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► **To cite this version:**

Eric E G Clua, Carl G Meyer. The ‘Mistaken Identity Hypothesis’ for shark bites on humans is an anthropomorphic fallacy. *Behaviour*, 2023, pp.1 - 13. 10.1163/1568539x-bja10196 . hal-04145862

HAL Id: hal-04145862

<https://univ-perp.hal.science/hal-04145862>

Submitted on 29 Jun 2023

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Behaviour (2023) DOI:10.1163/1568539X-bja10196

Behaviour
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Comments/Reflections

Special Issue on Elasmobranch cognition

The ‘Mistaken Identity Hypothesis’ for shark bites on humans is an anthropomorphic fallacy

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Received 10 September 2022; initial decision 27 October 2022; revised 3 November 2022; accepted 10 November 2022; published online 15 February 2023

Abstract

The Mistaken Identity Hypothesis (MIH) interprets shark bites on surfers, swimmers and snorkelers as ‘mistakes’ stemming primarily from similarities in the visual appearance of ocean users and the sharks typical prey. MIH is now widely accepted as fact by the general public and some sections of the scientific community despite remaining unproven. This hypothesis assumes that ‘mistaken’ shark bites on humans result primarily from confusing visual cues and ignores the important role of other senses (e.g. hearing) in discriminating potential prey. A far simpler ‘natural exploration’ hypothesis can reasonably explain not only shark bites that have been characterized as ‘mistaken identity’ events but also those that cannot be reasonably explained by MIH (e.g. shark bites that occur in very clear water). Simply stated, sharks don’t make ‘mistakes’ but instead continually explore their environments and routinely investigate novel objects as potential prey by biting them.

Keywords

bite motivation, investigation exploration process, predation strike, shark attacks, shark behaviour, shark senses.

1. Introduction

The Mistaken Identity Hypothesis (MIH) interprets shark bites on surfers, swimmers and snorkelers as ‘mistakes’ stemming primarily from similarities in appearance of ocean users and the sharks typical prey. For example, Tricas & McCosker (1984) noted that “The shark attacks the surfer because it mistakes his silhouette for that of a seal”. The MIH is appealing because: (i) it is simple to understand and therefore intellectually satisfying, especially for the general public, and (ii) it exonerates the shark from intentional responsibility for shark bites on humans by characterizing such bites as tragic ‘accidents’. However, despite being widely accepted, the MIH remains at best an unproven hypothesis. Here we trace the origins of the MIH, critically evaluate the arguments for and against this hypothesis, and propose more plausible alternative natural explanations for shark bites on humans.

2. Origins and characteristics of the Mistaken Identity Hypothesis

The ‘mistaken identity’ concept was first mentioned by Baldrige (1974) who noted “... some shark attacks (may have) resulted from mistaken identity (black suited diver possibly appearing as a seal, etc.)” and “(it)... is certainly not beyond reason that a person so clad might appear to a shark to resemble a seal or other marine animals upon which the shark might be feeding in a particular area, especially if the water were murky and the range of vision limited.”. However, the term received relatively little attention (44 citations — source: google scholar) until it was again invoked by Tricas & McCosker (1984) (317 citations, source: Google Scholar) and began to enter the mainstream. The specific characterization of the mistaken identity concept as a hypothesis occurred relatively recently, appearing in two theses (Quester, 2013; Chapuis, 2017) and two recent peer-reviewed publications (Clua & Linnell, 2019b; Ryan et al., 2021). NB: Ritter & Quester (2016) mention the mistaken identity ‘theory’ as a synonym for ‘hypothesis’. The MIH is now widely accepted by both the general public and many scientists as is demonstrated by the high percentage (30%) of articles mentioning the MIH as a given fact without providing any further description or proof of the hypothesis (see item 2 in Table 1). In a recent search we found the ‘mistaken identity’ concept mentioned in 50 scientific publications, including 46 peer-reviewed articles or book chapters and four popular articles (see Tables 1 and 2). Many scientific publications dealing with attacks on humans

Table 1.

General description of arguments structuring and supporting the MIH.

