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Sharks and people: Insight into the global practices of tourism operators and their attitudes to Shark behaviour

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ABSTRACT

Shark tourism is a popular but controversial activity. We obtained insights into this industry via a global e-mailed questionnaire completed by 45 diving/snorkelling operators who advertised shark experiences (shark operators) and 49 who did not (non-shark operators). 42% of shark operators used an attractant to lure sharks and 93% stated they had a formal code of conduct which 86% enforced "very strictly". While sharks were reported to normally ignore people, 9 operators had experienced troublesome behaviour from them. Whilst our research corroborates previous studies indicating minimal risk to humans from most shark encounters, a precautionary approach to provisioning is required to avoid potential ecological and societal effects of shark tourism. Codes of conduct should always stipulate acceptable diver behaviour and appropriate diver numbers and shark operators should have a moral responsibility to educate their customers about the need for shark conservation.

1. Introduction

The historical portrayal in many cultures of sharks as dangerous killing machines has tended to instil in people a fear of sharks that can be difficult to overcome (Neff and Hueter, 2013; Whatmough et al., 2011). In reality sharks rarely attack humans (West, 2011) and observations indicate sharks demonstrate a lack of interest in humans when in close proximity (Neff and Hueter, 2013). By contrast, humans have rendered three-quarters of pelagic sharks and rays at an elevated risk of extinction through overfishing (Dulvy et al., 2008). It is estimated that each year, between 73 (Clarke et al., 2006) and 100 million (Worm et al., 2013) sharks are traded worldwide and the true total catch is likely to be significantly greater given the difficulty of accounting for bycatch, discards and artisanal fishing (Worm et al., 2013). Compounding the problem of overexploitation, sharks are characterised by slow growth, high longevity, late age of sexual maturity and low fecundity (Cortés, 2002; Ferretti et al., 2010), which makes populations slow to recover from anthropogenic impacts including direct and indirect effects from, amongst others, fishing, marine pollution and habitat destruction. (e.g. Baum and Blanchard, 2010; Baum et al., 2003; Ward-Paige et al., 2012).

Amid declining shark population trends, in recent years there has been a surge in shark-specific tourism to SCUBA dive or snorkel with them. Research into diver perception of sharks shows a gradual change in attitude towards them has occurred, whereby 'excitement', has replaced 'fear' such that many people are now attracted to the thrill of diving with these top predators (Gallagher and Hammerschlag, 2011; Whatmough et al., 2011). Places where sharks congregate due to high natural abundances of food are obvious spots for shark tourism to develop (Gallagher and Hammerschlag, 2011). For instance, whale shark tourism first developed in 1989 at Ningaloo Reef, Western Australia where 300–500 whale sharks gather annually to feed on seasonal coral spawn (Catlin and Jones, 2010). This site has become internationally renowned and by 2010 attracted around 10,000 people a year (Catlin and Jones, 2010).

People will pay highly for shark experiences (e.g. Farr et al., 2014); for example, in 2014 it cost up to US$2,900 for a 4 day great white cage diving trip to Isla Guadalupe, Mexico.[1] A recent estimate suggests that shark watching generates over 314 million USD and supports more than 10 thousand jobs worldwide (Gallagher and Hammerschlag, 2011). Consequently the activity can help benefit

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[1] Solmar V Great White Shark Adventures, (2013), Great White Shark Diving at Isla Guadalupe. Retrieved February November 2517th 20143, http://www.solmarv.com/schedules.html.

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local economies (Topelko and Dearden, 2009; Vianna et al., 2011) and could thereby create an economic incentive to conserve sharks (Gallagher and Hammerschlag, 2011; Maljković and Côté, 2011). In Palau, for example, it has been estimated that the value of an individual reef shark over its life time is about US$1.9 million based on the revenue it generates from tourism (Vianna et al., 2010). By contrast a fisher could only expect to make US$20 – US$90 from catching a shark (Vianna et al., 2010). With increasing interest in shark tourism for its economic and potential conservation value, greater knowledge is required into the effects such activities may have on sharks as well as the potential for increased risks to the tourists themselves.

In many countries dive operators attract sharks through provisioning (i.e. feeding, e.g. Hammerschlag et al., 2012), with some allowing their clients to do this by hand (Orams, 2002; Semeniuk et al., 2007). In other places such as Florida, Hawaii and South Africa feeding is prohibited as a result of fears that the practice could increase risk to tourists (Hammerschlag et al., 2012; Maljković and Côté, 2011). Feeding sharks results in the concentration of large predatory animals in close proximity to tourists and acts to encourage their consumption of a non-natural food source. Aside from being potentially dangerous to people, it is a controversial practice since little is known about how it affects shark behaviour and ecology (Hammerschlag et al., 2012; Maljković and Côté, 2011; Orams, 2002) although there is a growing interest and consequently an increasing literature on this subject (e.g. Barker et al., 2014; Brunnschweiler et al., 2014; Huveneers et al., 2013). Some studies have indicated limited or no evidence for shifts in shark behaviour following long-term provisioning whilst others indicate increased residency and aggression. For example, Maljković and Côté (2011) investigated the effects of feeding on the behaviour of Caribbean reef sharks that had been provisioned for over 20 years. The authors concluded that a small number of larger sharks monopolised more than 50% of the bait on offer but there was no evidence for shifts in behaviour, such as different degrees of residency and daily minimum travel distances, which may have affected ecological roles. Conversely, research into provisioned sicklefin lemon sharks showed that shark residency significantly increased at feeding sites, particularly of males, as did intraspecific and interspecific aggression (Clua et al., 2010). In this study the authors concluded there to be potential for long-term losses in genetic variability amongst provisioned sharks due to the aggregating effect and the increased potential for inbreeding.

