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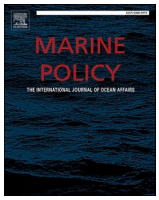

Stakeholder perceptions reveal obstacles and opportunities to change lethal methods of protecting bathers from sharks

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ABSTRACT

Bather protection gear—shark nets and baited hooks—is set to catch and kill sharks to protect bathers at popular swimming beaches. This lethal practice contributes to human well-being and safeguards beach tourism, a valuable income-generator. However, it is costly—financially and environmentally. Here we identify obstacles and opportunities to change this lethal method of bather protection in KwaZulu-Natal, South Africa, by assessing the knowledge of people closely involved in this bather-shark conflict. We conducted semi-structured interviews with 29 stakeholders from various organisations—KwaZulu-Natal Sharks Board which manages the gear, three government levels (local, provincial, national), and tourism and conservation organisations—to identify their perceptions about how the gear works, its advantages and disadvantages, and the possibility of changing this method of protecting bathers. Half the interviewees were unaware that the gear intentionally kills sharks. Barriers to changing the 70-year *status quo* include: mindsets regarding sharks and bather protection in KwaZulu-Natal (compared to other places); government officials' fear of negative consequences of change; politicians prioritising constituents' short-term well-being; lack of proven alternatives; high cost of potential alternatives; challenging surf conditions; and slow progress of innovation. Opportunities included promising technologies, research and education to rectify misconceptions. We recommend assessing the obstacles and opportunities for change to governance structures (institutions, policies, systems) to implement a programme that accelerates the development and testing of alternatives in KwaZulu-Natal, coupled with a well-designed communication campaign. It is crucial to revisit this long-standing bather protection programme and make it safe for both humans and sharks.

1. Introduction

As human populations grow and spread across the globe, human-wildlife conflicts escalate [44], both in the terrestrial and marine realms. Human-wildlife conflicts can be mutually detrimental, often resulting in injuries and/or death to people and animals, and loss of livelihoods, biodiversity, and ecosystem functioning. A prime example is the conflict caused by the threat of human-shark interactions. Many (but not all) interactions between sharks and humans are negative for at least one party—for example, directed fishing of sharks, unintentional catches in fishing gear, competition between sharks and humans for resources, shark bites (previously referred to as "attacks") and the resulting human response [55]. Human fascination with shark bites is high [41], even though the real risk is low [37]. They are low-probability, high-consequence events [8], which makes them quintessential human-wildlife conflicts.

South Africa has exceptionally high shark biodiversity [10] and is a hotspot for human-shark interactions, both positive and negative—it has many non-consumptive shark ecotourism operations [18] and has one of the highest incidences of shark bites [37]. Human-shark conflict has

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been particularly high in the province of KwaZulu-Natal, where a spate of shark bites in the 1940–1950 s resulted in a fishing programme in which gillnets, and more recently baited hooks, are set at popular beaches to reduce the number of sharks [5,6]. Theoretically, reducing the population of sharks close to bathing beaches reduces the probability of negative shark-human interactions and the negative repercussions for coastal communities—the protection programme was not only introduced because of bite events but also the severe negative impact on the tourism economy that followed [13]. In addition, however, non-target species (dolphins, turtles, etc.) are frequently caught and killed incidentally. Therefore, this method of bather protection adds to the list of threats (e.g., overfishing, habitat degradation) that are resulting in a drastic decline in the number of sharks and other large marine species [51,46,34,54]. In fact, sharks are one of the most threatened taxa on the planet [15], and sharks in the Indian Ocean are particularly impacted [34,46]. To reduce the environmental impact of the KwaZulu-Natal (KZN) bather protection programme there has been a steady decrease in the number of nets set and the associated catch (~500 sharks killed annually in 23 km of nets in the 2010 s) compared to previous decades (~1300 sharks killed annually in 44 km of nets in the 1980 s) [6], KwaZulu-Natal Shark Board unpublished data). Yet even on a relatively small scale, fishing can impact large sharks, which grow slowly and are slow to reproduce,[17,55]. As apex predators, sharks are vital for healthy marine ecosystems as their removal may cause community restructuring [42]. For ethical reasons, for biodiversity conservation, and to prevent disruption of ecosystem functioning, we cannot continue to deliberately catch and kill large sharks as a method to reduce the risk to bathers. We need alternative strategies.