Ref. No.	Category	Description	References	Approx.
1	Basic hypothesis	MI occurs because sharks cannot distinguish between objects of broadly similar shape due to low visual acuity	Baldrige (1974); Tricas & McCosker (1984); McCosker (1985); Ellis & McCosker (1991); Anderson et al. (1996); Burgess & Callahan (1996); McCosker & Lea (1996); Johnson (2006); McCosker & Lea (2006); Ihama et al. (2009); Burgess et al. (2010); Gore et al. (2011); West (2011 (2015); Lapinsky et al. (2013); Tinker et al. (2016); Ryan (2016)	50%
2	No evidence — Fallacy of circular argument	Hypothesis considered as demonstrated (no need to describe nor provide evidence)	Burnett (1998); Dobson (2008); Lamberth (2008); Zartman (2011); Ritter et al. (2013); Frazer-Baxter (2017); Gomez (2018); Roy et al. (2018); Pepin-Neff (2019a,b); Cooper et al. (2021)	30%
3	Facilitating factors to the basic hypothesis	Environmental factors (water turbidity, strong surge, etc.)	Baldrige (1974); Tricas & McCosker (1984); McCosker (1985); Richard & McCosker (1991); Howard & Burgess (1993); Burgess & Callahan (1996); Johnson (2006); Hammerschlag et al. (2012); West (2014, 2015)	30%
4		Wetsuits similar appearance (uniform and black colour, etc.) to pinniped skin	Baldrige (1974); Tricas & McCosker (1984); McCosker (1985); Ellis & McCosker (1991); Burgess & Callahan (1996); Pease (2015)	15%
5		State of petulance' of the shark (mainly young sharks)	Caldicott et al. (2001); Ritter & Levine (2004); Clua et al. (2014); West (2014); Ryan (2016)	10%
6		Proximity of a seal colony (concept of 'site prone')	West (2011)	3%

Table 1.

(Continued.)

Ref. No.	Category	Description	References	Approx.
7	Circumstantial evidence	Bite-and-Spit' behaviour supports the MIH (a shark releases a prey because the taste was unexpected)	Howard & Burgess (1993)	3%
8	Factual demonstration	Computer-based simulations show surfer and pinniped shapes appear similar when visual acuity is low	Ryan et al. (2021)	3%

do not mention the MIH or propose alternative hypotheses. However, the grey scientific literature — including many popular books on sharks — and mass media articles are replete with mentions of the MIH. In this analysis we have voluntarily confined ourselves to publications that can be considered ‘scientific’ and that specifically mention the term ‘mistaken identity’). Among these 50 publications, 72% ($N = 36$) accept the MIH (Table 1) while 38% ($N = 14$) are critical of it (Table 2). We have divided these publications into four categories which respectively mention: i) the hypothesis itself or an alternative hypothesis, ii) factors facilitating the probability or improbability of the hypothesis, iii) indirect evidence (for or against MIH) or iv) a factual demonstration (for or against MIH).

Among publications in favour of MIH, approximately 50% mention and describe the hypothesis (see Table 1). Proponents of MIH suggest ‘mistaken identity’ bites are attributable to combinations of four main factors including environmental conditions (such as turbidity or agitation in the water) (see item 3 in Table 1), the wearing of clothing reminiscent of shark prey (see item 4 in Table 1), a “state of petulance” in the sharks that would facilitate the strike (see item 5 in Table 1) and finally the proximity of the victims to an area inhabited by natural prey (see item 6 in Table 1). However, closer scrutiny suggests that these alleged causal factors may in fact be largely

Table 2.
General description of counter-arguments to the MIH.

