

Stakeholder perception of the danger posed by sharks in the world's largest shark sanctuary

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ABSTRACT

Shark conservation can be achieved through a combination of spatial protections, traditional fisheries regulations, and shark-based tourism development. The effectiveness of these approaches depends on stakeholder perception of the animals, and on the personal impacts legislation will have. We assessed stakeholder attitudes towards sharks in the French Polynesia sanctuary using the perception of (i) the risk that sharks pose to humans and (ii) the practice of shark feeding to support ecotourism. Despite few bites locally, about 50% of the people believed that sharks are potentially dangerous. Furthermore, 74% of people held a negative opinion about provisioning as potentially increasing the risk of bites or having negative effects on sharks. When crossed with the lack of compliance with the regulations of the sanctuary and the feeding, these results suggest the importance of local political decision-making to better integrate validated scientific data. These results could improve shark conservation and support for current efforts.

1. Introduction

Around one-third of chondrichthyans (i.e., sharks, rays, and chimaeroids) are currently threatened with extinction according to IUCN Red List criteria [1], and overfishing continues to drive population declines from coastal to pelagic environments including coral reefs to areas beyond national jurisdiction (ABNJ) previously referred to as the 'high seas' [2–4]. Sharks can sometimes play important roles in maintaining the structure and function of ecosystems [5,6], therefore, a precautionary approach to their conservation is warranted.

Shark conservation and management approaches are often varied and context-specific but typically consist of traditional fisheries management, including gear restrictions and catch limitations, or spatial protections including time-area closures or marine protected areas (MPAs) [7]. Some nations have enacted legislation designating their waters as "shark sanctuaries" where catching, possessing, and trading sharks is prohibited or extremely limited throughout their entire Exclusive Economic Zone (EEZ) [8,9]. The largest shark sanctuary was implemented in French Polynesia in 2006, making it the first Pacific

nation to protect its shark populations (with the exception of shortfin makos, *Isurus oxyrinchus*, until 2012) within its 5.5 million km² EEZ (article 3 of the Ministers' Council statement N°396 CM of 28 April 2006).

In addition to protecting sharks from targeted fishing pressure, French Polynesia has developed a robust shark-watching industry which caters to multiple audiences (from novice tourists and snorkelers to skilled scuba divers). Shark tourism activities operate in both lagoon and forereef habitats in 17 islands located in 3 archipelagoes (Society, Tuamotu and Marquesas) (Séguigne et al. unpublished results). They contribute a substantial proportion of the overall tourism revenue for French Polynesia, as they represent 57% of the total animal watching-based ecotourism [10]. Shark provisioning in French Polynesia covers different practices varying from chumming to active feeding of target animals. While not ubiquitous across all shark-tourism activities and operators, shark provisioning is regularly used to attract several species of elasmobranchs in established shark-tourism sites, the most popular being the tiger shark (*Galeocerdo cuvier*), the sicklefin lemon shark (*Negaprion acutidens*), the grey reef shark (*Carcharhinus amblyrhynchos*),

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the blacktip reef shark (*Carcharhinus melanopterus*) and the pink whipray (*Pateobatis fai*). However, the practice was prohibited nationally in October 2017 (Law of the Country 2017–25). The provisioning prohibition was implemented over concerns that provisioning might influence shark behavior and increase the risk of bites on humans, despite no empirical studies in French Polynesia that have addressed these potential issues [11–13]. Although illegal, artificial provisioning still occurs and is tolerated in certain locations such as lagoon-based activities of the Society islands, mainly in Moorea and Bora Bora [12].

The effectiveness of the sanctuary and compliance with the provisioning prohibition might be limited if the public does not support these policies or views sharks negatively [14–16]. In traditional Polynesian culture, sharks symbolized a link between the spiritual underworld and physical life on earth. Sharks acted as both guardian protectors as well as a potential threat to be feared [17,18]. In contrast, the prevailing perception of sharks in Western cultures is particularly negative [14]. This may be explained by different perceptions of reasons and prevalence of shark bites on humans. Among ancestral Polynesian populations, shark bites represent divine punishment, with responsibility placed on the victim [17,19,20]. In Western cultures, these extremely rare events are sensationalized in the written, audiovisual, and digital media. This phenomenon greatly magnifies the real danger faced and personifies sharks as criminals [21,22], despite recent awareness campaigns that appear to slowly initiate a shift in the way these animals are viewed [23,24]. Nevertheless, to date, no information is currently available on the modern public perception of sharks in French Polynesia.