Finding a better way to manage the human-shark conflict is imperative. But change is difficult. Successfully managing a conflict requires an understanding of not only the conflict but also the social-ecological system around it [50]. A vital part of this process involves understanding the social dimensions of the conflict. Previous research has addressed the knowledge and perspectives of beach-goers and ocean-users (e.g., [8,20,33], but to date, no one has examined the views of the network of people involved in this bather-shark conflict at a professional (occupational) level.

Here, we investigate the knowledge of and perceptions towards shark nets of stakeholders involved in the bather protection programme in KwaZulu-Natal. The selected stakeholders are those whose occupations intersect with the bather-shark conflict. We draw on discussions held individually with these stakeholders about bather protection generally and the work they do specifically in relation to the management of the bather-shark conflict. This research examined what is being said about three issues: 1) how the shark nets work; 2) the advantages and disadvantages of using shark nets; and 3) the obstacles and opportunities to change the bather protection programme in KwaZulu-Natal. Our ultimate goal was to answer the following question: what are the conditions that hinder, and the conditions that facilitate, changing the use of this lethal method?

2. Material and methods

2.1. The philosophical basis of the research

Our philosophical position was oriented towards critical theory, which aims to challenge and bring about change [38]. We employed "human dimensions of human-wildlife conflict" as our theoretical framework [11], seeking to understand the social and cultural factors shaping the mitigation of shark bites. The research focused on the stakeholders whose work intersects with the bather protection system—that is, the stakeholders who, in their professional (i.e. paid occupation) capacity, engage with the system that has arisen around preventing shark incidents, particularly using lethal bather protection fishing gear (i.e., shark nets and baited hooks). Our broad aim was to understand people's perspectives within this social-ecological system and the research is rooted in a constructionist epistemology, i.e., it assumes that reality is tied to the human experience [40]. We explored the stakeholders' knowledge and perceptions of shark nets, baited hooks, and other methods to protect bathers.

2.2. Data collection and research ethics

We focused our research on the stakeholders who have invested time in their professional capacity to manage, understand and/or mitigate some aspect of the bather-shark conflict. These are people who work in various parts of this social-ecological system and belong to the organisations that are most likely to initiate and/or implement any changes. To identify these stakeholders, we used a combination of key informant and purposive sampling [2]. We started with the staff at the organisation that manages the bather protection operation (the KwaZulu-Natal Sharks Board) and the municipal Beach Manager at Richards Bay (as the municipalities pay the Sharks Board for their services). Richards Bay is one of the 37 beaches in KwaZulu-Natal that has bather protection fishing gear and we selected this focal area for study because more animals are caught there than at other beaches [12]. We asked all interviewees who else they perceived as stakeholders (within and outside of their organisations), these stakeholders' roles, and others we should interview. Based on their suggestions, we invited others to participate. We tried to sample a range of roles within each organisation and at different levels within the organisations' hierarchies.

We conducted all interviews between March 2019 and April 2021. We initially invited 40 stakeholders via e-mail to participate in individually-conducted, semi-structured interviews. Of these, 33 consented, and seven declined or did not respond to the request. We conducted 30 interviews in-person and three virtually. Potential respondents were provided with information as per the ethical procedure required of the University of the Witwatersrand's Human Research Ethics Committee (Non-medical) (Clearance Certificate Protocol H18/09/01).

The interview guide was based on Kansky et al.'s [27] questionnaire, a standard set of survey questions that have been used to understand the context of human-wildlife conflicts. We modified it to be open-ended and more appropriate for the context of our study (Appendix 1, Supplementary Material). We asked respondents about how their work related to the bather protection programme. We asked knowledge-based questions about how the shark nets work and alternative methods to protect bathers. We elicited respondents' opinions about the use of shark nets and possible alternatives. Based on their work, four interviewees did not meet the criterion of sufficient work with the bather protection programme, and although the interviews were continued to completion, their data were not included in the analysis. The final sample comprised 29 respondents.