Ref. No.	Category	Description	References	Approx.
1	Alternative hypothesis	Exploratory bites are more likely	Compagno (1993); Collier et al. (1996); Clua & Séret (2010); Clua & Reid (2013); Tinker et al. (2015); Ritter & Amin (2017); Roy et al. (2018); Clua & Linnell (2019)	50%
2	Non facilitating factor	Shark visual acuity is better than suggested	Anderson et al. (1996); Strong (1996); Ritter & Levine (2004)	20%
3	Circumstantial evidences	Seals are not natural prey for other shark species that also bite humans	Clua & Séret (2010); Curtis et al. (2012); Clua & Reid (2013); Ritter & Quester (2016)	30%
4		White sharks also bite (but do not consume) objects with no similarities to pinnipeds including sea birds and inanimate objects of a variety of shapes, colors and sizes.	Compagno (1993); Collier et al. (1996); Strong (1996); Hammerschlag et al. (2012)	30%
5		Multimodal nature of shark senses used for predation	Compagno (1993); Gardiner et al. (2014); Chapuis (2017)	20%
6		Other sharks species which do not consume pinnipeds also bite surfers	Ritter & Amin (2018); Clua & Haguenaer (2019)	15%
7		Attacks on surfers also happen in clear waters	Clua & Haguenaer (2019)	8%
8	Factual demonstration	Patterns of attacks on humans differ from those on pinnipeds	Quester (2013); Ritter & Quester (2016); Ritter & Amin (2018)	20%

coincidental. For example, although turbid water is routinely invoked as a cause of mistaken identity bites and some shark bites do indeed occur in turbid waters, the majority of shark bites occur in clear water (see Collier, 1964; Baldrige, 1974; Taglioni et al., 2019). Until recently most neoprene wetsuits were black hence it has not been possible to compare shark bite frequency among subgroups of ocean users wearing wetsuits of different colours to demonstrate any statistically significant higher probability of being bitten by a shark while wearing a black wetsuit (item 4). The ‘state of petulance’ (item 5) results from a confluence of instinct, personality traits (such as boldness and risk taking) and hunger that increases the probability of shark bites but does not prove the validity of the MIH. For example, grey reef sharks (*Carcharhinus amblyrhynchos*) sometimes bite ocean users despite being predators of reef fishes that in no way resemble humans. The density of sharks may simply be higher in areas where their natural prey occur (item #6), hence the probability of a shark bite in such areas might be higher simply because there is a higher probability of encountering a shark in these areas.

The ‘bite-spit-and wait’ behaviour observed in white sharks (Tricas & McCosker, 1984) has been suggested by proponents of MIH as evidence of sharks first mistaking and then abandoning the ‘mistaken’ prey due to an unexpected or inappropriate taste (see item 7 in Table 1). However, this ignores the plausible alternative explanations that such bites may actually be intentional ‘taste tests’ to evaluate the palatability of potential prey (Curtiss et al., 2012, see some atypical events diagrammed in Fig. 10 in Klimley et al., 1996).

3. Virtual tests of the Mistaken Identity Hypothesis (Ryan et al., 2021)

In a recent study, Ryan et al. (2021) used computer simulations to demonstrate that the visual acuity of young white sharks is so low that they may mistake a surfer’s silhouette for that of a pinniped, thus validating the MIH promoted by Tricas & McCosker (1984). However impeccable it may be from a technical point of view, this study is a simplified computer simulation of predator behaviour and does not capture the complex reality of this process in the natural environment. As the authors themselves admit in the discussion, their hypothesis, which is based entirely on low visual resolution, completely ignores the other six senses that a top marine predator —

which has evolved for more than 5 million years in this environment — can use to apprehend its prey. For example, sound likely plays an important role in shark predation (Gardiner et al., 2014) and a recent study showed that pinnipeds porpoising strokes are spectrally and temporally different from the sounds made by paddling surfers (Chapuis, 2017). Therefore, given the array of sensory cues that sharks simultaneously process (Gardiner et al., 2014) it is hard to understand and accept how sharks would mistake a human for a prey such as a pinniped (Chapuis, 2017). Thus, although vision plays an essential role in the surface predation process as demonstrated in some studies (Anderson et al., 1996; Strong et al., 1996), there is no reason to seriously hypothesize, as Ryan et al. (2021) do, that the shark's other senses will be unable to compensate for a potential impairment of sight.

