises but had relatively low head:body length ratios (Table 1), consistent with incomplete development of secondary sexual dimorphism (Nakamura et al., 2013)and a smaller female (Fig. 3). In this case the headbutting occurred after a period of surface activity with the males repeatedly diving under each other and surfacing next to the female, headbutting was performed by one of the males on the female. This impact appeared directed (whale 1 deviated from its heading to strike whale 3) and to involve significant force: the midline posture of whale 3’s body was visibly displaced by the impact. Just before whale 1 made contact with whale 3, whale 2 abruptly deviated course to join whales 1 and 3. Following this interaction whale 3 left the group and was not followed by whales 1 or 2, which continued to interact at the surface.

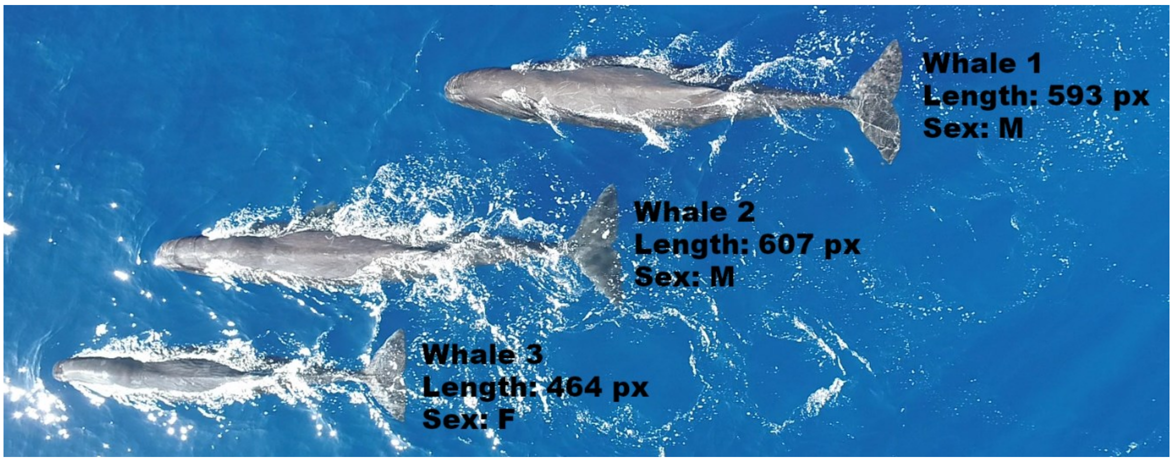

Fig 3. Size comparison among individual whales observed in Case 2

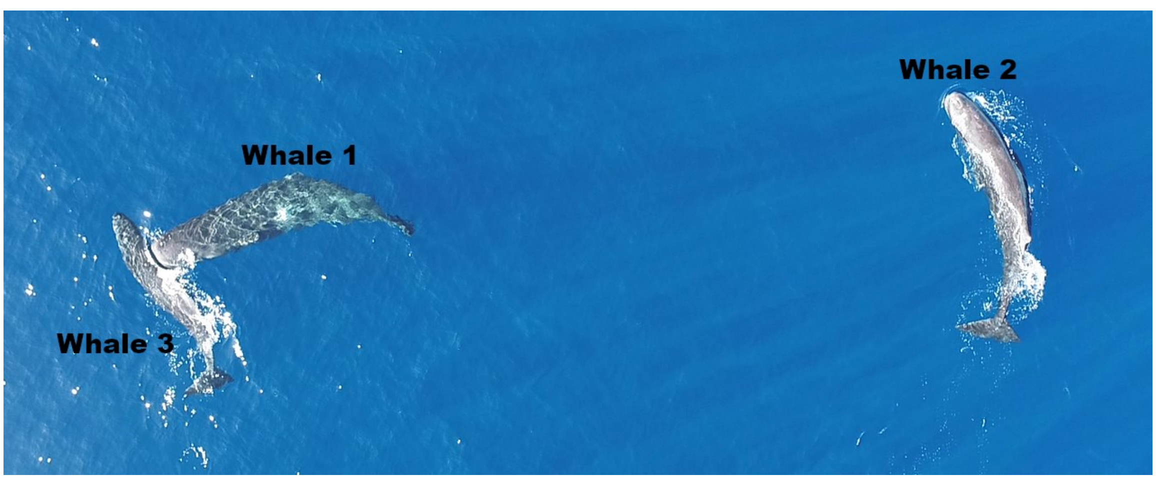

Fig 4. One of the males (whale 1) headbutting the female (whale 3) at 07:39 in video Case2_3.mp4 (Digital supp. info)