2.3. Data analysis

All but two of the interviews were voice-recorded and transcribed verbatim. For the two who preferred not to be recorded, notes were taken during the interview and then sent to the interviewees for approval and correction to ensure that their answers had been captured accurately. We formulated codes inductively to analyse the data [16]. During the initial stages of coding, multiple codes were identified to capture as many ideas as possible on three specific subjects of interest:

1. How each stakeholder described the modus operandi of the shark nets
2. What they perceived to be the pros and cons of the current method
3. Any mention of changing the situation or of alternative situations (i.e., bather protection in the past, future or places other than KwaZulu-Natal)

One researcher (S.A.) coded the data, and these codes were assessed by another (J.M-L.). The codes were then reviewed and refined, i.e., we

used debriefing for triangulation [39]. Codes that shared a commonality were grouped into categories [22] which were then identified as obstacles or opportunities to change or neutral (i.e., neither obstacles nor opportunities). Non-neutral categories were then placed within themes. All individual data were anonymised for analysis and presentation.

3. Results

3.1. Stakeholders are diverse

The respondents worked for various governmental and non-governmental organisations. These included the KwaZulu-Natal Sharks Board (n = 3), the Government (Municipal, n = 4; Provincial, n = 3; and National, n = 6), the Provincial conservation entity (Ezemvelo KZN Wildlife, n = 4), five environmental N.G.O.s (one respondent per organisation: WildOceans; Wildlife and Environment Society of South Africa; Endangered Wildlife Trust; South African Association for Marine Biological Research; SharkSpotters). Other organisations included the provincial tourism entity (Tourism KZN, n = 1), a company that develops an alternative method of bather protection (SharkSafe Barrier Pty. Ltd., n = 1); a consortium of marine biologists who work with humpback dolphins in South Africa (The SouSA Consortium, n = 1), and a biologist who necropsied dolphins caught in the shark nets.

3.2. Many stakeholders are unaware of how shark nets work

In describing the modus operandi of the shark nets, we identified three categories of stakeholders' perceptions: shark nets as fishing gear; shark nets as barriers; and those who were unsure. The KwaZulu-Natal Sharks Board respondents, and others (in total: 14 out of 29), described shark nets as fishing gear (e.g. "*They are fishing nets*") or talked about removing, killing, culling or reducing the number of sharks, sometimes linking the reduction in numbers with a reduction of risk (of encounters, bites or attacks) (e.g. "*They are designed to capture sharks and essentially reduce the local population in that area and thereby reduce the risk*."). Most of the remaining respondents (11 out of 29) described the shark nets as barriers (e.g., "*Sharks won't go through them*", "*They stop sharks from coming towards the shore*") though some of them stated that the barrier is permeable (e.g. "*There is still opportunity for sharks to get through that barrier*", "I'm *aware that a lot of sharks get through anyway*."). A few respondents (4 out of 29) talked around the issue without answering the question, including one who admitted: "*I just know they are there*."

3.3. The pros of shark nets were safety and tourism, while the cons were loss of marine life

Two main themes emerged in response to the question, "What are the pros of having shark nets?": tourism and safety. The safety theme included four categories of responses (details and quotes can be found in the Supplementary Material):

1. Perceived safety conferred by the nets;
2. Actual safety conferred by the nets;
3. Both perceived and actual safety;
4. The perception of safety, although actual safety was questioned.

All stakeholders, except three, described the cons of having shark nets as the loss of marine life. There were subtle differences among the answers, categorised as 1) deaths of individual animals or 2) impact on the ecosystem. Within both categories, bycatch was mentioned frequently. (The three interviewees who did not specifically refer to the loss of marine life referred to the non-selective, outdated nature of the shark nets and were thereby indirectly referring to the loss of marine life) (Fig. 1).

3.4. Obstacles pertained to governance and technology, and there were few opportunities

Obstacles to change were divided into two: general obstacles and those specific to alternative methods (Table 1; greater detail and quotes are available in the Supplementary Material). General obstacles pertained to governance and social issues. Related to governance: a) politicians make the decisions and are compelled to demonstrate that their constituents' well-being is their priority. This may result in subjective factors being prioritised over objective facts: "*politics trumps facts*". Although not explicit, it appears short-term human well-being is prioritised over longer-term ecosystem health; b) government officials talked about their personal fears of the unacceptable emotional and/or legal consequences if a shark bite followed any changes they or their organisation had recommended; c) respondents discussed the difficulty of challenging the *status quo*. The social issue respondents talked about was the mindsets of people, sometimes comparing KwaZulu-Natal to other provinces.