In addition to basing their simulation on vision as the essential sense in the pinniped predation process, Ryan et al. (2021) use the fact that the attack rate of surfers is inversely correlated with the age of white sharks to reinforce their hypothesis. Ryan et al. (2021) postulate without reason or evidence that young sharks have less effective vision than adults and are hence more likely to mistakenly bite surfers. However, they ignore the plausible alternative link between behaviour and ontogenetic development. At around 3 m total length young sharks undergo a dietary shift toward larger prey (Estrada et al., 2006; Hussey et al., 2012) that may make them more likely to explore potential large prey in their environment. Such exploratory/learning behaviour could lead young white sharks to target surfers more often than larger individuals without “making a mistake”.

4. Further criticisms of the MIH

We found 16 publications containing criticisms of the MIH (Table 2). In the earliest example Compagno (1993) notes that “Attacks on surfers are attributed to mistaken identity, because the boards and riders look like seals to us. However, little is known of the white shark's discriminatory powers, and arbitrarily assuming that such attacks are triggered by resemblance to a seal may be misinterpreting the white shark's senses.”. Subsequent authors also criticize the MIH with half of them postulating alternative explanations (Collier et al., 1996; Clua & Séret, 2010; Clua & Reid, 2013; Tinker et al., 2015; Ritter & Amin, 2017; Roy et al., 2018; Clua & Linnell, 2019b) (see item 1 in Table 2). A recurrent (see Anderson et al., 1996; Strong et al., 1996;

Ritter & Levine, 2004) counter-argument to the MIH is that shark vision is not as bad as advocates of the MIH suggest and this fact is supported by several studies of shark visual systems (Lisney et al., 2007; Collin, 2018).

Several authors cite circumstantial evidence that directly contradicts the MIH, such as the fact that; (i) pinnipeds are not yet prey for the sub-adult white sharks that bite surfers (Clua & Séret, 2010; Curtis et al., 2012; Clua & Reid, 2013; Ritter & Quester, 2016) (see item 3 in Table 2), (ii) if a white shark attacked a pinniped with the same low intensity as it bites a surfer or a board, the prey would be barely stunned and definitely not incapacitated, hence would likely get away (Quester, 2013), (iii) if white sharks were mistaking surfers for seals, we would likely see energetically expensive breaching behaviour associated with these interactions (Martin et al., 2005; Semmens et al., 2019) whereas the ‘low-energy’ interactions with surfers are more consistent with energy-saving hunting strategies than typical seal predation behaviour (Watanabe et al., 2019), (iv) white sharks in South Africa frequently bite but rarely consume penguins (Randall et al., 1988; Hammer-schlag et al., 2012) despite millions of years of co-evolution of these species suggesting that these interactions are not simply mistakes, (v) other species of sharks that bite surfers do not consume pinnipeds (Ritter & Amin, 2018; Clua & Haguenaer, 2018) (see item 6 in Table 2), (vi) shark bites often happen in clear water (Clua & Haguenaer, 2018) (see item 7 in Table 2), (vii) sharks use other senses than vision to identify and locate prey during the predation process reducing their probability of making ‘mistakes’ (Compagno, 1993; Gardiner et al., 2014; Chapuis, 2017) (see item 5 in Table 2), and (viii) sharks also bite inanimate objects of various shapes, colours and sizes with no similarities to pinnipeds (Compagno, 1993; Collier et al., 1996; Hammer-schlag et al., 2012) (see item 4 in Table 2). Collectively, these arguments make a compelling logical case against the veracity of the MIH without directly disproving it. However, there is a simple alternative hypothesis that not only explains the shark bites attributed to MIH but also those that cannot be reasonably explained by this hypothesis.

5. Natural investigative/exploratory behaviour is a simple, logical explanation for many shark bites

Sharks are opportunistic predators whose survival and lifetime fitness depends on their ability to optimize their environment and available resources.

Sharks have personalities (Jacoby et al., 2014) with traits such as Shyness/Boldness or Taking/Avoidance of risk that influence their behaviour (Careau et al., 2008) and all share a propensity to explore their environment. This exploratory behaviour is particularly crucial for sharks which lack parental care and thus any vertical transmission of knowledge about prey or hunting — individual sharks must use innate senses and exploration to learn predatory skills by themselves. Despite this natural reliance on exploration and investigation, sharks have a limited capacity to touch and examine objects and thus have little choice but to bite these unfamiliar substrates/objects in order to determine whether they are viable prey.