Whilst some shark diving and snorkelling trips seek to experience sharks in their natural environment, great white cage diving operators deliberately try to change shark behaviour. Baited lines encourage great whites to remain at the surface, whilst normally these ambush predators stalk their prey from below (Laroche et al., 2007; Martin et al., 2005). Encouraging such behavioural changes could therefore have repercussions throughout the ecosystem by affecting both the behaviour of the predator and the prey species. However, evidence to date is contrary (e.g. Bruce and Bradford, 2013; Laroche et al., 2007) and may depend on the quantity and reliability of food rewards offered (Clua et al., 2010).

In general, a perception exists that provisioning wildlife does not conflict with conservation goals and may even have a positive effect, although little research has investigated the latter view (e.g. Dubois and Fraser, 2013; Topelko and Dearden, 2009). By contrast, there is a large volume of literature for a broad range of vertebrates which concludes that being fed by humans may lead to a variety of impacts, including increased aggression and 'begging' behaviours (Hodgson et al., 2004 (rock-wallabies); Hsu et al., 2009 (primates); Pinto de Sá Alves et al., 2013 (river dolphins); Ram et al., 2003 (primates)) as well as reduced body condition (Amo et al., 2006 (lizards)) and juvenile fitness (Foroughirad and Mann, 2013 (dolphins)). Given the shortage of empirical evidence about any potential ecological effects of shark tourism, advocates who favour this activity have argued that so long as the practise is sensibly performed it should allow people to enjoy something which will assist in ridding sharks of their dangerous reputation and thereby be of assistance to conservation efforts (Dobson, 2008; Meyer et al., 2009). However, concerns that provisioning causes habituation of sharks to humans, which may result in increased conflict with people (Dobson, 2008; Topelko and Dearden, 2009) cannot be dismissed and should be addressed with appropriate management to regulate shark tourism to reduce potential problems. Common measures used are control on tourist numbers and the promotion of appropriate behaviour from people towards sharks (e.g. Smith et al., 2010) although practices differ considerably between countries. For example in South Africa, great white cage diving is regulated by the Government's Marine Living Resources Act 1998 which makes it illegal for tourism operators to feed great whites, although they can place a fish-based chum slick in the water and use a fish-based bait tethered on a rope to entice sharks towards the cage (Johnson and Kock, 2006). By contrast whale shark tourism at Tofo Beach, Mozambique has no formal regulation and as a result harassment of whale sharks by tourism operators and their clients appears to be common (Pierce et al., 2010). The controversial nature and risks involved in feeding sharks has prompted several areas of the world to ban it in their waters including the Cayman Islands, Hawaii and Florida (Dobson, 2008).

Many papers exist which aim to assess behavioural changes in sharks at provisioning sites (e.g. Bruce and Bradford, 2013; Brunnschweiler et al., 2014; Clua et al., 2010; Hammerschlag et al., 2012; Huveneers et al., 2013; Laroche et al., 2007) but few define and describe the details of its practise. Without knowledge of existing practices, informing decision-making in terms of relevant management of the shark tourism industry is problematic. In this global survey we obtain insights into SCUBA/snorkelling tourism operators' attitudes to shark behaviour based on responses to an e-mail questionnaire sent to a sample of diving and/or snorkelling operators who either specifically advertised shark experiences or who did not. On the basis of their responses we describe the varied practices of shark tourism, the differing levels of risk it poses to humans and management measures adopted. Finally we highlight how shark tourism could be improved for the benefit of people, sharks and the environment.

2. Materials and methods

In 2011 we conducted internet searches and consulted diving magazines to identify dive or snorkel operators who advertised trips where the specific intention was for clients to encounter sharks (hereafter termed shark operators). Concurrently, we also identified companies who operated in areas where sharks were likely to occur but who did not overtly advertise shark dives (hereafter termed non-shark operators). In total, we sent out three e-mail questionnaires in which we guaranteed anonymity to all respondents. The first questionnaire (Appendix A) targeted 128 shark operators to request information regarding: shark species encountered, type of habitat most commonly dived/snorkelled in, maximum number of participants allowed on a shark trip, whether sharks are fed, and if so, how regularly and on what. We also asked if they had a shark encounter code of conduct, and if so what it involved. To all who responded, we sent a follow-up survey (Appendix B) which asked whether there were any local concerns regarding shark encounter tourism, and how sharks have been observed behaving towards tourists. These questions were not included in the initial questionnaire in case their sensitive nature deterred shark operators from responding to our first survey. Our third questionnaire (Appendix C) targeted 101 non-shark operators and requested information concerning the shark species they

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encountered and whether they might want to operate shark dives in the future. If affirmative, we asked if they would be prepared to attract sharks through feeding.

Respondents to our questionnaires are self-selecting hence are likely to reflect operators who engage in practices they consider responsible. Results therefore are likely to exclude operators who engage in practices they know to be dangerous or inappropriate. Data presented within this paper relies on the honesty of the operators when completing their questionnaire. In addition, whilst response rates were considered to be good, sample sizes remain small which is reflected in the qualitative nature of our reporting.