Obstacles to change that explicitly related to alternative, non-lethal methods to protect bathers included technological, environmental, and economic issues. Regarding technological issues, nine respondents perceived a lack of proven alternatives and expressed frustration about the slow progress of innovation. Nine respondents noted the challenging

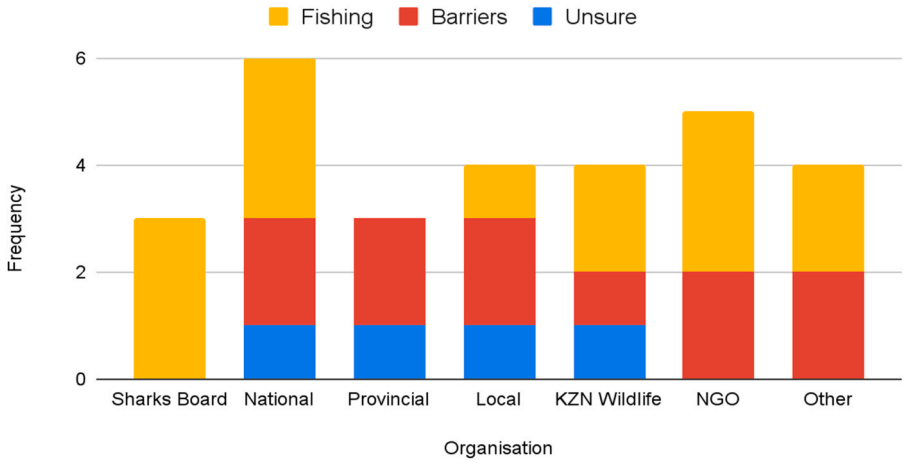

Fig. 1. Knowledge of how shark nets work relative to the number of respondents within each organisation type. The 29 respondents described the shark nets as fishing gear or physical barriers or were unsure how they work. "Other" includes Tourism KwaZulu-Natal (KZN), SharkSafe Barrier Pty Ltd, and university academics.

Table 1
The main categories (mentioned by five or more respondents) within the themes of obstacles and opportunities to change the lethal methods used to protect bathers in KwaZulu-Natal, South Africa, the number of respondents who mentioned each category and the types of organisations they represented.

Theme	Category	Type of issue	n	Organisation types
Obstacles to change (general)	Politicians prioritise short-term well-being	Governance	10	Sharks Board, National, Provincial, Local, KZN Wildlife, NGO, Other
	Government officials fear consequences	Governance	8	Sharks Board, National, Provincial, Local, NGO
	Mindsets (in KZN)	Social	8	National, Local, KZN Wildlife, NGO, Other
	Difficulty changing *status quo*	Governance	6	Sharks Board, National, Provincial, Local, NGO
Obstacles to change (alternative methods)	Lack of proven alternatives	Technology	9	Sharks Board, National, Provincial, Local, Other
	Difficult surf conditions	Physical environment	9	National, Provincial, Local, NGO, Other
	High cost of alternatives	Economic	5	National, Local, KZN Wildlife, NGO, Other
	Slow progress of innovation	Technology	5	National, Local, KZN Wildlife, NGO
Opportunities to change	Education can influence perceptions	Social	9	National, Provincial, NGO, Other
	Research	Technology	7	National, Provincial, Local, KZN Wildlife, NGO
	Promising technologies	Technology	6	National, Provincial, Local, KZN Wildlife, NGO

physical environment along the KwaZulu-Natal coast (especially the large surf) and the high costs of alternatives. Only three categories of opportunities were mentioned (Table 1), these included social opportunities (education and awareness can contribute to influencing people's perceptions), research and technological opportunities (several promising alternatives are being developed).