Although exploration/investigation is clearly crucial behaviour for sharks, most individuals will remain naturally cautious in novel situations with only a few bolder risk-taking individuals likely to bite novel prey (Clua & Linnell, 2019a). This would explain why despite a growing population of surfers and despite drones revealing frequent interactions between sharks and surfers (Butcher et al., 2021), shark bites remain rare events (Ferretti et al., 2015). If sharks were simply mistaking surfers for seals because of turbid water, then attacks on surfers should be far more common than they actually are. The prey exploration hypothesis neatly explains superficial shark bites on humans regardless of the turbidity of the water, the proximity to natural prey colonies or the colour of the victim's attire. The fact that sharks often abandon human victims with superficial wounds after an initial bite suggests is better explained by sharks rejecting novel prey because of low palatability rather than by sharks mistaking humans for another more typical prey (Klimley, 1994; Martin & Hammerschlag, 2012).

Thus, in our opinion, sharks are very well adapted to exploring an environment where they sometimes encounter, and depending on the animal's personality and hunger levels, investigate novel objects such as humans by biting them. External environmental factors (such as water turbidity) or internal factors (other than satiety, such as 'petulance') can certainly have an influence, but only to a limited and marginal extent. Sharks don't make 'mistakes' but instead explore novel objects as potential prey, which may be either abandoned or consumed.

Acknowledgement

Both authors contributed equally to this work. This work was supported by Labex CORAIL and ANR-21-CE03-0004 fundings.

References

- Anderson, S.D., Henderson, R.P., Pyle, P. & Ainley, D.G. (1996). White shark reactions to unbaited decoys. — In: Great white sharks: the biology of *Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, pp. 223-228.
- Baldrige, H.D. (1974). Shark attack: a program of data reduction and analysis. — Mote Marine Laboratory, Sarasota, FL.
- Burgess, G.H. & Callahan, M. (1996). Shark attacks on humans. — In: Great white sharks: the biology of *Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, pp. 457-469.
- Burgess, G.H., Buch, R.H., Carvalho, F., Garner, B.A. & Walker, C.J. (2010). Factors contributing to shark attacks on humans: a Volusia County, Florida, case study. — In: Sharks and their relatives: II. Biodiversity, adaptive physiology, and conservation (Carrier, J.C., Musick, J.A. & Heithaus, M.R., eds). CRC Press, Boca Raton, FL, p. 541-565.
- Burnett, J.W. (1998). Aquatic adversaries: shark bites. — *Cutis* 61: 317-318.
- Butcher, P.A., Colefax, A.P., Gorkin III, R.A., Kajiura, S.M., López, N.A., Mourier, J. & Raoult, V. (2021). The drone revolution of shark science: a review. — *Drones* 5: 8.
- Caldicott, D.G.E., Mahajani, R. & Khun, M. (2001). The anatomy of a shark attack: a case report and review of the literature. — *Injury* 32: 445-453.
- Careau, V., Thomas, D., Humphries, M.M. & Réale, D. (2008). Energy metabolism and animal personality. — *Oikos* 117: 641-653.
- Chapuis, L. (2017). Examining the mistaken identity hypothesis: do sharks mistake the acoustic signatures of humans for Pinnipeds? — In: The acoustic world of sharks. PhD thesis. The University of Western Australia, Perth, WA, Chapter 5.
- Clua, E.E.G., Bescond, P.M. & Reid, D. (2014). Fatal attack by a juvenile tiger shark, *Galeocerdo cuvier*, on a kitesurfer in New Caledonia (south Pacific). — *J. Forens. Legal Med.* 25: 67-70.
- Clua, E.E.G. & Haguenaer, A. (2018). Nonfatal bites by a sicklefin lemon shark *Negaprion acutidens* on a surfer in Makemo Atoll (French Polynesia). — *J. Forens. Sci.* 65: 979-983.
- Clua, E.E.G. & Linnell, J.D. (2019a). Individual shark profiling: an innovative and environmentally responsible approach for selectively managing human fatalities. — *Conserv. Lett.* 12: e12612.
- Clua, E.E.G. & Linnell, J.D. (2019b). Problem individuals among sharks: a response to Neff. — *Conserv. Lett.* 12: e12641.
- Clua, E.E.G. & Reid, D. (2013). Features and motivation of a fatal attack by a juvenile white shark, *Carcharodon carcharias*, on a young male surfer in New Caledonia (south Pacific). — *J. Forens. Legal Med.* 20: 551-554.
- Clua, E.E.G. & Séret, B. (2010). Unprovoked fatal shark attack in Lifou Island (Loyalty Islands, New Caledonia, south Pacific) by a great white shark, *Carcharodon carcharias*. — *Am. J. Forens. Med. Pathol.* 31: 281-286.
- Collier, R.S. (1964). Report on a recent shark attack off San Francisco, California. — *Bull. Calif. Dept. Fish Game* 50: 261-264.
- Collier, R.S., Marks, M. & Warner, R.W. (1996). White shark attacks on inanimate objects along the Pacific Coast of North America. — In: Great white sharks: the biology of

- Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, p. 217-222.
- Collin, S.P. (2018). Scene through the eyes of an apex predator: a comparative analysis of the shark visual system. — Clin. Exp. Optometr. 101: 624-640.
- Compagno, L.J.V. (1993). Great white shark. — Fish Biol. Fish. 3: 188-191.
- Cooper, J.S., Kong, E.L. & Murphy-Lavoie, H.M. (2021). Shark trauma. — StatPearls Publishing.
- Curtis, T.H., Bruce, B.D., Cliff, G., Dudley, S.F., Klimley, A.P., Kock, A. & Lowe, C.G. (2012). Responding to the risk of white shark attack. Global perspectives on the biology and life history of the white shark. — In: Global perspectives on the biology and life history of the white shark (Domeier, M.L., ed.). CRC Press, Boca Raton, FL, p. 477-510.
- Dobson, J. (2008). Shark! A new frontier in tourist demand for marine wildlife. — In: Marine Wildlife and Tourism Management (Higham, J. & Luck, M., eds). CAB International, Cambridge, p. 49-65.
- Ellis, R. & McCosker, E. (1991). Great white shark. — Harper Collins, New York, NY and Stanford University Press, Stanford, CA.
- Estrada, J.A., Rice, A.N., Natanson, L.J. & Skomal, G.B. (2006). Use of isotopic analysis of vertebrae in reconstructing ontogenetic feeding ecology in white sharks. — Ecology 87: 829-834.
- Ferretti, F., Jorgensen, S., Chapple, T.K., De Leo, G. & Micheli, F. (2015). Reconciling predator conservation with public safety. — Front. Ecol. Environm. 13: 412-417.
- Frazer-Baxter, S. (2017). Evaluating the media's role in public and political responses to human-shark interactions in NSW, Australia. — Msc thesis. University of Otago, Dunedin.
- Gardiner, J.M., Atema, J., Hueter, R.E. & Motta, P.J. (2014). Multisensory integration and behavioral plasticity in sharks from different ecological niches. — PLoS ONE 9: e93036.
- Gomez, N. (2018). The shark fin trade.— Msc thesis, California State University Maritime Academy, Vallejo, CA.
- Gore, M.L., Muer, B.A., Lapinsky, M.K., Neuberger, L. & Vander Heyde, B. (2011). Risk frames on shark diving websites: implications for global shark conservation. — Aquat. Conserv: Mar. Freshw. Ecosyst. 21: 165-172.
- Hammerschlag, N., Martin, R.A., Fallows, C., Collier, R.S. & Lawrence, R. (2012). Investigatory behavior toward surface objects and nonconsumptive strikes on seabirds by white sharks, *Carcharodon carcharias*, at Seal Island, South Africa (1997–2010). — In: Global perspectives on the biology and life history of the white shark (Domeier, M.L., ed.). CRC Press, Boca Raton, FL, p. 91-103.
- Howard, R.J. & Burgess, G.H. (1993). Surgical hazards posed by marine and freshwater animals in Florida. — Am. J. Surg. 166: 563-567.
- Hussey, N.E., McCann, H.M., Cliff, G., Dudley, S.F.J., Wintner, S.P. & Fisk, A.T. (2012). Size-based analysis of diet and trophic position of the white shark (*Carcharodon carcharias*) in South African waters. — In: Global perspectives on the biology and life history of the white shark (Domeier, M.L. ed.). CRC Press, Boca Raton, FL, chapter 3.