3. Results

3.1. Number of responses and respondent characteristics

Table 1 shows the distribution of respondents by region. Of the 128 shark operators initially targeted, 45 responded to our initial questionnaire, 30 of which also responded to our second questionnaire. This equates to response rates of 34% and 67% respectively. Of those shark operators who initially responded, 58% worked within the tropics, with the remainder based in temperate regions. Of the 101 non-shark operators targeted, 49 responded, a response rate of 49%. Amongst non-shark operators, 73% of respondents were located within the tropics and 27% in temperate regions. Whilst response rates of the two groups (i.e. shark operators and non-shark operators) to the questionnaire as a whole were as reported above, the response rates to individual questions varied, and where this occurred "N" is noted as appropriate.

3.2. Responses from shark operators

3.2.1. Initial questionnaire

Shark operators reported observing 25 species of shark.[2] The great white was most commonly observed (reported by 12%), followed by whale and nurse sharks (reported by 9% each) (Fig. 1). Coastal reefs and open water were the only two habitats in which shark excursions commonly occurred (Fig. 2). 19 operators solely dived or snorkelled on coastal reefs while 10 solely operated in open water and 7 operated in both habitats; the remainder undertook trips to other habitats. Fig. 3 details the shark species respondents identified within coastal reefs and open water. On coastal reefs, Caribbean reef, grey reef and nurse sharks were most commonly observed, while great white, hammerhead and whale sharks were most often seen in open water.

Of the shark operators, nearly half (44%) catered solely for SCUBA divers, with 13% exclusive to snorkelers. The maximum number of participants (divers or snorkelers) on trips ranged from 2 to 40 with a group size of 7 to 12 most common (Fig. 4). Shark diving trips were most often conducted daily or near daily with 12% of those respondents who answered this question (i.e. question 4) reporting more than 21 shark dives a week ($N = 33$) (Fig. 5).

31% of shark operators said they intentionally fed sharks whereas 69% claimed not to lure sharks with attractant. However of the latter, 36% (i.e. 12) also said that they did use bait but not in what they considered to be intentional feeding. If those who report using bait are added to those who admitted intentional feeding then 42% of operators used shark attractant. Of those who intentionally provisioned and who reported the number of times they fed sharks ($N = 10$), 40% fed between one and three times a week, and a sizeable minority (20%) fed more than 10 times a week (Fig. 6). All of the shark operators who provisioned did so on all their dives, and all used some form of fish (e.g. fish scraps and tuna heads). Of the 12 respondents who practised great white cage diving, 8 said they used an attractant for this purpose and four did not provide information on the subject. Of the 8 who did, 5 did not think such techniques constituted shark feeding while the remaining 3 acknowledged that they intentionally fed great whites. None of the three were from South Africa where chumming (defined as "means to attract white sharks by any means") is allowed (DEAT, 2008) but intentional feeding is not (Johnson and Kock, 2006). Diving permit conditions there detail the type and quantity of bait an operator may use, and a Code of Conduct, developed by DEAT, states that operators must drop the line if a shark takes the bait (Johnson and Kock, 2006). Any breach in the conditions placed by the operator's permit and the Code of Conduct can result in the loss of a permit.[3]

Methods applied by shark operators to attract sharks varied considerably, for example, one said "food taken down for the sharks is hidden under coral so that the sharks will swim around looking for it". Another described how "a 5 gallon bait ball is suspended above the reef" and a third reported "chumming with a washing machine drum".

Of those who responded to question 11 ($N = 43$), which asked if operators worked to a formal code of conduct, 93% of shark operators said they did with 86% of them stating that rules were "very strictly" enforced (question 13, $N = 37$). From information provided about what codes of conduct involved, it was clear these were principally designed to ensure the safety of people and sharks ($N = 37$). Only 8% of the people who provided any information noted that they educated participants about shark conservation. When asked to list the three most important measures in their code of conduct, shark operators who provisioned sharks most commonly cited: (1) no touching sharks, (2) restrict diver movement and (3) safety of shark(s) and people ($N = 11$). Shark operators who did not lure sharks most commonly cited: (1) no touching sharks, (2) restrict diver movement and (3) no feeding ($N = 25$). Nine operators provided copies of their codes of conduct, seven of which consisted of voluntary practices and two South African operators provided compulsory permit regulations. Voluntary codes of conduct provided ranged from simple graphics illustrating the space around the shark within which tourists were allowed to enter and minimum distances to detailed sets of rules.

3.2.2. Follow-up questionnaire

Thirty shark operators answered our follow-up questionnaire, and while 90% said sharks generally ignored their clients, 56% had observed sharks bumping into people and 28% had seen sharks swimming erratically. Of the 27 operators who responded to whether they felt that any of the interactions they had witnessed between sharks and their clients were a cause for concern (question 4) only 4 (15%) did. One operator stated "New sharks will usually cruise by the divers and check them out before feeding... They soon figure out the divers are no threat and they will go on with their feeding". However, of the 29 operators that responded to our first question about whether concerns by local communities had been raised about shark diving, 9 (31%) said this had happened. One operator stated "due to their bad image created over the years, lots of people think sharks are going to start eating tourists" while another identified concerns with "other operators that do not comply with regulations". Of the 14 operators who reported baiting or feeding sharks, and who responded to our second questionnaire, 6 (43%) stated that concerns had been raised regarding

[2] NB Where shark species were reported ambiguously, these were combined into species groups. For example, operators reported observations of smooth, great and scalloped hammerheads however some did not state the species, therefore all observations were combined into a single 'hammerhead' group.