Here, we assessed public perceptions of sharks in French Polynesia to evaluate (i) views of sharks and the threat they pose to humans, and (ii) the perception of provisioning sharks for ecotourism purposes.

2. Material & Methods

2.1. Sampling design

French Polynesia is amongst the most popular diving locations in the world and renowned for its shark viewing, snorkeling, and diving. Although sharks are present and can be observed throughout the entire EEZ [25,26], tourism mainly occurs in the Leeward Islands (which includes the capital, Papeete, on the island of Tahiti) and the Tuamotu Archipelago that consists primarily of atolls.

Six study sites were assessed and categorized depending on their low, moderate, or high degree of tourism development (Table 1). Tourism development was determined based on objective criteria linked to the extent of tourism development at each site. The number of hotels (>5 rooms), diving centers, as well as the extent of the influence provided by expatriates and/or tourists, were evaluated. Tahiti and Moorea, from the Society archipelago, were assessed as the islands with the strongest tourism development. Tikehau Island (Tuamotu Archipelago) and Rurutu Island (Austral Archipelago) were considered to be moderately developed. Finally, Hao, Amanu (Tuamotu Archipelago), Nuku Hiva and Ua Pou (Marquesas Islands) were defined as having a low degree of tourism development (Fig. 1; Table 1).

From October 2017 to January 2018, 50 interviews were conducted

directly with members of the local population at each location ($n = 300$ surveys). Surveys were conducted in French, the official language, by two trained interviewers. The minimum age of respondents was 18 years old, and the interviewers attempted to balance the surveys across age demographics. This was done by grouping individuals by age into four categories: 18–30 years old, 31–45 years old, 46–55 years old and > 55 years old. Approximately two thirds of respondents at each study site were of Polynesian descent and one third were of European descent. We aimed to obtain a cross section of different stakeholder groups at each location. This was accomplished by interviewing ten fishermen, five members of the administration (public service), five tourism operators, five people involved in conservation (through their work or NGOs), five ocean goers other than fishermen (e.g., surfers, scuba divers, kayakers) and finally 20 people without any specific profile. The interviews were conducted opportunistically, trying to display a diverse and representative panel.

2.2. Survey structure

The semi-structured interview survey consisted of 6 questions (Table 2). We differentiated the bites towards adults and children because they usually present different types of activities. For example, while children usually swim or play close to the shore, adults may more often be involved in activities such as spearfishing or fish cleaning, which might carry more risk of shark bites due to the presence of attractive stimuli (Clua et al. unpublished data). The surveys were conducted in Hao and Amanu (Tuamotu) in October 2017, in Tikehau (Tuamotu) and Rurutu (Austral) in November 2017, in Nuku Hiva and Ua Pou (Marquesas) in December 2017, and in Tahiti and Moorea in January 2018.

2.3. Statistical analysis

Chi-squared tests of independence were performed between the factors **Nationality** (Polynesian descendants, European), **Sex** (Male, Female – as the sex assigned at birth), **Age** (18–30 years old, 31–45 years old, 46–55 years old, > 55 years old), **Island** (Tahiti, Moorea, Tikehau, Rurutu, Hao/Amanu, Nuku Hiva/Ua Pou), **Occupation** (Fisherman “Fish.”, Tourism operator “TO”, Other sea user, “OSU”, Conservationist (through their work with Non-Governmental Organizations), “NGO”, Administration, “Admin.”, and Without specific relationship with the marine environment, “WSR”), and the potential responses to the questionnaire. When significant, Pearson residuals (std res.) were calculated and categories presenting values beyond the range of ± 2 were considered as a major contribution to the Chi-squared value [27]. All relevant post-hoc analysis visualizations can be found in ESM1. Significance was tested at the p -value < 0.05 level, and all statistical analyses were performed using R software (V 4.2.3) [28]. Graphs were created using ggplot2 R package [29], and mosaic plots were generated for all factors showing a significant Chi-squared test.

Table 1

Parameters used to categorize the areas on a tourism development continuum. Data from 2016 is presented and issued by the local statistical institute (ISPF).