The third example (28 July 2022, Azores, digital supplementary folder 'Case 3') occurred in a group of two sperm whales, with the only other marine mammal present being a solitary small delphinid (likely

Tursiops truncatus or *Stenella frontalis*). Neither animal extended its penis and the genital slit was only visible for whale 1 but the head:total length ratio of whale 2 (0.28) would be unusually high for a female, suggesting that it was also a male. This case involved several head-head/body contact events of varying force with whale 1 repeatedly initiating surface/underwater travel and being followed and re-approached by whale 2 as well as repeated striking to the head of whale 2 by the peduncle by whale 1 (02:47, case 3_2.mp4)

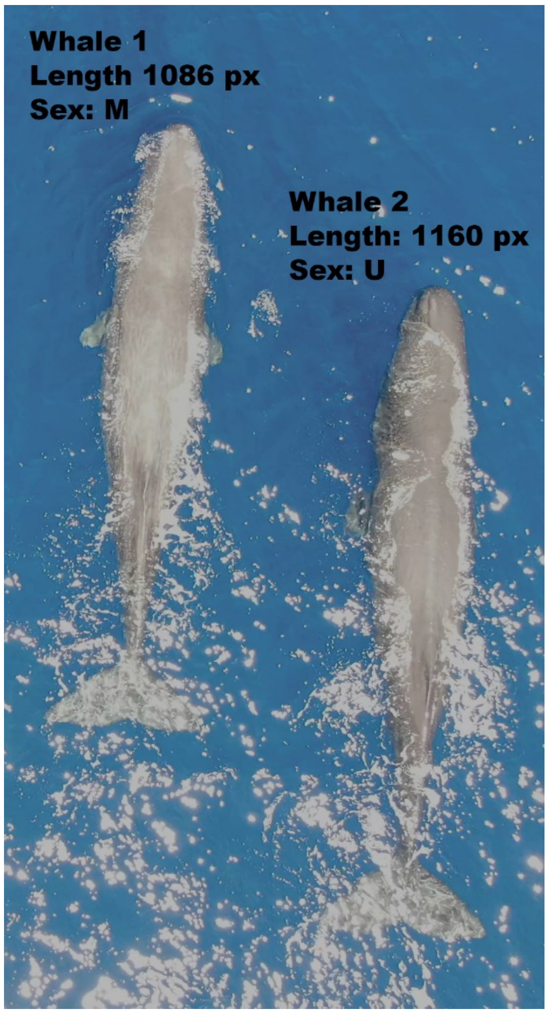

Fig 5. Size comparison among individual whales observed in Case 3.

This image has been lightly post-edited to correct overexposure.

Fig 6. Head-head contact between whales in Case 3.

Occurs at 01:54 in video Case3-3.mp4 (Digital supp. info)