[3] Great White Shark Protection Foundation (GWSPF) Permit and Exemption Conditions. Available online at: http://www.gwspf.co.za/permit.html [Accessed 10/07/2014].

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Table 1
The global distribution of shark operators and non-shark operators contacted via email and their response rates.

		USA and Canada	Central America and Galapagos	Caribbean and Bermuda	Europe	Africa (excluding South Africa) and Red Sea	South Africa	Indian Ocean Islands	South East Asia	Australia and New Zealand	Pacific Ocean Islands
Shark operators	Number of operators contacted	18	19	18	3	4	19	2	18	16	11
	Number responded	8	8	9	0	0	6	1	5	5	3
	% Responded	44	42	50	0	0	32	50	28	31	27
Non-shark operators	Number of operators contacted	4	8	19	21	12	0	8	15	5	9
	Number responded	4	3	9	5	6	0	2	8	4	8
	% Responded	100	38	47	24	50	0	25	53	80	89

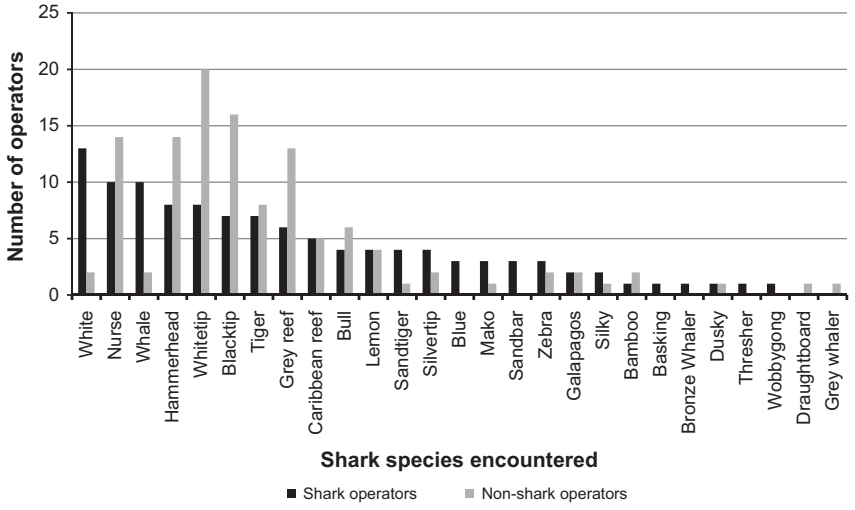

Fig. 1. Shark species observed on excursions by shark operators and non-shark operators.

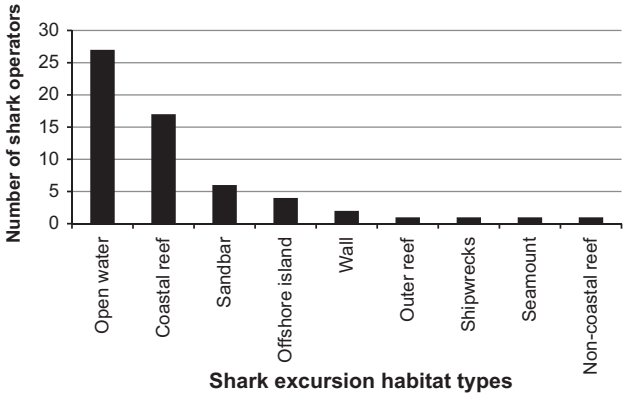

Fig. 2. The type of habitats most commonly used by shark operators for shark excursions.

shark diving in the area, compared to only 25% who did not bait or feed. While these figures are suggestive that baiting and feeding may be the main cause of controversy, the difference in local reaction to the practices of those who fed or baited compared with those who did not was not statistically significant at this sample size ($\chi^2 = 0.42$, 1 d.f, $p > 0.05$, $N = 30$).

We analysed the frequency of problem behaviours observed in sharks in relation to whether or not sharks were baited or fed. While results show that shark operators do not consider sharks bumping into people as a problem behaviour, we consider that it is as bumping may be considered a 'close call' event (Neff and Hueter, 2013; West, 2011) based on reports of shark behaviour during attacks (e.g. Caldicott et al., 2001). Hence we have included this in our analyses of problem behaviours. There was no significant statistical association between the frequency of bumping into people ($\chi^2 = 3.16$, 3 d.f., $p > 0.05$, $N = 25$), the frequency of erratic swimming ($\chi^2 = 2.57$, 3 d.f., $p > 0.05$, $N = 25$) or the total frequency of problem behaviours ($\chi^2 = 2.78$, 3 d.f, $p > 0.05$, $N = 50$) and use of baiting or feeding, although sample sizes were again low, which limits statistical power.

3.3. Responses from non-shark operators

67% of the 49 non-shark operators who responded to our questionnaire reported that they regularly encountered sharks on dives. Collectively, 21 different species were reported, the most common of which were whitetip and blacktip sharks[4] (encountered by 17% and 14% of operators respectively) while whale and great white sharks, two of the species' most commonly encountered by shark operators, were rarely or never seen (Fig. 1). Non-shark operators were asked their opinion regarding the statement "sharks may learn to associate divers and boats with food, therefore becoming bolder and more aggressive, leading to an increased risk of attacks". 40 of the 49 respondents chose to answer this question, of which 25 (63%) disagreed with the statement. Of those who provided additional information in support of their answer ($N = 27$), 59% stated in some form that they believed feeding affects a shark's natural behaviour although it was not evident from our questionnaire if this belief was based on personal experience. While 26% ($N = 47$) of non-shark operators said that shark operators worked in their vicinity,

[4] Operators often failed to specify the species of shark and simply referred to blacktip or whitetip. As we were unsure whether the operator knew the species, we combined all references to blacktip or whitetip into their own respective categories.