	Archipelago	Surface (emerged land) (km ²)	Number of people	Number of hotels (> 5 rooms)	Number of diving centers	Indicator of tourism development
Tahiti	Society	1 040	180 000	> 20	8	High (++++)
Moorea	Society	134	16 000	> 10	5	High (++++)
Tikehau	Tuamotu	30	529	6	3	Moderate (++)
Rurutu	Austral	33	2 300	6	1	Moderate (++)
Nuku Hiva	Marquesas	339	3 000	5	1	Low (+)
Ua Pou		106	2 000	1	0	
Hao	Tuamotu	40	1 300	2	0	Low (+)
Amanu		17	200	0	0	

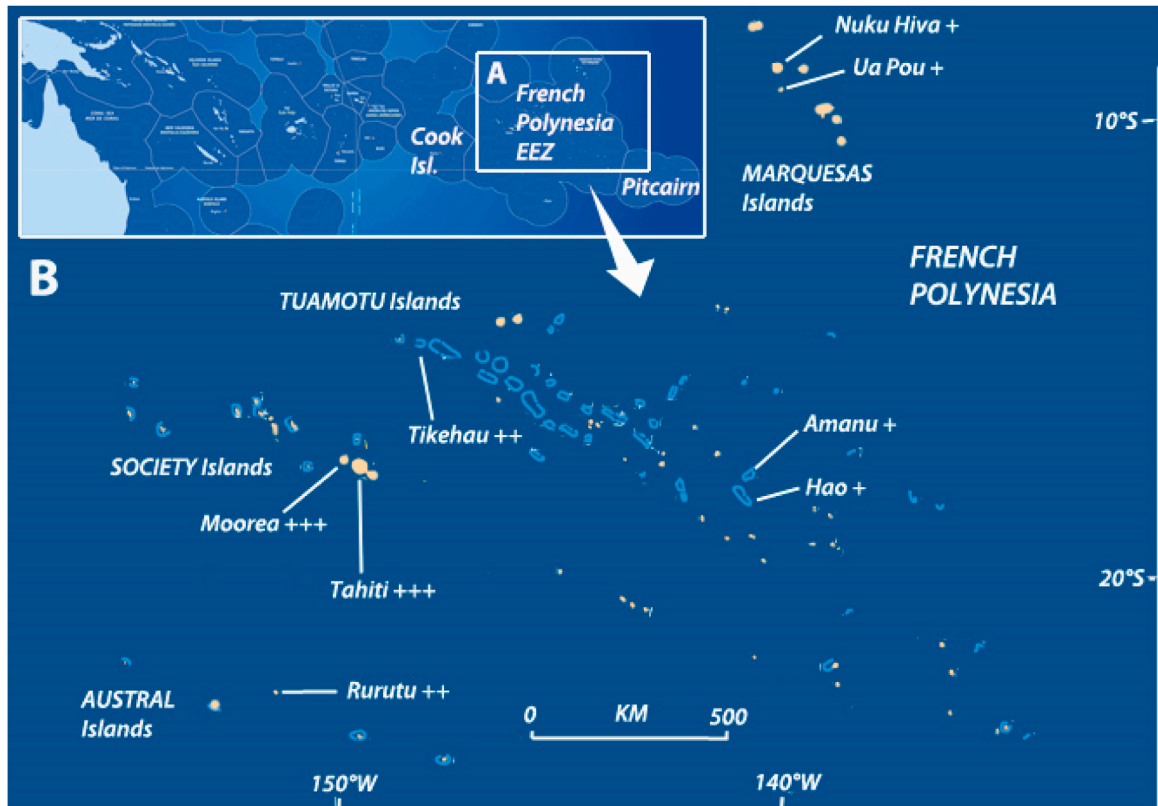


Fig. 1. (A) French Polynesia lies, in the east central Pacific. (B) The six sampling areas were located on two islands of the Society archipelago with a strong tourism development (Tahiti and Moorea, +++), two islands of the Austral and Tuamotu archipelagoes with a moderate tourism development (Rurutu and Tikehau, ++) and two islands of Marquesas and Tuamotuan archipelagoes with a low tourism development (Nuku Hiva/Ua Pou and Hao/Amanu, +).

Table 2

Survey questions, possible answers, and target population.