4. Discussion

We interviewed representatives from the important stakeholder organisations, and our findings reveal that among these diverse stakeholders whose work intersects with the shark nets, directly or indirectly, many were not aware of how the shark nets work. While those directly involved in deploying shark nets describe them as fishing gear—in other words, set to catch and kill sharks—half of the remainder of the interviewed stakeholders mistakenly explained shark nets as barriers that prevent the movement of sharks, or were uncertain about how they work. Discussions around their advantages and disadvantages indicate that stakeholders know that animals die in the fishing gear but some believe the deaths are accidental. Perceived obstacles to changing the current method of bather protection were predominantly social issues (mindsets in KwaZulu-Natal), governance issues (government officials fear consequences, political prioritisation of short-term well-being and the difficulty changing the *status quo*), and logistical issues relating to alternatives (no proven alternatives, the high cost of potential alternatives, difficult surf conditions, slow progress of innovation). There were fewer perceived opportunities to change shark nets as a method of bather protection however methodological opportunities (promising technologies), social (education can change perceptions), and research opportunities were mentioned. Below, we first discuss the general lack of awareness about the function of the shark nets and then discuss three sets of obstacles and opportunities for changing this bather protection programme.

4.1. Lack of awareness of how shark nets work

Many people are unaware of how the shark nets work, and our interviews illustrate how pervasive this lack of awareness is. Despite their professional interest in shark nets, only half (48%) the interviewees described the shark nets as fishing gear for catching and killing sharks. However this level of awareness is higher than that of the general public where only 10% of people using the ocean at a Durban beach accurately described how the nets function [53]. The respondents who did not describe the shark nets as fishing gear included representatives from government institutions responsible for: (i) permitting the operation; (ii) payment for the service; and (iii) an annual grant that covers the costs of management, administration and research. Despite the lack of understanding of the fishing mechanism of shark nets, all the stakeholders were aware that animals (sharks and other species) die in the nets though many believe that the deaths are incidental, as one of the respondents articulated, "*Remember, it is not their intention, it is caught by accident.*" Clearly many stakeholders did not know that the nets are set with the intention to kill sharks and thus reduce local populations.

While an understanding that the nets are set to deliberately catch sharks may not be sufficient to stop the use of this lethal method of bather protection, better understanding of the function of the nets may increase the motivation for change and the development of alternative methods.

4.2. Social obstacles and opportunities

An important obstacle to changing the use of shark nets for bather protection is a social one: people's mindset, particularly in KwaZulu-Natal. Generally, this was about current mindsets or perceptions and the need to change them. Some stakeholders explained that they perceived people's attitudes in KwaZulu-Natal towards sharks to be more negative than in other places, e.g. "It's a much more healthy conversation whereas in KwaZulu-Natal it feels like it's been brushed under the carpet. We have shark nets. We will always have shark nets and we don't talk about it anymore." Attitudes to sharks can differ by place [1], and people in KwaZulu-Natal may have more negative attitudes. Shark bites are low-risk, high-consequence events that generate much media attention, and there have been multiple shark bites, some fatal, in KwaZulu-Natal in living memory [5]. People's recollection and recounting of these traumatic incidents and their economic consequences could explain KwaZulu-Natal's attitude to the risk of shark bites. In addition, popular beaches in KwaZulu-Natal all have signage that reminds people of the danger of sharks, and whenever nets are not in place (removed ahead of bad weather or to prevent potentially high catches associated with the influx of predators following sardine *Sardinops sagax* shoals in winter), bathing is immediately banned, and people are not allowed to enter the water (Fig. 2). Such repeated messages to the public over seventy years have probably distorted the perceived risk of shark bites and lowered tolerance of sharks [33]. It may also subtly perpetuate the misperception that the nets are physical barriers, rather than long-term fishing gear, by suggesting that as soon as they are removed, bathers are no longer safe. Although the vast majority of ocean-users were against killing sharks, those in KwaZulu-Natal were

Fig. 2. An example of communication with the public regarding the risk of shark bites following the temporary removal of the shark nets. Note the dire consequences of contravention.
This signboard was photographed on the beach at Richards Bay, KwaZulu-Natal, in 2018.

slightly but significantly less opposed to the practice [53]. Two of our interviewed stakeholders talked about how the use of this fishing method (which people know results in the deaths of many marine animals) has a subtle influence on how people perceive sharks because it suggests that they are so dangerous that we need to protect ourselves from them at all costs. Future studies should involve surveys or use content analysis of media articles [3] to establish whether attitudes towards sharks in KwaZulu-Natal are more negative than in other provinces, and if so, how these perceptions arose and could be influenced.