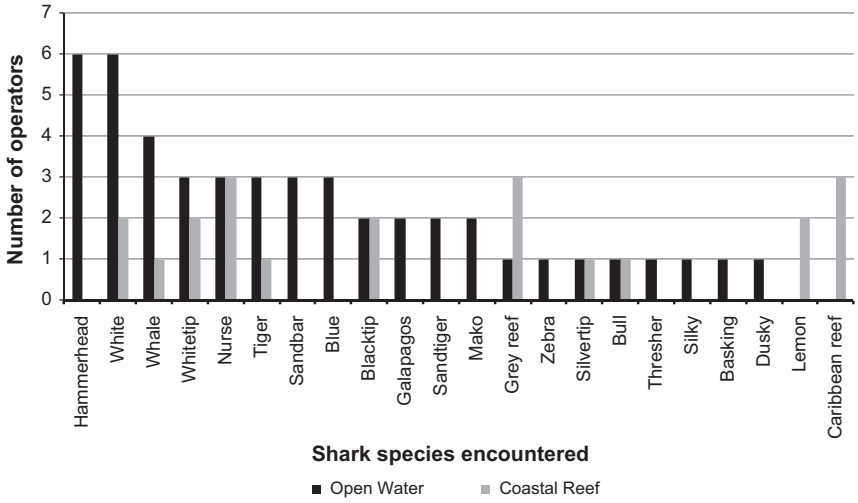

Fig. 3. Shark species viewed by shark operators at coastal reefs and in open water.

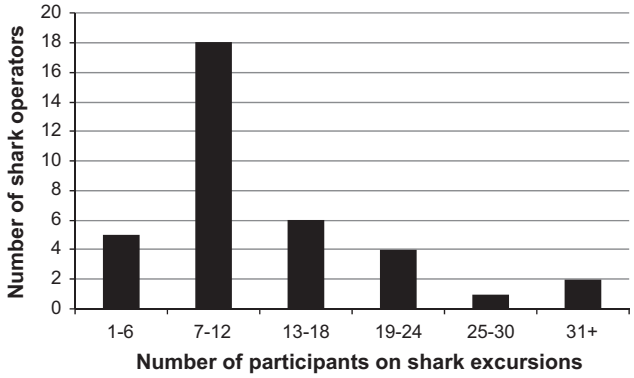

Fig. 4. The number of participants shark operators permitted on shark excursions.

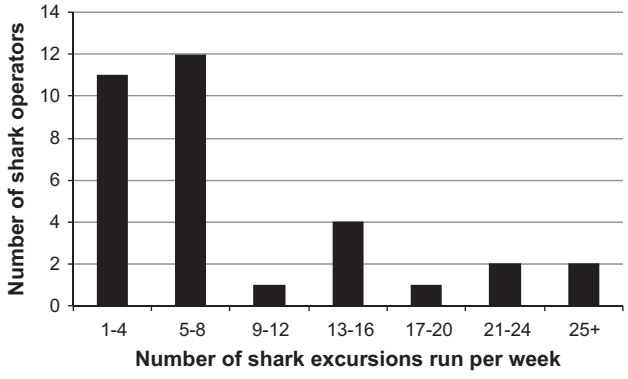

Fig. 5. The number of shark excursions run per week by shark operators.

only 8% ($N = 48$) said they would be interested in marketing shark dives themselves (question 4).

4. Discussion

There is an increasing demand from tourists for shark encounters and the shark tourism industry is increasing globally in response (Gallagher and Hammerschlag, 2011). Due to this, questions about the effects of shark tourism and associated activities such as SCUBA diving and provisioning on shark behaviour should be asked in order to establish effective management for the practise

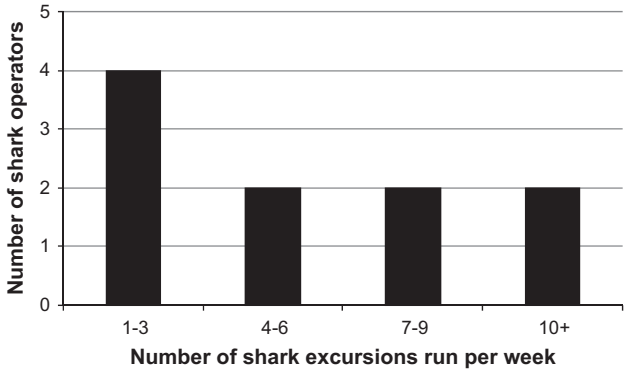

Fig. 6. The number of times sharks are fed per week by shark operators who provision sharks.

and to pre-emptively mitigate risk of unwittingly increasing shark attacks on humans. While an increasing number of studies assessing the ecological effects on different species of sharks exist (e.g. Brunnschweiler et al., 2014; Hammerschlag et al., 2012; Laroche et al., 2007), none that we know of have attempted to conduct a global study to provide insight into the practices of SCUBA operators and their observations of shark behaviour towards people.