Questions	Answers	Type	Target population
(i) Are sharks dangerous animals?	3-levels: Yes, No, I don't know	Single answer	All interviewees
(ii) How many adults bitten by a shark do you know?	6-levels: None, One, Two, Three, Four to Five, Six to Ten	Single answer	All interviewees
(iii) How many children bitten by a shark do you know?	3-levels: None, One, Two	Single answer	All interviewees
(iv) Do you think shark provisioning is a good practice?	3-levels: Yes, No, I don't know	Single answer	All interviewees
(v) If yes, why?	5-levels: It feeds sharks, It pays tourism operators, It reuses food wastes, It keeps away sharks from fishermen, It destigmatizes sharks	Multiple answer	Interviewees answering "Yes" for (iv)
(vi) If no, why?	5-levels: It may facilitate attacks, It is bad for shark health, It is dangerous for fishermen, It is dangerous for other sea users, It is dangerous for watchers	Multiple answer	Interviewees answering "No" for (iv)

3. Results

3.1. Profiles of interviewees

Of the 300 interviews completed across the six sites (6×50), 77% of respondents were of Polynesian descent and 23% of European descent. The overall sex-ratio was 1.6:1 (63% males and 37% females) and 20% of interviewees were 18–30 years old, 32% 31–45 years old, 24% 46–55 years old and 24% > 55 years old. The sample included 20% fishermen/hunters, 13% administration, 9% tourism operators, 9% sea users other than fishermen, 7% as members of conservation NGOs and 42% with another profile.

3.2. Perception of the danger posed by sharks to humans

Slightly more than half of respondents (52%; n= 154 of 296) answered that sharks were not dangerous, with 46% answering that they were dangerous and 2% indicating they did not know. The proportions of answers varied significantly with **nationality** (Chi-squared = 18.86, df = 2, p-value = 8.05×10^{-5}), **island** (Chi-squared = 39.73, df = 10, p-value = 1.89×10^{-5}) and **occupation** (Chi-squared = 25.83, df = 10, p-value = 3.98×10^{-3}). More people of European descent than expected by the Chi-squared test thought that sharks are not dangerous (75%; std res. = 2.63), while less than expected indicated that they thought they were dangerous (24%; std res. = -2.76). More people than expected on Rurutu answered that they don't know about the dangerousness of sharks (6%; std res. = 2.48). On Tahiti, more respondents than expected saw sharks as not dangerous (78%; std res. = 2.55) and fewer thought they were (22%; std res. = -2.52). The opposite pattern was observed in Hao and Amanu (resp. 30%; std res. = -2.16 & 68%; std res. = 2.26). Tour operators selected "I don't know" more than other professions (26%; std res. = 2.29).

Overall, 45% of interviewees did not know of an adult who had been bitten by a shark, but 55% knew of at least one adult who had been bitten. Overall, 13% of people were aware of bites on children. The proportion of people who knew adults who had been bitten varied with **Nationality** (Chi-squared = 23.26, df = 6, p-value = 3.01×10^{-4}) and **Island** (Chi-squared = 81.24, df = 25, p-value = 7.29×10^{-8}). Respondents of European descent were less likely to know someone bitten by a shark (69%; std res. = 2.80), and less than expected knew two adults who had been bitten (6%; std res. = -2.15) or of four or five victims (no answer for this category; std res. = -2.25). Less individuals than expected on Tahiti knew any victims of shark bites (68%; “none” std res. = 2.27), while on Tikehau people were more likely to know at least one person bitten (26%; “none” std res. = -2.02). Significantly more respondents than expected on Tikehau knew one adult that was bitten by a shark (38%; std res. = 2.65). Similarly, Hao & Amanu had fewer people than expected answering “None” (16%; std res. = -3.07) and significantly more answered “Four to Five” (26%; std res. = 4.57) and “Six to Ten” (2%; std res. = 2.00).

The probability of knowing a child bitten by a shark varied only with **Island** (Chi-squared = 40.47, df = 10, p-value = 1.40×10^{-3}). More people than expected knew one person bitten off Hao & Amanu (22%; std res. = 2.33) and Nuku Hiva & Ua Pou (27%; std res. = 3.27). On the Marquesas Islands, more people than expected were aware of two bitten children (6%; std res. = 2.34).

3.3. Perception of shark provisioning

Most respondents, (73%; n = 215 of 295) did not think shark provisioning was a good practice compared to 18% (n = 53) who did. These proportions did not vary with any factor.

Of the 53 individuals who supported shark provisioning, less than one quarter (24%) identified generating income for tourism operators as the reason for their support. More supporters (34%) cited providing food for sharks as their reason for support. Reasons for supporting provisioning varied with **Nationality** (Chi-squared = 18.02, df = 4, p-value = 1.23×10^{-3}). Interviewees of European descent were more likely than expected to support provisioning because it helps to destigmatize sharks (49%; std res. = 3.28).