The social opportunity to change was evident in the stakeholders' confidence that educating people about sharks would change their perceptions. Studies have linked greater knowledge of sharks and careful messaging to more positive attitudes and behaviours towards sharks and their conservation [21,1,47,48]. A public awareness campaign focused on the behaviour and ecology of sharks, backed by relevant, local research following a series of shark bites, reduced public outcry in Hawaii and changed the state's support of shark hunts [25,14,9]. Unsurprisingly, people who are more exposed to sharks (like surfers and divers) perceive them more multi-dimensionally, and fear is less likely to predominate [19]. Important information that may support more positive attitudes towards sharks includes the lack of intentionality of most bites, the basic biology of sharks, and their vulnerability to overexploitation [33]. The mismatch between people's perceived risk of shark bites and the actual, very low risk of bites should also be corrected [8]. As Lucrezi et al. Lucrezi et al. [33] conclude, while public support can be an important driver for shark bite mitigation and conservation, it is just one of many drivers.

4.3. Governance obstacles and opportunities

Another obstacle to change relates to politicians prioritising constituents' short-term well-being. This is a major obstacle to conservation changes globally - without public support to influence political decisions, conservation is assigned low priority [52]. The solution proposed by the world's conservation scientists, practitioners and policy-makers is to mainstream conservation and change decision--makers' attitudes in favour of pro-environmental, long-term decision-making [52].

One might wonder why the issue of reducing the risk of shark bites is within the political realm. Shark bites are traumatic, high-consequence events, and an incident is usually not only an issue for the individual at the beach, but it also impacts broader issues such as tourism, business, and the economy at larger scales [45]. In response, the public exerts pressure on the government to prevent future incidents, as has occurred in various parts of the world such as Australia, Brazil, Hawaii and La Reunion [35,9,14]. Legal scholars in human-wildlife conflict suggest that scientific information is useful at the risk assessment stage but is less so at the risk management stage when the political, social, and economic contexts must be included in the deliberations [24].

The next governance obstacle is the government officials' fears of the unacceptable emotional and/or legal consequences of decisions that potentially lead to human harm. Many of the interviewed government officials stated they would not support the removal of the bather protection fishing gear in case a beach-user was injured or killed, and some specifically feared litigation. As a part of the decision-making process that provides bather protection, fears around the consequences of their recommendations are understandable for high-consequence events like shark bites. This sense of liability was contrasted with responses from stakeholders who were not responsible for decision-making, such as those from NGOs, KZN Wildlife and academics. These stakeholders were convinced that when bathers enter the water, they should do so at their own risk. In a South African study, more beach-users (40%) felt that it is the government's responsibility to prevent shark bites than not (20%) [32]. There were no documented instances of litigation following shark bites in South Africa or internationally prior to 2006 [45], nor has there been any litigation since then (determined from a Google-search for news items with combinations of two sets of search terms: shark/shark bite/shark attack and litigation/legal action/lawsuit/sue on 2022/02/12).

The last governance obstacle to change is the *status quo*. Since the 1950 s responsibility for bather protection has been assumed by the authorities, making it challenging to change. This obstacle seems partly related to the liability issue, as it is often easier to leave things as they are rather than make changes in the face of uncertainty. Although stakeholders noted many obstacles to change related to governance, far fewer noted governance opportunities. Two stakeholders saw the national government's Shark Biodiversity Management Plan (BMP) as a useful tool. This BMP could be considered a governance opportunity as it stipulates the need to reduce the bather protection programme's shark catches and increase awareness. In addition, the national process to rationalise government expenditure is likely to see the Sharks Board's functions being absorbed by the province's conservation agency, KZN Wildlife. This process could be taken as a governance opportunity to accelerate change. Literature on transformative change suggests that the relational values demonstrated by the government officials not to harm others yields the sense of responsibility/liability to make good decisions. The challenge is to extend it from an interpersonal context to emphasise their responsibility to the animals harmed by the operation [4]. Another potential way around these obstacles may be to scrutinise the existing governance structures, i.e., examine the institutions, policies, and socio-economic systems, to identify obstacles and opportunities at the larger scale. Integrating a holistic, system-level view of governance structures with a reductionist focus on individuals' perceptions and behaviours should theoretically enable understandings that lead to strategies likely to yield transformative change [43].