In response to our survey shark operators reported encounters with a total of 25 species covering the spectrum from harmless, e.g. nurse and whale, to potentially dangerous, e.g. bull and great white sharks. Whilst non-shark operators reported encounters with a total of 21 species, whale and great white sharks, the species' most commonly encountered by shark operators, were rarely or never seen. The restricted presence of these charismatic species which likely have the highest immediate economic value in terms of tourists' willingness to pay to see them, (as seen in terrestrial game species (Di Minin et al., 2012)), may explain the apparent reluctance within our sample of non-shark operators to enter into shark specific tourism.

While shark operators feel that their operations are performed safely, non-shark operators are more sceptical. Indeed, behaviour such as bumping is likely to be considered worrisome by the general public but is treated as normal and acceptable by shark operators. Non-shark operators frequently expressed concerns about potential risks from shark diving with 59% of $N = 27$ commenting that provisioning for shark diving has negative ecological or behavioural effects on sharks. However, none of the shark operators surveyed reported any problems from their own operations

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and only 15% reported ever seeing any interactions between sharks and their clients that appeared risky to them. That said it is possible that any dive operators who had experienced problems would have been less likely to answer our survey than those who had not. However, our findings indicates that in the great majority of encounters sharks pose very little risk to tourists corroborating previous research (e.g. Gibbs and Warren, 2014)

4.1. Provisioning sharks

Provisioning is conducted by shark operators in order to allow them to 'guarantee' shark sightings (Lobel, 2008; Topelko and Dearden, 2009). Many shark operators' websites offer guaranteed sightings with a money back guarantee should a shark not be encountered on the dive. We suggest that willingness to pay by tourists, particularly those on time restricted trips, will be driven by assurances of sightings and experiences and therefore provisioning at appropriate locations will likely pay dividends for the shark operator. Several methods were used to attract sharks including hiding food to encourage foraging activity and suspending food above a reef. With more than 24 shark dives conducted a week in some cases and with all operators who reported feeding sharks doing so on every dive, our study indicates potentially high levels of provisioning for individual sharks. Feeding rates for elasmobranchs are, on a body weight basis, considerably lower than in many teleost fish (Wetherbee and Cortés, 2012). Such feeding frequencies may therefore reinforce concerns that without appropriate regulation sharks could potentially become dependent on human handouts, or at least come to expect them and therefore potentially be aggressive if food is not forthcoming (Orams, 2002). Whilst, it is estimated that tiger sharks for example must consume between 0.56% (Hammerschlag et al., 2013) and 3.7% (Hammerschlag et al., 2012) of their body weight per day (between 1.2 kg and 7.8 kg per day for a 210 kg tiger shark) and consequently are unlikely to have their metabolic needs met solely from visiting provisioning sites, variations in daily food requirements between life stages and shark species, as well as the dietary value of food provided by operators at different provisioning sites, may result in varying degrees of dependence.

One country actively managing the provisioning activities of great white shark operators is South Africa, thought to be home to the largest remaining population of coastal great white sharks (Towner et al., 2013). Here, the law states that operators must drop a baited line if a shark takes the bait, meaning the shark will then be able to eat the bait, and therefore requires operators to adhere to strict government regulations about what they can feed sharks (DEAT, 2008).[5] As each cage diving boat is allowed 25 kg of bait per day and sharks are able to catch bait before it is removed (DEAT, 2010), it is possible that despite active management against great white provisioning in South Africa the individuals here could obtain significant quantities of potentially high quality food from the activity. In the majority of countries where shark baiting or provisioning occurs, legislation is less demanding than in South Africa and sharks may simply be fed with what is cheaply available rather than what is nutritionally good for them and in varying quantities (Semeniuk et al., 2007). Consequently, while managed provisioning activities in South Africa may still result in behavioural changes associated with the regular availability of food, overall limits to the expansion of the industry could be put in place using the existing permitting system, thus limiting provisioning activities as necessary information on their effects becomes available.

Should shark attacks occur, or even increase, in nearby areas to provisioning sites, links are likely to be drawn between provisioning and any attack whether justifiably or not. Illegal provisioning of sharks by a diving company was one theory put forward to explain a cluster of shark attacks near the Egyptian resort of Sharm-el-Sheikh in 2010 (http://en.wikipedia.org/wiki/2010_Sharm_el-Sheikh_shark_attacks), leading to a local cull. Provisioning could therefore counteract potential conservation benefits to sharks from shark tourism as shark culls are frequently proposed and sometimes carried out in the wake of attacks, such as recently occurred in Western Australia despite worldwide criticism (Gibbs and Warren, 2014; the cull was halted in late 2014, http://www.bbc.co.uk/news/world-asia-29170035). In addition, provisioned sharks that are used to approaching boats for food have also been suggested to be more likely to take baited lines from recreational fishing boats than sharks which have not been fed, which may result in increased incidental fishing mortality (Orams, 2002).

Our analysis highlights that despite continuing efforts to address gaps in scientific knowledge regarding the provisioning of sharks, substantial research is still required into the effects of provisioning, the influence variations in food quality may have and how provisioning activities can be best managed. In particular, the potential for high feeding rates indicated by this research and the possible behavioural changes this may induce (Orams, 2002) provide justification for concern if this activity is not regulated, at least to some degree. While we would not actively advocate including provisioning as part of any management plan as a result of the paucity of knowledge regarding its potential effects, we recognise its economic importance to the tourism industry of many countries. Consequently, rather than suggesting an outright ban in those countries that currently permit the use of bait or chum, we recommend a precautionary approach to provisioning to avoid unknown ecological, societal and economic consequences. Such an approach might include limitations on the amount and/or type of bait an operator may use over a time period, and the number of operators allowed to provision sharks (i.e. a permitting system).