The respondents who opposed provisioning (n = 200), cited negative impacts on shark health and its potential to increase the risk of shark bites on humans as the main reasons for opposition. **Nationality** was the only significant factor (Chi-squared = 11.16, df = 4, p-value = 0.025), but Pearson residuals did not reveal any categories showing strong differences.

4. Discussion

Overall, we found respondents had a surprisingly evenly mixed perception of shark dangerousness, even in a territory where a shark sanctuary is implemented. Furthermore, shark provisioning is deeply rejected although the practice is still running in lagoon-based activities. It is generally associated with a potential increase of aggressivity in sharks as well as appearing deleterious for targeted species.

Respondents of European descent had a significantly more optimistic view of sharks and their potential danger to humans (i.e., they were less fearful of sharks). This result suggests a contemporary shift in the public's perception of sharks due to increased awareness of sharks, and their conservation status which has been observed in studies from other globalized countries [16,30,31]. A weakening of the “Jaws effect”, which encourages a strong cognitive bias against sharks [16,32], as suggested here has the potential to positively influence the public's support for shark conservation measures. Interestingly, although Polynesian ancestors in traditional societies had a more positive and balanced perception of sharks, our results suggest they might have developed a more fearful view in contemporary societies, potentially influenced by the amalgamation of Western-attributed fear of sharks, inherited from

colonization [33,34]. We found no evidence that respondent age influenced their perception of the threat sharks pose, which differs from other studies that suggest younger generations exhibit a reduced fear of sharks [16].

Respondents of European descent and those residing in Tahiti, the most developed island in French Polynesia, knew significantly fewer people to have been bitten by a shark compared to the islands of Hao and Amanu. Respondents from Hao and Amanu had both the greatest fear of sharks and the threat they pose to humans and knew the highest number of people who had been bitten by a shark. A potential driver of this pattern could be the degree to which the influx of Western culture has influenced the prevalence of different water-based activities and how certain activities have a higher or lower likelihood of attracting a shark. Activities such as spearfishing, which is traditionally popular among Polynesian descendants, has an increased likelihood of attracting a shark due to the sensory stimuli produced by an injured or struggling fish that has been speared compared with the foreign sensory stimuli produced by scuba diving, an activity which is more popular with expatriates (C. Séguigne, pers. obs.). Consistently, aside from a few rare events, most shark bites recorded in French Polynesia are on spearfishermen (36%), whereas bites on scuba divers are sparser (20% in an unregulated shark provisioning context, and 5% without fishing) (Clua et al. unpublished results). Interestingly, our results differed from those of Ward-Paige & Worm (2017) who found conservation awareness was “low in Micronesia and high in French Polynesia” [35]. One possible explanation for this difference could be attributed to survey design. Indeed, Ward-Paige and Worm exclusively surveyed scuba divers, both professional and amateur, that are considered to be part of a more “shark-enthusiast” group and mainly composed of European descendants, which is a significant factor of lower fear.

Scuba diving has the capacity to increase people's awareness and support for shark conservation via non-threatening encounters [36–38]. Worldwide, shark provisioning is used in many locations to increase the probability of encountering rare or large sharks [39,40], however, results indicate this practice is controversial in French Polynesia, with little public support. In spite of the banning, provisioning remains a daily and intentional occurrence in French Polynesian waters, as it is mainly linked to lagoon-based activities. Indeed, lagoon-based shark-watching appeared to be strongly dependent on provisioning to ensure a sustainable number of encounters. This was demonstrated by the complete desertion of sharks and rays, i.e., no animal of both these taxa was observed, on one of the most important feeding sites in Moorea in the absence of any olfactory and auditory stimuli by the confined tourist operators. [12]. Furthermore, forereef targeted species, such as lemon sharks (*Negaprion acutidens*) showed a drop in their sightings by scuba divers in the same island after the provisioning ban [26]. Nevertheless, French Polynesia is characterized by natural or indirect (or passive) artificial provisioning areas of aggregations, mainly located in the pass. Indeed, large schools of fish have the potential to strongly lure predators, such as for the famous Tumakohua pass, attracting hundreds of grey reef sharks (*Carcharhinus amblyrhynchos*) [41] or traditional fishing techniques, such as fishing traps [42], possibly playing an important role in escalating their sighting. This could favor a strong disparity in the perception of the public who gets access to sharks by hindering the spread of awareness among those who are not scuba divers. This is because scuba divers are automatically more likely to know their importance and the threats that they are currently facing.