4.4. Methodological obstacles and opportunities

The last set of obstacles and opportunities are methodological and logistical issues related to non-lethal alternatives to shark nets. Many stakeholders mentioned the lack of proven alternative methods to protect bathers. There is a paucity of published data about the efficacy of most of the non-lethal methods, but of 20 non-lethal alternatives reviewed by McPhee et al. [36], nine have been tested (and proved effective in peer-reviewed studies) on at least one or sometimes two, or all shark species of interest in KwaZulu-Natal (Zambezi *Carcharhinus leucas*, white *Carcharodon carcharias* and tiger *Galeocerdo cuvier*). While it is true that none of the alternatives can detect or deter sharks 100% of the time, neither do lethal methods [36,13]. The next logistical issue

noted was the rough surf conditions along the KwaZulu-Natal coast: many stakeholders know that the physical characteristics of the environment make it challenging to deploy and maintain equipment near the shore or to detect sharks in the water. Indeed, KwaZulu-Natal has a high-energy coastline with coarse-grained, sandy reflective to intermediate beaches with steep slopes and large-amplitude swells, with average wave heights of about 1.6 m, and extreme significant wave height measuring 8.5 m [7,56]. Water clarity in the region is about 4.5 m in winter and 2.9 m in summer, approaching zero in summer near estuary mouths following rain [13], which makes it very difficult to observe sharks and precludes shark-spotting programmes, such as those that have been implemented in Cape Town and elsewhere [28]. The respondents also cited the high costs involved in implementing alternative methods. Finally, respondents discussed the slow progress of innovation around these alternatives. For instance, in 1958, shortly before the Sharks Board was established, scientists in KwaZulu-Natal began experimenting with electrical shark repellents [49]. There have been significant developments since then, most notably the effective electrical personal protection devices [26], but the Sharks Board has yet to develop technology capable of large scale roll-out [31].

Despite the obstacles, many stakeholders mentioned the potential of promising alternatives. This included a general hope that suitable alternatives are possible in the future and specific reference to two alternatives currently being developed in South Africa. The Sharks Boards' own electrical shark repellent cable, mentioned above, and the Shark-Safe Barrier, are both non-lethal alternatives being developed for beach-wide use [36]. The nexus of technology, innovation and investment is considered an important leverage point on the pathway to sustainability [4] and some stakeholders talked about issues related to this nexus (Supplementary Material): The lack of profitability of bather protection inhibits investment in research and innovation by the private sector, resulting in a dependency on already-constrained government funds. However, if bather protection does become profit-driven, there could be changes in motivation and thus decision-making. Competition has a role to play in spurring innovation and new ideas.

4.5. Research as an opportunity for change

Research was the final category within the theme of opportunity for change. National and provincial government stakeholders felt they provide a supportive environment for research. Broadly, stakeholders suggested that useful research would include shark behaviour and ecology and the spatial and temporal variation in the risk of shark bites to identify hotspots where mitigation was required and how to mitigate the risk of shark bites in various contexts. They suggested research to yield measures of efficacy (sharks' responses to alternative methods) and impact (the effect of alternatives on sharks and the environment). These studies should be supplemented with studies of the social, cultural, and economic implications of different conservation actions, and investigations into what underlies this human-wildlife conflict (such as competing interests, attitudes, values and beliefs) and research into new methods to deal with conflict [55]. It would also be useful to investigate more effective ways to communicate about the risks associated with sharks.

4.6. Weaving the ideas together: A holistic overview

Although governance and social issues are perceived to be significant obstacles to change, some stakeholders framed positively how change might come about, alluding to the need for alternative strategies that would allow them to confidently ("*backed by science*") continue to accept responsibility. One interviewee said "*You need to be confident that what you're changing is going to work otherwise I can't see anybody really having a go.*" In the past, decision-makers at the KwaZulu-Natal Sharks Board have changed bather protection fishing gear, when they felt sufficiently confident that the changes were unlikely to reduce people's safety. In 1998, they reduced the number of shark nets in KwaZulu-Natal by 25% and, in 2007, they began to replace some of the shark nets with baited hooks [6]. Both changes were made to reduce the environmental impact of the gillnets. The baited hooks were especially unpopular as many people believed (mistakenly) that they attract sharks into the bathing area [23]. In both cases, the Sharks Board had compiled substantial evidence allowing them to be confident that the changes would not increase the risk to bathers. This shows that, with sufficient evidence that alternative strategies will maintain high standards of bather safety, governance and social obstacles are not insurmountable.