4.1.1. Shark habituation to divers and perceptions of the industry

Several shark operators noted in the comment section of our questionnaires that sharks which were new to an area were much more curious towards divers than sharks that encountered them regularly. This, and the fact that 93% of all shark operators surveyed said sharks generally ignored their clients, supports the idea of shark habituation to divers (Quiros, 2007). Several respondents said that individual shark's behaviour towards people differed, for example, if divers approached too closely, some sharks quickly moved away while others were bolder, corroborating research that shows shark species and individuals show varied responses to provisioning and that behavioural responses can change over time (Brunnschweiler et al., 2014).

While four of our respondents reported shark incidents involving their clients, respondents had a range of opinions regarding the risks of shark tourism. In general, shark operators did acknowledge the potential for accidents to happen, but most defended their own practices even when scientific evidence contradicted their view, suggesting lack of awareness for potential effects of their activities. For example, one great white shark cage operator said "we are always the first to get blamed whenever there is a shark bite, even if it is 1000 miles away from where we operate. But there is NO, NADA, ZERO impact on specific white shark behaviour because of white shark cage diving". Several scientific studies however indicate behavioural changes in white sharks as a result of cage diving (e.g. Bruce and Bradford, 2013; Huveneers et al., 2013). Another operator commented "Shark attacks always get locals up in arms as they need to blame someone. Misinformation and media hype are to be blamed". One operator who had witnessed worrying interactions between sharks and their clients stated, "Divers who drop their guard worry me. For the most part, the friendly shark stays friendly. But on occasion I have witnessed a dramatic change that could take

[5] Department of Environmental Affairs and Tourism, South Africa.

place in an instant". This view places responsibility for safety on tourists who may be inexperienced underwater and will most likely have little or no experience of shark behaviour. Such attitudes from shark operators therefore raise concern for shark-related tourism management. Whilst individuals should always take responsibility for their own actions and follow rules or codes of conduct as specified, as facilitators of tourism shark operators should ultimately assume responsibility for the safety of their clients and the wellbeing of the sharks. By contrast other operators were confident that their knowledge of shark behaviour would prevent clients from getting hurt; for example one stated, "dive staff are very experienced and can read shark behaviour so well. If a shark gets too close to a line of divers, we escort our customers away". Given our finding that group size varies considerably amongst shark operators their ability to have such control over clients will also vary. Research has suggested that the number of people and their behaviour in the water can substantially affect shark behaviour in the form of, for example, avoidance (e.g. Quiros, 2007), increased swim speed and agnostic behaviours (e.g. Barker et al., 2014; Smith et al., 2010). It is therefore important to keep group sizes to manageable levels and to place restrictions on the number of operators that can dive at known shark aggregation sites at any one time. This form of management is commonly adopted in places such as Australia and South Africa (Catlin and Jones, 2010; DEAT, 2008).

Whilst our research corroborates previous studies highlighting that the majority of shark encounters pose very little risk to people, the fact that a small minority of shark operators did report concerns about shark behaviour towards clients, and that threat displays such as bumping people and swimming erratically were reported, suggests that people should never become complacent. Indeed, research has indicated that diver behaviour is one of the key determinants of changing behaviour in various shark populations (e.g. Barker et al., 2014; Quiros, 2007). As such, we recommend that appropriate national, and legally binding, codes of conduct should be developed and enforced within shark tourism operations around the world to minimise potential risks.

4.1.2. Regulations for shark diving

Results of our survey indicate that shark operators take responsibility for good practise seriously, given that 93% of 43 shark operators said they followed a code of conduct either voluntarily or because of national guidelines, although the quality and detail of voluntary codes of conduct provided varied widely. Our results however cannot differentiate between those who do this out of concern for sharks or for fear of liability should a shark harm a customer.

The desire of operators to either manage their operations appropriately, or to appear to in order to attract tourists or to pre-empt potential legal regulation, is evident. However, wide variation in the quality of voluntary codes of conduct indicates that self-regulation is unlikely to adequately manage individual operator activities or the effects arising from the industry as a whole. This shows a real need for research into the effects of management of shark tourism activities to inform regulations and national codes of conduct, and a real opportunity to integrate such management into the industry. Further research arising from this study would be to investigate tourist perceptions to regulations on shark tourism.

The level of regulation under which shark operators conduct activities varies considerably between countries. Great white cage diving operators in South Africa and whale shark operators in Australia require a government licence to practise (Catlin et al., 2012; DEAT, 2010) and a Code of Practice for great white cage diving has recently been introduced by the Department of Conservation in New Zealand (DEC, 2013b) with the introduction of a permitting system as of October 2014 (DEC, 2013a). By contrast whale shark operators in countries such as the Seychelles, Mozambique and the Philippines either have government regulations which are poorly enforced or need only adhere to voluntary codes of conduct that have been designed by Non-Governmental Organisations and which many operators fail to follow (Quiros, 2007). Whilst different management regimes exist, the actual impacts of these rules and regulations are unknown with no known studies attempting to quantify the impacts of implementation of shark tourism and provisioning regulations on sharks themselves. However, despite this lack of knowledge, regulatory frameworks provide an important element to ensure sustainable wildlife tourism (Catlin et al., 2012; Techera and Klein, 2013) as without any framework in place, no action to control potentially damaging activities or overuse of resources can be taken.