Furthermore, the consequences of the shark provisioning ban are unbalanced between those that exploit the lagoon, essentially Polynesians and those that exploit the outer reef, mainly Europeans. The inequity of these measures might create unnecessary conflicts between parties as it is the lagoon-based operators who suffer economically from the ban. Such conflicts between sea users in the face of disparity caused by shark conservation regulations have already been demonstrated [43, 44]. Researchers have petitioned government agencies to consider, the livelihoods of local communities, before making management decisions

to protect the ecosystem [43,44]. To not disrupt the local economy, the authorities turn a blind eye to Polynesians who are still provisioning, yet these individuals are still at legal risk if any incident occurs. This tendency to illegally continue to practice shark feeding in French Polynesia is contrary to what is promoted elsewhere in the world. Feeding is regulated by a strict code of conduct to maximize the safety of animals, operators, and tourists [45–50]. The fact that no standardized protocol is implemented to feed the sharks increases the level of bite risk, especially where some practices such as hand feeding are regularly used [11]. This has the potential to raise the level of bad perception if any incident occurs [22].

There was no significant difference between European and Polynesian respondents concerning the perception of provisioning. Amongst those supportive of provisioning, the main justification provided was because it “feeds the animals”. This response aligns with the traditional attitude of Polynesians towards sharks, where it was even practiced as part of some cultural rituals. Respondents who did not support provisioning cited facilitating the occurrence of attacks, attracting potentially dangerous sharks such as tiger sharks (*Galeocerdo cuvier*), as well as the risk of deteriorating their ecological balance as the reasoning behind their opinion. Previous studies highlighted some negative impacts on sharks targeted by provisioning practices such as the modification of the composition of elasmobranch communities [51,52], a reduced mobility or a shift of habitat [53–57], an altered activity pattern [54,55,58], or an elevated intra- and inter-specific competition [45,51,53]. However, no marked increase in the number of bites in a controlled provisioning environment has been documented [11,52,59]. Furthermore, even though the effects of shark provisioning appear to vary between species and practices [11,57], an increasing number of studies shows that there is a limited – if any – effect on the targeted species’ ecology in a well-managed context [13,48,60–64]. In French Polynesia, the only two predation-motivated bites in the last century that have happened to our knowledge (Clua et al., unpublished results) were by an oceanic whitetip shark (*Carcharhinus longimanus*) in a whale-watching operation after the shark provisioning ban was introduced [65] and by a tiger shark (*Galeocerdo cuvier*) in the context of aquaculture farming [66], both in sites where provisioning was never implemented.

Shark provisioning is conducted in other shark sanctuaries, e.g. the Bahamas and Palau, suggesting that when well-regulated they do not necessarily conflict with conservation measures. In both these locations shark-watching activities provide an attractive economic alternative to shark fishing, as it gets the local human population involved, generating revenues, all the while ensuring the ecological sustainability of shark populations [62,67]. As tourism is one of the primary generators of revenue for French Polynesia (ISPF 2015), ecosystem services provided by sharks should be conserved. Our results indicated that only a few of the respondents considered the economic potential of sharks as a reason for their conservation. Thus, increasing public awareness of these advantages should be prioritized to foster stronger linkages between the economic and ecological benefits of shark conservation [68].

To help French Polynesia’s shark sanctuary obtain its optimal efficiency, it is critical to communicate more about the importance of sharks for the coral ecosystem, as well as the ecosystem services they render. Indeed, knowledge appears to be one of the main drivers of positive public attitudes towards conservation measures [23]. Important cognitive bias on the danger sharks pose to humans, originating from Western culture, persists throughout the entire population, including those of Polynesian descent. The implementation of appropriate regulations on shark provisioning, first and foremost for lagoon-based activities, must be considered to safeguard the local operators from legal issues arising from clients being bitten, and to ensure animal well-being is maintained, thereby mutually beneficial. Implementing a strict code of best practice would benefit sharks and help to develop a strong associated economy. It could also support research programs and citizen science initiatives, which can be an important tool to involve people in science and conservation [26,69].

CRedit authorship contribution statement

Eric EG Clua: Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Frédéric Torrente:** Project administration, Methodology, Investigation, Conceptualization. **Mark Bond:** Writing – review & editing, Validation. **Clémentine JM Séguigne:** Writing – original draft, Visualization, Formal analysis, Data curation. **Michael R Heithaus:** Writing – review & editing, Validation. **Adeline Goyaud:** Methodology, Investigation. **Gilles Siu:** Visualization, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare no competing interests.

Data Availability

Data will be made available on request.

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