- Ihama, Y., Ninomiya, K., Noguchi, M., Fuke, C. & Miyazaki, T. (2009). Characteristic features of injuries due to shark attacks: a review of 12 cases. — *Legal Med.* 11: 219-225.
- Jacoby, D.M., Fear, L.N., Sims, D.W. & Croft, D.P. (2014). Shark personalities? Repeatability of social network traits in a widely distributed predatory fish. — *Behav. Ecol. Sociobiol.* 68: 1995-2003.
- Johnson, R.L., Venter, A., Bester, M.N. & Oosthuizen, W.H. (2006). Seabird predation by white shark, *Carcharodon carcharias*, and Cape fur seal, *Arctocephalus pusillus pusillus*, at Dyer Island. — *S. Afr. J. Wildl. Res.* 36: 23-32.
- Klimley, A.P. (1994). The predatory behavior of the white shark. — *Am. Sci.* 82: 122-133.
- Klimley, A.P., Pyle, P. & Anderson, S.D. (1996). The behavior of white shark and prey during predatory attacks. — In: *Great white sharks: the biology of Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, p. 175-191.
- Lamberth, S.J. (2008). White shark and other chondrichthyan interactions with the beach-seine (treknet) fishery in False Bay, South Africa. — *Afr. J. Mar. Sci.* 28: 723-727. DOI:10.2989/18142320609504222.
- Lapinsky, M.K., Neuberger, L., Gore, M.L., Muter, B.A. & Van der Heyde, B. (2013). Shark bytes: message sensation value and emotional appeals in shark diving websites. — *J. Risk Res.* 16: 733-751.
- Lisney, T.J., Collin, S.P. & Bennett, M.B. (2007). Volumetric analysis of sensory brain areas indicates ontogenetic shifts in the relative importance of sensory systems in elasmobranchs. — *Raffles Bull. Zool.* 14: 7-15.
- Martin, R.A., Hammerschlag, N., Collier, R.S. & Fallows, C. (2005). Predatory behaviour of white sharks (*Carcharodon carcharias*) at Seal Island, South Africa. — *J. Mar. Biol. Ass. UK* 85: 1121-1136.
- Martin, R.A. & Hammerschlag, N. (2012). Marine predator-prey contests: ambush and speed versus vigilance and agility. — *Mar. Biol. Res.* 8: 90-94.
- McCosker, J.E. (1985). White shark attack behavior: observations of and speculations about predator and prey strategies. — *Mem. S. Calif. Acad. Sci.* 9: 123-135.
- McCosker, J.E. & Lea, R.N. (1996). White shark attacks in the eastern Pacific Ocean: an update and analysis. — In: *Great white sharks: the biology of Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, p. 419-434.
- McCosker, J.E. & Lea, R.N. (2006). White shark attacks upon humans in California and Oregon, 1993–2003. — *Proc. Calif. Acad. Sci.* 57: 479.
- Pease, A. (2015). Shark attacks: a cultural approach. — *Anthropol. Today* 31: 3-7.
- Pepin-Neff, C.L. (2019a). Considering sharks from a post-jaws perspective. — In: *Flaws*. Palgrave Macmillan, Cham. DOI:10.1007/978-3-030-10976-9_8.
- Pepin-Neff, C.L. (2019b). A response to Clua and Linnell. — *Conserv. Lett.* 12: e12626.
- Quester, A. (2013). Approach directions and bite angles of white sharks, *Carcharodon carcharias*, on surfers based on wound patterns. M.Sc. thesis, University of Vienna, Vienna.
- Randall, B.M., Randall, R.M. & Compagno, L.J.V. (1988). Injuries to jackass penguins (*Spheniscus demersus*): evidence for shark involvement. — *J. Zool.* 214: 598-599.
- Ritter, E. & Amin, R. (2018). The importance of academic research in the field of shark-human interactions: a three-pronged approach to a better understanding of shark encoun-