Observed examples included both head-head and head-body impacts, the apparent forces of which ranged from mild to considerable (closing speed 0.8-3.6 m s^{-1}, Table 2). The maximum closing speed was observed in case 2 and, assuming the allometric mass equation of Lockyer et al (1976) and a conservative impact delivery distance of 1m (neglecting any post-impact thrust and velocity), corresponded to a force of approximately 200 kN. Under the same assumptions a large (17m) male closing at the same speed would deliver approximately 1000 kN, which is in excess of the peak forces hypothesised in physical simulation work on the topic (Panagiotopoulou et al., 2016). Thus, in our interpretation, case 2 demonstrates that sperm whales do strike with force using the head while cases 1 and 3 provide additional context regarding, for example, head-first orientation and contact as a focus of social, agonistic and/ or rough play interactions in young sperm whales. Common behaviours associated with head-head/body contact included jaw opening and rolling, which are behaviours commonly performed by sperm whales in social contexts (Whitehead, 2003 & references therein). In case 1, where acoustic behaviour was recorded, the presence of codas and fast click trains at the surface also suggest a background of social interaction. In case 3, one whale was observed using its peduncle to strike the other, a behaviour associated with antagonistic interactions between male humpback whales (Tyack and Whitehead, 1982). Of the individuals seen performing the behaviour where there was any indication of the likely sex of individuals all were known or putative males. In case 2 the 2 males displaying their penises prior to the event may hint at a (proto) sexual context. The behaviour was directed at both putative/known males and a smaller female. Potential explanations for the behaviour include (primary or displaced) aggression, competition or 'rough play' which may itself form a precursor to the more strongly antagonistic headbutting contests involving large males described by observers (Panagiotopoulou et al., 2016). Rough play is thought to help young animals prepare for and practice (and thus predict) adult competition, courtship, and/or sexual behaviour in several mammalian taxa (Ahloy Dallaire and Mason, 2017; Marley et al., 2022), including cetaceans (Kuczaj and Eskelinen, 2014).Competitive behaviour in adults is often 'rehearsed' during rough play between immature animals, so observations of young and juveniles can provide important insights into function underlying observed behaviours. For example, some of the relatively gentle interactions observed here (e.g., cases 1 and 3) may represent attenuated forms of otherwise similar antagonistic (e.g., competitive or coercive) behaviours hypothesised in adult male sperm whales (e.g. Carrier et al., 2002; Panagiotopoulou et al., 2016).

Whatever its ultimate or 'intended' function, forceful headbutting behaviour by immature males directed towards other, much smaller members of the social group (e.g. Case 2) may be expected to be detrimental to group cohesion, which is thought to be maintained by communal care in sperm whales (Gero et al., 2013). By provoking a negative response from adult females in this matrilineal societal structure, such behaviour could potentially be a contributory factor in the transition from the social to solitary life history state seen in young male sperm whales (Gero et al., 2013; Whitehead, 2003). Such a mechanism would be consistent with the increase in aggression- and dominance-focused rough play as males approach sexual maturity which is seen in many mammals (Marley et al., 2022). It would also be consistent with observations of abrupt, adult-female-driven social ostracism of young male sperm whales following which the males leave their natal groups after the birth of young calves (Gero et al., 2013). Such a sequence of events occurs in African elephants (*Loxodonta africana*), a species often considered a terrestrial analogue to sperm whales due to several shared aspects of life history and social structure (Evans and Harris, 2008; Weilgart et al., 1996; Whitehead, 2003). Our observations are essentially anecdotal in terms of sample size, but may nonetheless be valuable for generating biologically plausible hypotheses (Bates and Byrne, 2007), in this case about the background to sperm whale behavioural dimorphism. As they have been documented on video, they are open to alternative interpretation by others, which we would welcome.

Additional observations, particularly involving large males, will be necessary to characterise the behaviour more fully and link its occurrence to specific functional and social contexts. For example, where combined with acoustic data, such observations could allow analysis of what acoustic signals are produced in the context of different physical interactions along the affiliative-aggressive spectrum, potentially helping to elucidate signal content and function (Palagi et al., 2016). While we are not aware of any previous video recordings of headbutting in sperm whales, the fact that all three cases documented here occurred within two years of each other soon after we incorporated regular UAV flights into our fieldwork efforts suggests that this behaviour may be more common than previously thought, but difficult to observe without the overhead viewpoint afforded by the UAV (Eguiguren et al., 2023). This, in turn, suggests that more observations may soon be obtained and raises exciting questions about what as yet unseen near-surface behaviours may soon be observed in free-ranging marine mammals.

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