Enforcement of tourism guidelines and regulations is often challenging in the marine environment (e.g. Parsons, 2012; Scarpaci et al., 2003, 2004). However, factors such as clarity of management documents (e.g. Smith et al., 2010), consistency in communicating their messages (e.g. Ballantyne et al., 2009), awareness raising and education can help increase compliance (e.g. Cornelisse and Duane, 2013; Keane et al., 2010). To overcome issues and inconsistencies arising from industry self-regulation we advocate the introduction of legally binding national guidelines for shark tourism which all shark operators need to be made aware of. Education could include mandatory classes for shark operators about species which are likely within their area, the threats facing them, current management practices, potential human impacts from tourism activities and best practice for mitigating them. Attendance at such sessions could be a formalised requirement of any permitting scheme and could be funded through charges to operators.

Based on our findings and review of literature, we propose that national regulations or codes of conduct for shark-related tourism should include limits on: group sizes, time spent in the water with sharks and provisioning (both in terms of quantity and quality of food items). There needs to be compulsory education about such regulations and legal consequence should they not be followed.

5. Conclusions

In recent years there has been increasing global interest in shark-encounter tourism and the potential economic incentive and awareness raising benefits this industry may bring to shark conservation. However, recent research has indicated negative behavioural impacts arising from shark diving or snorkelling and inadequacies in management have been highlighted. In this global study of shark tourism practices we found that in the majority of cases surveyed, shark operators apply codes of conduct (either mandatory or voluntary) to ensure the safety of both people and sharks even when no formal national guidelines exist. However, the practices and approaches taken varied widely, and we believe there is a good case for greater regulation to raise standards and minimise any adverse effects on both sharks and people. Such an approach would involve greater scrutiny of the industry and formalisation of legally enforced national guidelines. Links are frequently made between shark baiting/provisioning and attacks, and while these remain speculative, a precautionary approach is warranted that would be best delivered through regulation. Without this, shark tourism has the potential to cause accidents which could decrease the growing popularity of sharks and thereby have negative knock on effects for their conservation, particularly when culls follow attacks such as those recently witnessed in Western Australia. While our questionnaire indicates that the majority of shark encounters and shark tourism currently pose very little risk to people, more field research is required on shark behavioural responses to tourism practices to help assess best practices for sharks, people and environment. Shark diving management therefore needs to be dynamic and must evolve with continuing developments in the industry and understanding of shark behaviour.

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Author contributions

Conceived and designed the survey: KR, CMR, RO, MG, JPH. Analysed the data: KR, BCO. Wrote the paper: KR, BCO, JPH, CMR.

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Appendix A. Questionnaire for shark operators

Please answer the following questions by deleting as appropriate.

1. Are your shark trips run for:

Divers Snorkelers Both

2. If you cater for both divers and snorkelers please answer the questionnaire with respect to one group only and indicate which this is.

3. What best describes the type of location for your shark dives.

Open water Coastal reef Sandbar Other (please specify)

4. On average how many shark dives do you run each day OR week?

5. What is / are the main species of shark encountered? Please list below OR indicate if unknown.

6. Are the sharks fed or baited intentionally?

YES NO (Proceed to question 10)

7. What are the sharks fed?

8. Please indicate which of the feeding methods below you use.

By hand YES NO

Chumming YES NO

Bait on a line YES NO

Other (please specify)

9. On average how often do you feed or bait sharks? Please give answer in number of days per week.

10. Do you restrict the number of divers / snorkelers on shark dives?

YES and the maximum number is: NO

11. Do you have a formal code of conduct for clients?

YES NO (proceed to question **14**)

12. Please indicate what you consider to be the 3 most important aspects of this code:

i

ii

iii

13. How strictly is the code enforced?

Very strictly Moderately strictly Not strictly

14. Any further information about your shark dives or the code of conduct would be most appreciated. E.g. please send a leaflet.

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Appendix B. Follow up questionnaire for shark operators

Please answer the following questions by deleting as appropriate.

1. Have there been any concerns raised locally about shark diving?

YES NO If yes, please provide details

2. Do sharks normally appear to ignore your clients?

YES NO If no, please describe how they usually behave

3. Please indicate if you have observed any of the following behaviours from sharks towards your clients and how frequently this occurs.

(a) Bumping into people YES NO

OFTEN OCCASIONAL RARE

(b) Swimming erratically around divers YES NO

OFTEN OCCASIONAL RARE

4. Have you ever witnessed worrying interactions between sharks and your clients?

YES NO If yes, please describe

Appendix C. Questionnaire for non-shark operators

Please answer the following questions by deleting as appropriate.

1. During dives do you encounter sharks on a regular basis?

YES NO (proceed to question **3**)

2. What are the main species? Please list below OR indicate if unknown.

3. Do you undertake dives specifically to encounter sharks?

YES NO

4. Would you be prepared to try and attract sharks through feeding to develop shark dives for your clients?

YES (proceed to question **6**) NO

5. Does the following reason explain your reluctance to feed sharks "sharks may learn to associate divers and boats with food, therefore becoming bolder and more aggressive, leading to an increased risk of attacks"

YES NO If not please specify your own reasoning

6. Do other dive operators in your area offer shark diving?

YES NO

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