The biggest obstacle to changing to non-lethal alternatives is a consequence of the challenging surf conditions in KwaZulu-Natal. These surf conditions drastically limit viable alternatives and increase the costs. For the electrical shark repellent, these issues have delayed the development of this alternative [29,30]. Therefore, a meaningful way to accelerate change would be to attract support for the Sharks Board in their investigation and development of alternatives. The social and political obstacles do need to be addressed to increase and ensure the steady funding and capacity needed to accelerate the development and testing of a variety of alternatives in KwaZulu-Natal. Therefore, a good communication campaign is required in KwaZulu-Natal to change people's (especially politicians') attitudes toward sharks and managing the risk they pose. However, education is sometimes considered a weaker option compared to regulations [4]. Education's focus at the level of the individual is often insufficient to elicit the transformative change required here. Education is more likely to be transformative when integrated with holistic, system-level changes that include governance [43]. Therefore, in addition we need to understand and change social structures (institutions, policies, and systems) as well as individuals' attitudes.

5. Conclusions

To understand the conditions that hinder or facilitate changing the lethal method of bather protection, we interviewed stakeholders and documented their understanding of how the shark nets work, the nets' advantages and disadvantages, and of changing this method of protecting bathers. Using a qualitative approach allowed us to explore what the stakeholders felt was important and relevant (within our research focus) and highlighted issues that we might not otherwise have considered using a conventional, quantitative approach. It gave us insights into complexities in the underlying processes, dilemmas and relationships that require attention when trying to make changes in this bather-shark system.

As in Australian studies, we found that fear of negative human-shark interactions dominates in governance—despite their low probability and sharks' diverse behaviour and agency [19,8]. This one-dimensional view exacerbates the conflict, making it difficult to change to non-lethal strategies that might enable coexistence with sharks. We do not intend to minimise the trauma of those who experience, witness or deal with shark bites. Instead, we sought to contribute to understandings of shark bite mitigation so as to find solutions to move this human–wildlife conflict closer to co-existence by attending to the experiences and perceptions of the people most likely to effect change. Our study revealed many obstacles, but also a few opportunities to change, thereby providing foundational data to generate solutions for shark conservation whilst protecting people. Based on these results, we recommend a three-pronged approach working on 1) designing a communication campaign for attitude interventions within the province; 2) assessing the obstacles and opportunities for change to governance structures (policies, institutions and systems); and 3) implementing a research and engineering programme that accelerates the development and testing of multiple non-lethal strategies in KwaZulu-Natal. This approach that integrates communication, governance and technological solutions could potentially be used to mitigate other human-wildlife conflicts.

Human well-being and a thriving beach tourism industry should

remain priorities, but we suggest that these priorities can no longer be achieved at the cost of shark populations and the ecological services they provide. Achieving this goal, as in all issues of human-wildlife conflict, will require collaborative effort among all stakeholders towards mainstreaming conservation, building capacity, encouraging responsible investment in technology and other solutions, and unleashing people's sense of responsibility for sharks [52,4]. Protection programmes must ensure the safety and well-being of all coastal residents and visitors—both people and sharks.

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CRediT authorship contribution statement

Shanan Atkins: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Judy Mann-Lang**: Methodology, Formal analysis, Validation, Writing – review & editing. **Geremy Cliff:** Methodology, Writing – review & editing. **Neville Pillay**: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing. **Mauricio Cantor:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

Data Availability

The data used in this research come from individual interviews with stakeholders; we make direct, anonymized quotes available in the supplementary material but the full transcriptions of each interview are unsuitable to post due to ethical restrictions. The anonymised data are available on request from the corresponding author, S.A.

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Declaration

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105762.

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