- ters. — In: Chondrichthyes (da Silva Rodrigues Filho, L.F. & Bráullio de Luna Sales, J., eds). InTech, Rijeka, p. 63-90.
- Ritter, E. & Levine, M. (2004). Use of forensic analysis to better understand shark attack behaviour. — J. Forens. Odontostomatol. 22: 40-46.
- Ritter, E., Amin, R. & Zambesi, A. (2013). Do lunar cycles influence shark attacks? — Open Fish Sci. J. 6: 71-74.
- Ritter, E. & Quester, A. (2016). Do white shark bites on surfers reflect their attack strategies on pinnipeds?. — J. Mar. Biol. 2016: 1-7.
- Roy, M., Plant, M.A. & Snell, L. (2018). A shark attack treated in a tertiary care centre: case report and review of the literature. — Arch. Plast. Surg. 45: 80.
- Ryan, L.A. (2016). A shark's eye view: motion vision and behaviour in apex predators. — PhD thesis, University of Western Australia, School of Animal Biology and Ocean Institute, Perth, WA.
- Ryan, L.A., Slip, D.J., Chapuis, L., Collin, S.P., Gennari, E., Hemmi, J.M., ... & Hart, N.S. (2021). A shark's eye view: testing the 'mistaken identity theory' behind shark bites on humans. — J. Roy. Soc. Interf. 18: 20210533.
- Semmens, J.M., Kock, A.A., Watanabe, Y.Y., Shepard, C.M., Berkenpas, E., Stehfest, K.M., Barnett, A. & Payne, N.L. (2019). Preparing to launch: biologging reveals the dynamics of white shark breaching behaviour. — Mar. Biol. 166: 1-9.
- Strong, W.R. (1996). Shape discrimination and visual predatory tactics in white sharks. — In: Great white sharks: the biology of *Carcharodon carcharias* (Klimley, A.P. & Ainley, D.G., eds). Academic Press, San Diego, CA, p. 229-240.
- Taglioni, F., Guiltat, S., Teurlai, M., Delsaut, M. & Payet, D. (2019). A spatial and environmental analysis of shark attacks on Reunion Island (1980–2017). — Mar. Policy 101: 51-62.
- Tinker, M.T., Hatfield, B.B., Harris, M.D. & Ames, J.A. (2016). Dramatic increase in sea otter mortality from white sharks in California. — Mar. Mamm. Sci. 32: 309-326.
- Tricas, T.C. & McCosker, J.E. (1984). Predatory behavior of the white shark (*Carcharodon carcharias*), with notes on its biology (No. 59 CAL). — Proc. Calif. Acad. Sci. 43(14): 221-238.
- Watanabe, Y.Y., Payne, N.L., Semmens, J.M., Fox, A. & Huveneers, C. (2019). Swimming strategies and energetics of endothermic white sharks during foraging. — J. Exp. Biol. 222: jeb185603.
- West, J.G. (2011). Changing patterns of shark attacks in Australian waters. — Mar. Freshw. Res. 62: 744-754.
- West, J. (2014). Shark attack theories. — Australian Shark Attack File. Report. Available online at https://taronga.org.au/sites/default/files/content/pdf/Shark_Attack_Theories_Paper_2014.pdf.
- West, J. (2015). A review of shark attacks in the Sydney region. — Australian Shark Attack File. Available online at https://taronga.org.au/sites/default/files/content/pdf/Review_of_Shark_Attacks_Sydney_2015.pdf.
- Zartman, A. (2011). Shark sense: getting in touch with your inner shark. — Iuniverse, Bloomington, IN.